# THE WORLD FOOD PROBLEM

*A Report of the President's Science Advisory Committee*

## VOLUME II

## Report of the Panel on the World Food Supply

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THE WHITE HOUSE

MAY 1967

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## SUBPANEL REPORTS

### Preface

This compilation of the subpanel reports of the study conducted by the President's Science Advisory Committee Panel on the World Food Supply is Volume II of a three volume report. Volume I contains the general description of the problem and the study recommendations of the Panel, and summaries of subpanel reports. Volume III is an assembly of resource papers either developed as a part of the work of the subpanels or found to provide information considered especially appropriate and not otherwise readily available.

The Panel organized the work around the topics considered to represent factors of major importance in the description of and possible contribution toward the solution of the problems of the food supply and nutritional requirements for populations in the developing nations of the world. Each topic was studied by a subpanel composed of members of the PSAC Panel on the World Food Supply joined by national and international authorities in the subject matter area. Economic evaluations and implications of results contained in this report are provided in Chapters 13 and 14.

The subpanels had a total membership of 110 individuals. With only two exceptions, both for reason of health, every person invited to serve on these subpanels accepted, and excellent cooperation was provided by officials of the Federal Agencies, universities, foundations, and business concerns in making it possible for these key individuals to devote the necessary time to this study.

Subpanel membership was distributed as follows:

| | |
|---|---|
| Department of Agriculture | 30 |
| Agency for International Development | 10 |
| Other Government Agencies | 8 |
| Universities | 36 |
| Industry | 18 |
| Private Foundations | 8 |

While there was considerable communication between subpanels, some duplication exists in the reports. This is usually intended for emphasis. While presentations might have been refined even more

with a longer period for development of the subject, it is the consensus of subpanel members that the reports reflect their having utilized the best available information and that they have arrived at realistic conclusions with regard to the suggested programs of action by the developed and the developing countries.

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# THE WORLD FOOD PROBLEM

## VOLUME II

### Table of Contents


| Chapter | | Page |
|---|---|---|
| 1.0 | POPULATION AND NUTRITIONAL DEMANDS | 1 |
| 2.0 | PROJECTED TRENDS OF TRADE IN AGRICULTURAL PRODUCTS | 137 |
| 3.0 | INTENSIFICATION OF PLANT PRODUCTION | 191 |
| 4.0 | INTENSIFICATION OF ANIMAL PRODUCTION | 241 |
| 5.0 | INCREASING HIGH QUALITY PROTEIN | 295 |
| 6.0 | MANUFACTURED PHYSICAL AND BIOLOGICAL INPUTS | 373 |
| 7.0 | WATER AND LAND | 405 |
| 8.0 | TROPICAL SOILS AND CLIMATES | 471 |
| 9.0 | PRODUCTION INCENTIVES FOR FARMERS | 501 |
| 10.0 | MARKETING, PROCESSING, AND DISTRIBUTION OF FOOD PRODUCTS | 537 |
| 11.0 | TRANSPORTATION | 569 |
| 12.0 | RESEARCH AND EDUCATION | 593 |
| 13.0 | ECONOMIC IMPLICATIONS | 641 |
| 14.0 | EVALUATION OF POPULATION AND FOOD PRODUCTION PROBLEMS OF INDIA | 673 |
| | INDEX | 713 |

# CHAPTER 1

# POPULATION AND NUTRITIONAL DEMANDS

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## Contents

| | | Page |
|---|---|---|
| 1.1.0 | Summary | 5 |
| 1.2.0 | Introduction | 10 |
| 1.3.0 | The Impact of Nutrition on Health, Work Efficiency, and Social Attitudes | 11 |
| | 1.3.1 The Effects of Malnutrition in Adults | 12 |
| | 1.3.2 The Effects of Malnutrition in Children | 12 |
| 1.4.0 | Prevalence of Malnutrition Throughout the World | 16 |
| | 1.4.1 Protein-Calorie Malnutrition | 17 |
| | 1.4.2 Anemias | 17 |
| | 1.4.3 Goiter | 17 |
| | 1.4.4 Xerophthalmia | 18 |
| | 1.4.5 Other Deficiency Diseases | 18 |
| 1.5.0 | Growth and Characteristics of Human Populations | 19 |
| | 1.5.1 Demographic Characteristics of Developed and Developing Countries | 19 |
| | 1.5.2 Uncertainties of Population Estimates | 21 |
| | 1.5.2.1 Uncertainty in the Size of the Present Population | 21 |
| | 1.5.2.2 Uncertainty in Present Rates of Population Growth | 22 |
| | 1.5.2.3 Uncertainty in Future Levels of Fertility and Mortality | 24 |
| | 1.5.3 Present and Future Size of Populations | 24 |
| | 1.5.3.1 Assumptions for the Two Population Projections | 26 |
| | 1.5.3.2 Possible Range of Future Population Size | 27 |

1.50 Growth and Characteristics of Human Populations—Con. Page
1.5.4 Population Growth and Food Needs 28
1.5.4.1 Economic Effects of Rapid Rates of Population Growth 28
1.5.5 Prospective Changes in the Geographic Distribution of the World's Population 30
1.5.6 How Sharp a Decline in Fertility Can Be Expected in the Less Developed Countries 31
1.5.6.1 Factors Affecting Human Fertility 31
1.5.6.2 Fertility Control Programs in the Less Developed Countries 37
1.5.7 Population Characteristics Affecting Nutrition 38
1.5.7.1 Body Size 39
1.5.7.2 Sex Distribution 41
1.5.7.3 Income Distribution and Nutrition 42
1.6.0 Nutritional Requirements, Current and Projected 44
1.6.1 Requirements for Calories 44
1.6.1.1 Assumptions 45
1.6.1.2 Caloric Requirements for India 46
1.6.1.3 Caloric Requirements for Pakistan 48
1.6.1.4 Caloric Requirements for Brazil 48
1.6.1.5 Caloric Requirements for the World 49
1.6.2 Requirements for Protein 50
1.6.2.1 Assumptions 50
1.6.2.2 Protein Requirements for India 53
1.6.2.3 Protein Requirements for Pakistan 55
1.6.2.4 Protein Requirements for Brazil 56
1.6.2.5 Protein Requirements for the World 56
1.6.3 Requirements for Vitamins and Minerals 58
1.6.3.1 Thiamin 58
1.6.3.2 Riboflavin 58
1.6.3.3 Niacin 59
1.6.3.4 Vitamin A 61
1.6.3.5 Calcium 62
1.6.3.6 Other Vitamins and Minerals 65
1.7.0 Nutritional Requirements Translated into Terms of Food and Food into Agricultural Commodities 67
1.7.1 Some General Conclusions 67
1.7.2 Methodology Used in Converting Caloric and Protein Needs to Foods and Commodities 69
1.7.3 Limitations in Interpretation of Data 71
1.7.4 Some Possible Action Programs 77

Page

1.8.0 Nutrition Programs in Developing Countries ..... 78
1.8.1 Current Nutrition Programs ..... 78
1.8.2 Suggestions for National Nutrition Programs in Developing Countries ..... 82
1.8.2.1 Organization and Action Programs ..... 82
1.8.2.2 Programs of Nutrition Education and Training ..... 83
1.8.2.3 Nutrition Research Programs ..... 86
1.8.3 United States Assistance in Nutrition Programs in Developing Countries ..... 87
1.9.0 Appendix—Tables 1–14 ..... 90

## *1.1.0 Summary*

### POPULATION AND NUTRITIONAL DEMANDS

The prevention of malnutrition throughout the world through the provision of adequate diets for a rapidly expanding population is a task of staggering proportions. Solution of this problem is perhaps the greatest challenge facing nations of the world today. In the less developed countries, it was estimated in the Third World Food Survey of the FAO that at least 20 percent of the population was undernourished (received too few calories) and about 60 percent received diets inadequate in nutritional quality. Protein-calorie malnutrition which affects preschool children primarily, is the most widespread nutritional deficiency. Malnutrition causes retardation of physical growth and development and recent evidence strongly suggests that mental development may be impaired also. For the malnourished child, mortality and morbidity are extremely high and the common infectious diseases are catastrophic.

Nutrition has a vital role in the health of adults as well as children and profoundly influences socio-economic and cultural development. Malnutrition leads to deterioration of physical fitness and mental efficiency, to emotional and personality disturbances, and to reduction in the capacity to perform work.

The most urgent needs in less developed countries are an increased supply of calories and good quality protein. In some areas, specific vitamin and mineral deficiencies are prevalent and foods furnishing these nutrients must be made available. Anemias, endemic goiter (iodine deficiency) and xerophthalmia (vitamin A deficiency) are frequently encountered while beriberi (thiamine deficiency) and ariboflavinosis are observed in some countries.

The technological revolution, which has brought about rapid and self-generating economic growth in the developed countries, has had one critically important effect in the poor ones—a marked reduction in death rates. This decrease in mortality has not, as yet, been followed by a decline in birth rates, and, consequently, it has created an unprecedented occurrence in the history of mankind—very high rates of population growth over areas of ancient settlements. The times required to double the population in most less developed countries are 18 to 27 years; they are 55 to 88 years in the most developed ones. The less developed regions now contain about two-thirds of the world's human beings. By the year 2000, if present rates of growth continue, there will



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be more than four times as many people in the less developed countries as in the developed ones.

If fertility does not change, and mortality continues to decline, the population of the world will increase from 3.3 billion in 1965 to 5.0 billion in 1985, or by 52 percent. With a 30 percent decrease in fertility over the next 20 years, the world population would be 4.65 billion by 1985, an increase of about 40 percent above 1965. The difference between the high and the low figures is only 385 million persons, about the same as the uncertainty in the projected 1985 population of Mainland China. The difference, however, would rapidly widen in later decades. By the year 2000, the high projection would give a world population of 7.15 billion persons, and the low projection would give 6.0 billion.

By the year 2000, the population of India will have increased to such an extent, even with the low population projection, that the present area harvested for food crops would be only about three-tenths of an acre per person, about the same as in Egypt today. The situation will become more critical until 1980, before any likely decrease in the rate of population growth can have much effect.

A reduction in the rate of population increase may be necessary to increase food production. Economic growth and social development are made much more difficult by a high birth rate, which results in a very high proportion of children in the population, approximately 45 percent under 15 years old, and hence a heavy dependency burden on the producing adults in the society. Even if overall economic growth is taking place, rapid population increase minimizes improvement in per capita income, and, therefore, little increase in the ability to save for needed capital investment.

There are good reasons to believe that human fertility in most of the less developed countries will decrease during the next few decades, but when and how much cannot be predicted. Surveys of the attitudes of husbands and wives show clearly the recognition of a desire to limit family size. Many couples want no more children than they already have, and would like to know better ways of preventing further births.

However, the numbers of children desired are much higher than in developed countries, averaging four children per couple, which, with present and prospective levels of mortality, would result in a doubling of population every 30 to 35 years. The large number of children desired probably reflects an adjustment to high and unpredictable child mortality as well as a traditional community life built on family and kinship ties.

Favorable attitudes to family limitation in the less-developed countries are much more common among couples who already have three or four living children. Availability of birth control means may

thus be unimportant until the desired number of living children is secure. Low infant and child mortality and public awareness that mortality is low may be one of the necessary preconditions for reducing the rate of fertility.

We are faced with the apparent paradox that a reduction in mortality should reduce rather than raise the rate of population growth. If this is the case, reduction of malnutrition among children, by increasing the quantity and quality of food supplies, may be a key factor in solving the population problem of our time.

The transition from high to relatively low fertility rates in the developed countries occurred in a much less favorable atmosphere for family planning than exists in the world today. The governments of developing countries are now endorsing population control policies at a rate and in a climate of world approval unimaginable even a few years ago. The role of government in reducing fertility is to exhort, inform, and provide; decisions and actions must be taken by individual couples acting in accordance with their perceived interests. Even so, the governmental task is large and difficult, requiring a high degree of organization, adequate financial and logistic support, great flexibility in meeting changing conditions, and continuing objective evaluation of results. Only a small proportion of people in the less developed countries have even moderately good knowledge of family planning. The poor and the uneducated need to learn what the well-to-do and the educated already know—that there are a number of safe, reliable, and simple methods of limiting the number of births.

In computing the nutritional requirements of a population, we must consider more than numbers. The distribution by age and sex and the average body size of males and females at different ages are especially important. There are marked variations in average body weights among different peoples. Data for seven Asian and seven Latin American countries show that the difference in body weight between the average Indian and the average Malayan is nearly 15 percent; between East and West Pakistan it is about 20 percent; the total range between Indians and Vietnamese at one extreme, and Uruguayans and Chileans at the other, is about 40 percent. The differences in body weight between the peoples of the Asian and the Latin American countries are probably partly genetic, but several kinds of evidence suggest that nutrition can be a determining factor in fulfilling genetic potential. Hence a sustained improvement in the nutrition of children in poor countries can be expected to increase the average body weight of adults 10 percent or more during the next two decades, with a corresponding increase in food needs.

Caloric needs of the world and of India, Pakistan, and Brazil were estimated from caloric requirements developed by the Food and Agriculture Organization (FAO) of the United Nations. In applying these requirements to populations of these three countries, it was apparent that the average body size of children and adults was less than that suggested by FAO. Accordingly, current estimates of caloric needs were calculated at two levels, one from the FAO standard weights, and the other, from observed average body weights of the populations of these countries. Lack of satisfactory data on body weight in these countries introduces uncertainties as to accuracy. In projecting caloric needs for the future, the assumption was made that children should be provided with sufficient energy to allow for normal growth to age 14 (FAO child weights) and that the adult population would increase in body weight by three kilograms per decade.

Protein requirements were estimated by the procedures proposed by the Joint FAO-WHO Expert Group on Protein Requirements (1965). Protein needs were estimated in terms of a high quality protein, i.e., egg, which is the FAO "reference" protein. These "reference" values were then converted to the intake of protein in the national diet of each country. This was done by determining the net protein utilization (NPU) of different foodstuffs in these diets. NPU is an index of the digestibility of protein and of the biological value of the amino acid mixture absorbed from the intestine. Protein requirements were expressed as grams per kilogram of body weight for various age groups. The estimated increase in caloric requirements in 1985 over those of 1965, based on high and low population projections are as follows: for the World, 52 or 43 percent, for India, 108 or 88 percent, for Pakistan, 146 or 118 percent and for Brazil, 104 or 92 percent. The increase in protein needs in the next twenty years will be of approximately the same magnitude.

With most national food patterns, average protein requirements will be available to the population as a whole if calories are supplied in sufficient amounts. Large problems exist in meeting protein needs in countries where single foods provide the main source of food energy, or where food resources are not equitably distributed. Special attention must be given to mechanisms of food distribution within a country and within households to assure adequate intake of protein by young and growing children and other nutritionally vulnerable groups. When food supplies are limited in quantity or variety, it may be desirable to fortify foods with proteins or amino acids to meet the requirements of vulnerable segments of the population.

The needs for thiamine, riboflavin and niacin are related to caloric intake. Accordingly, the relative increase in needs for the next 20 years will be approximately the same magnitude as indicated for calories.

The recommended intake of these three vitamins were calculated as specified by the Joint Expert Committee of WHO-FAO. The needs for vitamin A and calcium were calculated also for the world and for India, Pakistan, and Brazil.

If similar foods are consumed in the next 20 years, calculated requirements for protein and calories indicate that for the world as a whole will need 50 percent more food in 1985. India and Brazil will need twice as much food as was available in 1965, and Pakistan will need an even greater increase. In calculating the needs for food and commodities, the only losses taken into account were those involved in processing. Thus, in estimating future needs for foods, an unknown underestimate is introduced because caloric and protein needs are projected at the consumption level without adjustment for losses from time of harvest through storage, transportation, marketing, home preparation and plate waste.

It is clear that calories constitute the most urgent need for countries, regions and the world although this obviously may not hold for certain segments of the population. If caloric needs of a country are met with current national food supply patterns, adequate amounts of protein will be supplied for the population as a whole, despite the overall poor quality of the protein. In the interpretation of averages it should be emphasized that they do not reflect distribution of food to individuals nor do they indicate the percentage or segments of the population receiving inadequate diets and suffering from malnutrition. Although a variety of foods may be available, some persons receive only a limited variety which may be relatively poor sources of protein.

Reduction of fertility does not offer much hope for solving the food supply problem by 1985 unless fertility decreases much more sharply than the projections have assumed; only 6 to 11 percent reduction of food needs is indicated for the three countries or the world as a whole. Decreases in fertility can make a substantial difference in the period after 1985. Increased production is the key to meeting the food problem of the expanding population in the next 20 years.

In a coordinated effort to combat malnutrition throughout the world, national *nutritional* policies should be developed in association with *food* and *agricultural* policies. A need for education and training in nutrition exists at all levels, in universities, agricultural colleges, primary and secondary schools, communities and rural areas. Personnel for carrying out nutrition programs should be sought from all possible sources. Regional training and research institutes should be established. Fellowships should be made available in the United States and other developed areas for training candidates at the doctoral and post doctoral levels. In the United States, steps should be

taken to stimulate career development in nutrition for foreign service. More collaborative programs should be developed between universities of the United States and other developed countries, and institutions in the less developed areas.

Action programs in nutrition should be organized in cooperation with agricultural, health, educational and economic agencies. Nutritional needs of the country must be determined first and then research and action programs should be tailored to meet these needs. Priorities should be given to relief of calorie-protein malnutrition but deficiencies of vitamins and minerals should receive consideration also. Nutrition research is urgently needed to further elucidate the etiology and effects of malnutrition and the relationships of nutrition to health and mental development.

### *1.2.0 Introduction*

The seriousness and magnitude of the problems of undernutrition and malnutrition in the less developed countries demand immediate long-term planning at national and international levels. Attention must be directed first to the most important aspect of the problem—protein-calorie malnutrition in preschool children who are the most vulnerable group and whose health may be seriously and irreparably affected. Malnutrition in childhood is a major deterrent to future social and economic development of the countries affected. The segment of the population most seriously affected by malnutrition is children of preschool age. It has been estimated that of 667 million children under the age of 14 in the less developed countries of the free world in 1966, 269 million are malnourished. It is predicted that there will be 815 million children in this age group by 1975, of whom 329 million will be malnourished.[1] Other vulnerable groups that require attention are pregnant and nursing women. The whole world must be made aware of the gravity of the situation and measures to relieve the present plight of the preschool children must be initiated without delay.

In 1963, it was estimated in the Third World Food Survey that at least 20 percent of the population of the less developed areas was undernourished and that some 60 percent received diets inadequate in nutritional quality.[2] For the world as a whole, it was concluded that 10 to 15 percent of the people were undernourished and nearly half suffered from hunger and/or malnutrition. These estimates were based on limited data and the exact incidence is unknown. In Asia,

[1] U.S. Agency for International Development. Food for freedom. Washington, 1966. 21 p.
[2] Food and Agriculture Organization of the United Nations. Third World Food Survey. Freedom from Hunger Campaign, Basic Study No. 11, 1963. 102 p.

Africa, and Latin America, the population is increasing at a rate of from 2.5 to more than 3 percent per annum. The average rate of increase in food production from 1958 to 1965 was 2 percent per annum with a reduction in the last four years of this period to about 1 percent. An increase of at least 3 percent per annum in food production will be needed to keep abreast of population expansion.[3] Other important aspects related to nutritional deficiency in the developing countries are unequal distribution of available food, insufficient individual income to purchase food and lack of education in the proper choice and use of food.

Resources must be developed to meet the nutritional needs of populations throughout the world. The effort will require the concerted efforts of the governments of less developed and developed countries, international agencies, foundations, universities, industries and other members of the private sector.

This report will be concerned with:

(1) the role of nutrition in physical and mental development of children and the maintenance of health throughout life;

(2) estimates of the current prevalence of malnutrition;

(3) projections of populations at five-year intervals from 1965 to 1985 for the world and for India, Pakistan, and Brazil;

(4) estimates of requirements for nutrients and foods of these populations;

(5) programs of nutrition education, research, and action that will be needed to correct and eliminate malnutrition.

The report will not consider programs of education, research, and action related to population control, although it is recognized that this is one of the most important problems facing mankind.

### *1.3.0 The Impact of Nutrition on Health, Work Efficiency, and Social Attitudes*

Inadequate nutrition is associated with suboptimal living and leads to a chain of events that has been described as: "Deficient nutrition → lowered energy output → lowered production → bare subsistence income → meager education → decreased resistance to disease → high death rates in children → lower life expectancy."[4] Raising the nutrition level according to this relationship would result in improvements at all links of this chain. Nutrition cannot be considered only as it influences health, but also as it relates to human well-being and to socio-economic and cultural development.

[3] Sen, B. R. "Indicative World Plan for Agriculture Development 1965–1975–1985," Food and Agriculture Organization of the United Nations, April 15, 1966.

[4] Food and Agriculture Organization of the United Nations. Survey of nutrition training for the Americas. n.p., 1961. 1 vol. (various paging).

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### *1.3.1 Effects of Malnutrition in Adults*

The serious effects of malnutrition on physical fitness and mental efficiency have been studied in starved populations and in volunteers in whom semi-starvation or deficiency diseases have been induced experimentally. Nutritional deprivation results in weakness, fatigue and inability to perform work. The individual becomes apathetic, depressed and lethargic. Emotional and personality changes occur frequently. In an experimental study of semi-starvation, subjects complained of loss of ambition, narrowness of interests, depression, irritability, and emotional instability.[5] The behavior of the group changed significantly during the experiment. At the beginning, good humor and friendliness existed among the subjects. As starvation proceeded, the ability to make rational decisions was lost and the subjects became increasingly submissive. Leadership and initiative disappeared. During the period of rehabilitation, the prevailing mood was one of rebelliousness and hostility. These behavioral changes have important socio-economic implications.

In population of workers "a poor diet resulting in undernutrition and malnutrition reduces working efficiency by (a) decreasing resistance to disease, (b) increasing the rate of absenteeism, (c) causing lethargy, lack of initiative and drive and (d) increasing accident rates." [6] In experimental studies and in field observations, it has been shown that provision of an adequate diet improves efficiency and general well-being and that these are reflected ultimately in increased production. Increased caloric intake is needed if the work output of semi-starved people is to be increased. The requirements for protein, vitamins and minerals vary less with activity than do those for calories but more protein may be needed to improve physical strength.

### *1.3.2 Effects of Malnutrition in Children*

Protein malnutrition in infants and young children is often called kwashiorkor, whereas caloric deficiency is referred to as marasmus. Kwashiorkor is an African term meaning the "displaced child" who is no longer breast fed and must fend for himself as a member of the family. This protein deficiency syndrome is characterized by loss of appetite, apathy and peevishness, pigment changes in the skin and hair, and growth failure. The liver becomes enlarged and the digestive and other body enzymes decrease. The proteins in the blood fall to low levels and massive edema develops.

Acute diarrhea can be a dangerous illness for well-nourished infants in the United States; for the weaned infants of the less developed areas

[5] Keys, A. B., and others. Biology of Human Starvation. Minneapolis, University of Minnesota Press, 1950. 2 volumes.

[6] Food and Agriculture Organization of the United Nations. Nutrition and Working Efficiency. Freedom from Hunger Campaign, Basic Study No. 5, 1962. 47 p.

of the world who are consuming a grossly inadequate diet, it can hasten the appearance of kwashiorkor, with an appallingly high mortality. In many cases, decreased intake and poor absorption of food are intensified by infestation with intestinal parasites, brought on by poor sanitation and the reduced resistance of the malnourished child.

The common infectious diseases of childhood are catastrophic in the malnourished infant. In 1960, measles caused 0.2 deaths per 100,000 population in the United States. In India in 1959, it caused approximately 20 deaths per 100,000 population and in Chile in 1960 it caused 27.7 deaths per 100,000 population.[7] These figures take into account only the deaths immediately related to the acute illness and do not portray the deaths from severe malnutrition precipitated by measles which occur weeks or months later. In most reported studies of kwashiorkor, measles had preceded by a matter of weeks a fourth to half of the total number of cases.[8]

In the United States, accidents account for more fatalities after the first year of life than the next six causes combined. In the developing countries, the mortality rate among pre-school children between 1 and 4 years of age is 10 to 30 times higher than that in the United States, the large difference is attributable to malnutrition and complicating infections. In the adolescent and young adult groups of these nations, undernutrition contributes to the high incidence of tuberculosis.

In the United States approximately 25 of every 1,000 liveborn infants succumb before the age of one year. Most of these deaths result from prematurity or congenital defects. In Southeast Asia, Africa, and Latin America, published infant mortality rates (generally underestimates) are often more than 100 per 1,000 live births, most of the excess being a direct or indirect result of poor nutrition. Early weaning and the use of unbelievably inadequate substitutes for human breast milk such as rice water, clear broths, weak teas and coffee are the common underlying causes.

Intrauterine infection or fetal undernutrition (usually from impaired placental blood flow) may lead to serious curtailment of an infant's potential for physical and mental development.[9] Survivors of severe infantile malnutrition are physically dwarfed and there is evidence that mental capacity may be impaired.[10]

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[7] International conference on measles immunization (six sessions). Amer. J. Dis. Child. 103(3) : 211–531, Mar. 1962.

[8] Graham, G. G., and Morales, E., Studies in infantile malnutrition I. Nature of the problem in Peru. J. Nutr. 79(4) : 479–487, Apr. 1963.

[9] Gruenwald, P., Chronic fetal distress and placental insufficiency. Biol. Neonat. 5 : 215–265, 1963.

[10] Cravioto, J., De Licardie, E. R., and Birch, H. G., Nutrition, growth and neurointegrative development: an experience in ecologic study. Pediatrics 38(2 [Pt. 2] Suppl.): 319–372, Aug. 1966.

It has been shown experimentally that undernutrition of animals during pregnancy results in a *permanently* reduced potential for growth.[11] A very brief period of undernutrition in early extrauterine life limits growth permanently; progressively longer periods of deprivation are required for irreversible stunting as life progresses.[12] The learning capacity of animals who have survived severe neonatal malnutrition has been shown to be permanently impaired [13] and chemical maturation of the central nervous system is altered.[14]

Children that survive severe malnutrition are stunted directly in onset.[15] Head size and, almost certainly, brain weight are reduced and in one study, a parallel degree of mental retardation has been documented, although it is not certain to what extent this resulted from environmental deprivation.[16] In the United States, no correlation between height and intelligence is demonstrable since the height of most of the population is determined genetically rather than nutritionally. In Central America and in Peru, however, where short stature is often a result of early undernutrition, a correlation between height and intelligence can be shown among underprivileged children.[17]

The relationship of nutrition to physical growth and development is well known. In Figure 1 the growth of boys in five Far East countries is compared with the growth of the lowest quartile of boys in Iowa. Malnutrition is an important factor in the markedly reduced rates of growth of children in the Far East although genetic differences are undoubtedly important. The effects of malnutrition during the period of growth will be discussed subsequently. Nutritional improvement leads to an increase in height and weight, a decrease in childhood morbidity and mortality and increased longevity.

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[11] Chow, B. F., and Lee, C. J., Effect of dietary restriction of pregnant rats on body weight gain of the offspring. J. Nutr. 82(1) : 10–18, Jan. 1964.

[12] Widdowson, E. M., and McCance, R. A., The effect of finite periods of undernutrition at different ages on the composition and subsequent development of the rat. Roy. Soc. London Proc. Ser. B158(972) : 329–342. Oct. 22, 1963.

[13] Lat, J., Widdowson, E. M., and McCance, R. A., Some effects of accelerating growth III. Behavior and nervous activity. Roy. Soc. London Proc. Ser. B153(952 : 347–356. Jan. 3, 1961.

[14] Dobbing, J., and Widdowson, E. M., The effect of under nutrition and subsequent rehabilitation on myelination of rat brain as measured by its composition. Brain 88(Pt. 2) : 357–366. 1965.

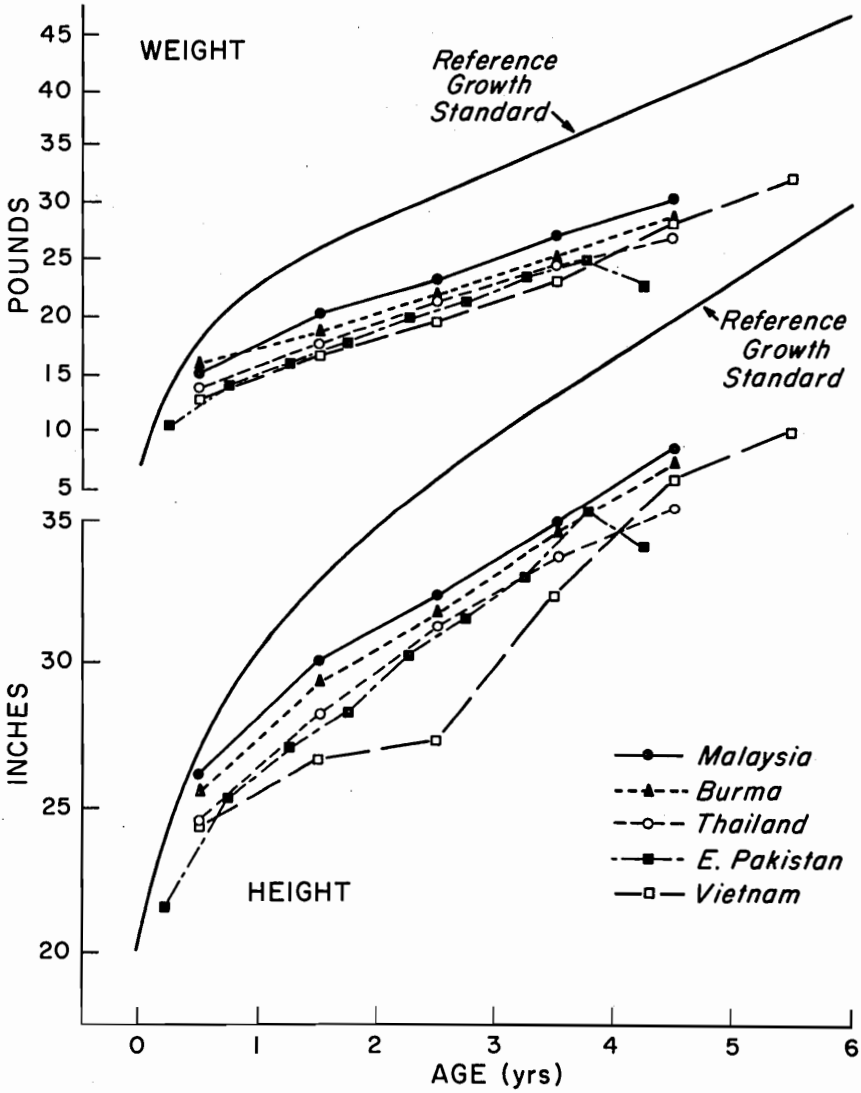
[15] Graham, G. G., Amer. Med. Wom. Ass. J. 21 : 727, 1966.

[16] Stock, M. B., and Smythe, P. M., Does undernutrition during infancy inhibit brain growth and subsequent intellectual development? AMA Arch. Dis. Child. 38(202) : 546–552. Dec. 1963.

[17] Cravioto, J., De Licardie, E. R., and Birch, H. G., Nutrition, growth and neurointegrative development : an experience in ecologic study. Pediatrics 38(2 Pt. 2 Suppl.) : 319–372, Aug. 1966.

Figure 1

HEIGHTS AND WEIGHTS OF BOYS IN SOME FAR EAST COUNTRIES COMPARED WITH REFERENCE GROWTH STANDARDS*




* Based on data obtained during ICNND Nutrition Surveys

### *1.4.0 Prevalence of Malnutrition Throughout the World*

The most widespread deficiency disease in developing countries of the world is protein and calorie malnutrition. Other nutrition-related deficiencies commonly encountered are anemia, endemic goiter and xerophthalmia, Rickets, pellagra, ariboflavinosis, beriberi and scurvy are less frequently seen (Table 1).

TABLE 1.—*Diseases Due to Malnutrition*

| Name of Disease | Cause | Manifestations |
|---|---|---|
| Kwashiorkor and Marasmus. | Protein and calorie deficiency. | Growth retardation, impaired mental development, edema, enlarged liver, pigment changes in skin, low serum proteins, enzyme deficiency. |
| Xerophthalmia and Keratomalacia. | Vitamin A deficiency | Night blindness, destruction of eye with loss of vision, skin changes (hyperkeratosis.) |
| Anemias | Deficiency of iron, folic acid or vitamin $B_{12}$. | Pallor, weakness, heart failure, low hemoglobin and red cell count. |
| Endemic goiter | Iodine deficiency | Thyroid enlargement, cretinism. |
| Beriberi | Thiamine deficiency | Peripheral neuritis, central nervous system disturbances, heart disease. |
| Ariboflavinosis | Riboflavin deficiency | Cheilosis, glossitis, seborrheic dermatitis. |
| Pellagra | Niacin-tryptophan deficiency. | Dermatitis, mental changes, diarrhea, inflammation of gastrointestinal tract. |
| Scurvy | Vitamin C deficiency | Hemorrhages, improper growth of bone and supporting tissue, anemia. |
| Rickets | Vitamin D deficiency | Improper bone growth, abnormal calcium and phosphorus metabolism, skeletal deformities. |

The predominance of protein-calorie deprivation, anemia, goiter and xerophthalmia suggests that international programs should be primarily concerned with these conditions and that regional programs should concentrate on other deficiencies that occur in specific areas.

Few data are available to indicate the general incidence of malnutrition. Health and nutrition surveys have been carried out but these have been limited to specific population groups and have neglected difficult-to-reach segments of the population. Comprehensive clinical and biochemical evaluation of nutritional status have been included in very few of these general, public health-nutrition surveys. The criteria used to establish specific deficiencies have not been well defined and methodology has not been standardized. Consequently, it is difficult to make meaningful comparisons of surveys from various parts of the world.

The following should be considered in estimating the magnitude of nutritional deficiencies:

(1) *the incidence of specific diseases* is of primary importance but these often occur late in the course of malnutrition;

(2) *biochemical analyses* assist in identifying major nutritional problems but have not been applied widely;

(3) *general information on mortality and morbidity* among infants and pre-school children gives some indication of the nutritional status of these segments of the population.

### *1.4.1 Protein-Calorie Malnutrition*

Isolated results, published since 1952, suggest that the prevalence of kwashiorkor and marasmus ranges from less than one to more than 10 percent in pre-school children of developing countries. Criteria for identifying these extreme deficiency states have been established only recently, however, and the extremely high mortality rates in the 1 to 4 year age group in developing countries suggest that moderate protein-calorie malnutrition affects at least 50 percent of these children. The mortality rate in the United States for this age group approximates one per 1,000, while in some of the developing countries, reported rates are 10 to 30 per 1,000. Mortality statistics rarely list nutritional disease as the cause of death. High mortality in young children, however, is directly related to chronic protein-calorie malnutrition.

### *1.4.2 Anemia*

Reliable statistics on the incidence of nutritional anemias are rare. Even in the United States, information on iron-deficiency anemia is limited largely to studies of pregnant women and infants. In some developing countries recent studies indicate that almost all children and pregnant women suffer from iron deficiency even though *average* hemoglobin levels are within the normal range. In addition, there is ample documentation that anemias caused by deficiency of nutrients other than iron are important in many areas.

In many countries, the high incidence of chronic intestinal parasitism, which leads to constant blood loss, complicates the picture. Thus, while dietary iron exceeds that needed to maintain normal hemoglobin concentration, these dietary levels may be inadequate in the presence of chronic loss of blood. There is urgent need to determine the actual incidence of iron deficiency in the less developed countries and to clearly define the prevalence and type of other anemias.

### *1.4.3 Goiter*

Endemic goiter is one of the major nutritional deficiency diseases of the world. Recent estimates are that over 200 million persons suffer from it. Surveys have shown that it is a current problem in West Africa, Ethiopia, Central America, South America, Southeast Asia, the Himalaya region, and the Near East.

Studies of the relationship between excretion of iodine in urine and the prevalence of goiter suggest that measurement of excretion may be useful in evaluating iodine nutriture of a population. Comprehensive investigations of the relationship of iodine nutriture to cretinism, deaf-mutism, and mental retardation, as well as to goiter, are needed in areas where these health problems are common.

The standard public health approach to prevention of goiter is the iodization of salt although iodine has been added to other food stuffs. Many areas with endemic goiter problems are isolated from commercial markets and the use of processed foods is limited. Practical ways to add iodine to the diet of populations in the Andes, the Himalayas, isolated areas of Africa, and the high jungles of Southeast Asia, are sorely needed.

### *144 Xerophthalmia*

Vitamin A deficiency leads to xerophthalmia and blindness. Despite the considerable variation in basic dietary patterns in the less developed countries, vitamin A intake tends to be extremely low during certain seasons. Surveys based on estimation of vitamin A levels in blood indicated this deficiency affects more than 20 percent of the population of Brazil, Bolivia, Chile, Colombia, Ecuador, India, Jordan, Korea, Nigeria, Pakistan, Peru, Venezuela, and Vietnam. A prevalence of 10 percent has been reported in Ethiopia, Malaysia, and Thailand.

### *145 Other Deficiency Diseases*

There have been isolated reports of the prevalence of other deficiency diseases but no systematic studies of their international incidence have been conducted.

Pellagra still occurs but is not ordinarily a major problem even where corn supplies more than 60 percent of the dietary calories. If poor crops reduce the availability of supplemental foods, pellagra may be a serious problem particularly in some parts of Africa.

Isolated reports of beriberi and ariboflavinosis continue to appear, especially in some parts of Southeast Asia. In the Philippines, beriberi ranks among the first five causes of death and in one province, the mortality from this disease exceeds 100 per 100,000 population.[18] The incidence of ariboflavinosis is uncertain but many authorities consider it to be one of the most common of deficiencies.

A health problem that is related to nutrition and has aroused public interest in recent years is dental caries. Data are incomplete but the role of fluorides in prevention has been established.

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[18] National Science Development Board. Food and Nutrition Research Center. Philippines health statistics, 1963, Manila, 1963.

Vitamin C deficiency and its clinical counterpart, scurvy, occur in isolated parts of the world but neither is widespread. Surveys indicate that significant deficiency of this vitamin is a problem in isolated population segments of a few countries only.[19]

Vitamin D deficiency, rickets, is not a major world health problem, but is found in isolated population segments of most countries.

No studies have been carried out in large population groups to identify deficiencies of vitamins such as vitamin $B_6$, vitamin $B_{12}$ and folacin. In some areas, vitamin $B_6$ (pyridoxine) may be consumed in less than desirable amounts, but the clinical and biochemical signs of this deficiency require elucidation.

Because vitamin $B_{12}$ (cobalamin) occurs primarily in foods of animal origin, it is probable that its intake is less than adequate in many countries. A few studies have shown that segments of the population in less developed countries exhibit symptoms possibly related to vitamin $B_{12}$ deficiency. Since anemia is prevalent in these areas, it is reasonable to suppose that a contributing cause may be lack of vitamin $B_{12}$.

Folacin (folic acid) deficiency appears to be a minor problem in many of the less developed countries. Deficiency of this vitamin may be due to malabsorption caused by parasitic infestation and other intestinal disorders as well as to an inadequate diet. The role of folic acid deficiency in the widespread anemias in these countries is unknown.

There is need to carry out comprehensive surveys of the incidence of deficiencies of other vitamins such as pantothenic acid, vitamin E, and vitamin K and of minerals such as calcium, phosphorus, copper, selenium, magnesium, and zinc. Data are also needed on the amounts of these nutrients in diets.

## *1.5.0 Growth and Characteristics of Human Populations*

### *1.5.1 Demographic Characteristics of Developed and Developing Countries*

In the 25 years prior to the crop season of 1960–1961, total cereal production in the less developed countries of the world increased by 42 percent, but per capita cereal production declined between 2 and 3 percent.[20] In contrast during the same time, cereal production in the developed countries increased 51 percent and per capita production increased by 26 percent. By the early 1960's, Latin America, Africa,

[19] Interdepartmental Committee on Nutrition for National Defense (now the Nutrition Section, Office of International Research, National Institutes of Health).

[20] Brown, L. R., Man, land, and food. U.S. Dep. Agr. Foreign Agr. Econ. Rep. No. 11, 153 p. 1963.

and Asia, which before World War II were exporters of cereals, had become importing regions, with net imports of more than 18 million tons. Only the United States, Canada, Australia, and New Zealand were exporters. The deterioration in production capacity in the developing countries may be even worse than is indicated by these data. Cereal production has been increased, in part, at the expense of production of animal and vegetable protein and "protective" foods, such as fruits and vegetables.

The growing gap in levels of living between the developed and the less developed countries is largely due to the technological revolution. This revolution has enabled rapid and self-generating economic growth to occur in the developed countries, but it has had one critically important effect in the poor ones—a marked reduction in death rates.

The reduction in mortality was not accompanied by a reduction in birth rates, and consequently, it has created something unprecedented in the history of mankind—very high rates of population growth over areas of ancient settlement. An inordinately rapid rise in human numbers is perhaps the most significant characteristic of most of the developing countries. It is commonly believed to be one of the basic causes of the widening economic disparity between the two parts of the world.

Many developing countries show average annual rates of population increase of 2.6 to 3.8 percent, two to three times higher than those in many rapidly growing and sparsely inhabited developed regions.[21] Populations in most less developed countries double in 18 to 27 years; while 55 to 88 years are required in most developed ones. The less developed regions now contain about two-thirds of the world's human beings. By the year 2000, if present rates of growth continue, there will be about four times as many people in the less developed countries as in the developed ones.

On an economic basis, a less developed country has a per capita Gross National Product of less than $400, while a developed country usually has more than $480.[21] Developing countries can be distinguished equally well by their birth rates which are, in almost all cases, more than 34 per 1000 population per year.[21] Birth rates in developed countries are less than 30 per 1000 ranging downward to 13.

Because of high birth rates, the percentage of children in the population is also high in the less developed countries. The proportion of persons less than 15 years old ranges from 36 to 48 percent,[21] whereas in the developed countries this proportion is rarely more than 34 percent and may be as small as 21 percent.

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[21] Revelle, R., Population and food supplies; the edge of the knife. Nat. Acad. Sci. Proc. 56(2): 328–351. Aug. 1966.

Although overall death rates are low in all developed countries, they are also low in some developing ones and moderately low in many others. Developed and developing countries therefore cannot be characterized by their overall death rates, but in almost all developing countries, mortalities of infants under one year of age are higher than in developed ones. With very few exceptions, developing countries can be defined as those in which more than 50 children out of every thousand live births die before the age of 1. In developed countries infant mortalities are almost always less than 50 per thousand.[22]

In the developed countries, most deaths of young children occur during the first month of life. But in many less developed ones, more children die between the ages of 6 months and 2 years than during the neonatal period.[22]

In the developed countries, most human beings live to middle age, and cardiovascular diseases and neoplasms are overwhelmingly the most important causes of death. In the less developed countries, the principal killers are the diseases of childhood that result from a combination of infection and malnutrition.

In the aggregate the developing countries occupy about the same land area as the developed countries, but they contain more than twice as many people. The average population density of the less developed countries is twice that of the developed countries, although, densities in most of Latin America and Africa are low. On the average throughout these two continents, there are 12 to 25 acres per person. [23] Much of the land in the sparsely inhabited poor countries of Africa and Latin America is desert, barren savanna, or tropical rain forest, and thus uninhabitable, with present technology, by more than a few people.

In Southeast Asia, Middle South Asia, Mainland China, and other East Asian less developed countries, human populations press harder upon the land. Here the average number of acres per person ranges from one to three.[23] These are the areas that contain more than half the world's people, and most of its poverty and misery; yet even here, surprisingly enough, the population densities are not as high, on the average, as those of Japan and Western Europe. Evidently, the ratio of numbers of human beings to land resources is not as important as other factors in determining the differences between the rich and the poor countries.

### *1.5.2 Uncertainties of Population Estimates*

*1.5.2.1 Uncertainty in the Size of the Present Population.* The estimate of 3.3 billion for the world's population as of the middle of 1965,

[22] Revelle, R., Ibid.
[23] Revelle, R., Ibid.

given in Table 2, is based on inadequate data for a number of countries. There are no recent censuses for many Asian, African, and Latin American countries. Uncertainty about the size of China's population contributes a possible error of more than 100 million.[24] Pakistan's population, according to one estimate,[25] was undercounted by nearly 8 million (7.6 percent of the total population) in the census of 1961. The growth rate for Pakistan since 1961 is uncertain, but if the most probable value of about 3 percent per year is accepted, the estimate of the present population is understated by another 5 percent. If India's population is assumed to be underestimated in somewhat the same proportions as that of Pakistan, the error is more than 50 million. Taking account of the possibility of errors of a similar magnitude for many other less developed countries, the paucity of data for others, and estimates of undercounts of 2.5 to 3 percent for some developed countries such as the United States, the possible error is an underestimate of more than 200 million for the world as a whole.

The population estimates and projections used in this report for Pakistan make allowance for an undercount while those for other areas have not been adjusted because of the different sources adopted for the projections.

*1.5.2.2 Uncertainty in Present Rates of Population Growth.* Of even greater significance to a study of the future relationship of population and food suppy is the rate at which the population is growing. Unfortunately, estimates of present growth rates for much of the world are of doubtful reliability or are simply not available. Greatly divergent values may be obtained by the technique used in estimates. For example, the rate of population growth for Pakistan is 2.1 percent per annum if one accepts the rate implied by the censuses of 1951 and 1961, but about 3.2 percent if one accepts the results of sample surveys conducted since 1962. A population growing at a rate of 3.2 percent annually will be 12 percent larger at the end of ten years than a population of the same initial size growing at an annual rate of 2.1 percent.

In this study we have accepted, as the assumed growth rate of the world population in 1965, the United Nations [26] estimate of 1.8 percent per year for the rate of growth from 1960 to 1964, but we have used other sources as a basis for estimating growth rates in Brazil, Pakistan, and India. Our estimate for Brazil is about 2.9 percent, for India about 2.6 percent, and for Pakistan, 3.2 percent.

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[24] Aird, J. S., personal communication.

[25] Brackett, J. W., and Akers, D. S., Projections of the population of Pakistan by age and sex, 1965–1986. Washington, U.S. Bureau of the Census, 1965.

[26] United Nations. Statistical Office. Demographic Yearbook, 1965. New York, 1966. Reference p. 103.

TABLE 2.—*Projected population and vital rates for the world, Brazil, India, and Pakistan: 1965 to 1985*

[Population data are in millions, vital rates are per 1,000 midperiod population. Although the data shown are not exact enough to warrant the distinction between beginning of the year and midyear figures, the projections for Pakistan relate to January 1 while those for other areas were intended to relate to midyear. The vital rates shown are averages for the 5-year period]

| Year and series | World | | | | Brazil | | | | India | | | | Pakistan | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total population | Natural increase rate | Birth rate | Death rate | Total population | Natural increase rate | Birth rate | Death rate | Total population | Natural increase rate | Birth rate | Death rate | Total population | Natural increase rate | Birth rate | Death rate |
| High series: | | | | | | | | | | | | | | | | |
| 1965 | 3,308 | 18 | 34 | 16 | 81 | 29 | 42 | 12 | 484 | 27 | 41 | 14 | 116 | 34 | 51 | 17 |
| 1970 | 3,624 | 20 | 34 | 14 | 94 | 31 | 41 | 11 | 552 | 29 | 40 | 12 | 137 | 36 | 51 | 15 |
| 1975 | 4,005 | 22 | 35 | 13 | 109 | 32 | 41 | 9 | 636 | 30 | 40 | 10 | 164 | 38 | 51 | 14 |
| 1980 | 4,467 | 24 | 35 | 11 | 128 | 33 | 41 | 8 | 739 | 31 | 40 | 8 | 198 | 40 | 52 | 12 |
| 1985 | 5,032 | | | | 150 | | | | 864 | | | | 241 | | | |
| Low series: | | | | | | | | | | | | | | | | |
| 1965 | 3,308 | 17 | 32 | 15 | 81 | 28 | 40 | 12 | 484 | 23 | 37 | 14 | 116 | 29 | 46 | 16 |
| 1970 | 3,599 | 17 | 30 | 14 | 93 | 27 | 37 | 10 | 542 | 21 | 32 | 11 | 134 | 27 | 41 | 14 |
| 1975 | 3,911 | 17 | 30 | 12 | 107 | 27 | 36 | 9 | 602 | 24 | 33 | 10 | 153 | 31 | 43 | 13 |
| 1980 | 4,264 | 17 | 28 | 11 | 122 | 26 | 34 | 8 | 677 | 25 | 34 | 9 | 178 | 33 | 45 | 12 |
| 1985 | 4,647 | | | | 138 | | | | 769 | | | | 211 | | | |

Source: See text and appendix tables.

The United Nations estimate of the world population growth rate assumes a rate of only 2.0 percent for Middle South Asia, an area comprised of India, Pakistan and several smaller countries. The combined populations of the smaller countries account for less than 10 percent of the total for the region. Had the higher rates for India and Pakistan, given above, been used by the United Nations, the growth rate for Middle South Asia would have been about 2.7 percent and that for the world about 1.9 percent.

*1.5.2.3 Uncertainty in Future Levels of Fertility and Mortality.* Future levels of human fertility and mortality are difficult to predict even when there is reliable information on current levels. Changes in fertility depend upon a wide array of factors, such as changes in the age of marriage, attitudes of married couples regarding family size, and the availability of contraceptives. A number of countries have undertaken official programs to provide family planning information and devices to their populations, and other countries undoubtedly will undertake such programs in the future. Because these programs are comparatively new and generally rely upon contraceptive techniques of uncertain effectiveness in the less developed countries, their impact on future levels of fertility cannot be foreseen with accuracy. It is quite possible also, that new techniques for controlling fertility will be developed in the foreseeable future, the impact of which cannot be predicted.

Mortality rates generally have declined in recent years and nearly all countries are committed in various ways, to further reduction. There is no certainty, however, that this commitment can or will be translated into markedly lower death rates. Population is already pressing hard on the food supply of a number of nations. Except for large shipments of grain from the United States, Canada, and a few other countries during 1966, death rates in India might have risen sharply.

As food requirements increase, the changes that a country will be able to forestall a major famine by importing food from abroad will diminish. The decline in reserves, in countries with surplus producing capacity lessens the likelihood of meeting a sudden increase in demand in less developed countries, such as that produced by drought or flood.

*1.5.3 Present and Future Size of Populations*

Estimates of the size of the populations of the world, Brazil, India, and Pakistan in 1965 have been used for two series of projections of future population at five-year intervals through 1985. (Tables 2, 3, and 4.)

TABLE 3.—*Percent distribution of the population of the world, Brazil, India, and Pakistan, by age groups; 1965 and 1985*

| Age and series | World | | Brazil | | India | | Pakistan | |
|---|---|---|---|---|---|---|---|---|
| | 1965 | 1985 | 1965 | 1985 | 1965 | 1985 | 1965 | 1985 |
| High series: | | | | | | | | |
| Under 5 years | 14.1 | 14.7 | 16.9 | 17.4 | 16.2 | 17.1 | 19.6 | 20.9 |
| 5 to 14 years | 23.7 | 23.1 | 26.4 | 26.5 | 25.4 | 26.1 | 27.5 | 28.8 |
| 15 to 34 years | 31.3 | 32.4 | 32.2 | 32.2 | 32.7 | 31.8 | 28.3 | 31.2 |
| 35 to 64 years | 25.9 | 24.6 | 21.6 | 20.4 | 22.7 | 21.4 | 20.4 | 16.2 |
| 65 years and over | 5.0 | 5.2 | 3.0 | 3.5 | 3.0 | 3.6 | 4.2 | 2.8 |
| All ages | 100.0 | 100.0 | 100.1 | 100.0 | 100.0 | 100.0 | 100.0 | 99.9 |
| Low series: | | | | | | | | |
| Under 5 years | 14.1 | 11.3 | 16.9 | 14.9 | 16.2 | 14.8 | 19.6 | 18.4 |
| 5 to 14 years | 23.7 | 21.9 | 26.4 | 24.7 | 25.4 | 22.6 | 27.5 | 25.4 |
| 15 to 34 years | 31.3 | 34.6 | 32.2 | 34.4 | 32.7 | 34.4 | 28.3 | 34.3 |
| 35 to 64 years | 25.9 | 26.6 | 21.6 | 22.2 | 22.7 | 24.1 | 20.4 | 18.6 |
| 65 years and over | 5.0 | 5.6 | 3.0 | 3.8 | 3.0 | 4.1 | 4.2 | 3.2 |
| All ages | 100.0 | 100.0 | 100.1 | 100.0 | 100.0 | 100.0 | 100.0 | 99.9 |

Source: See appendix tables.

TABLE 4.—*Projected population of the world, Brazil, India and Pakistan, by age groups, 1965 and 1985*

[Population figures in millions]

| Age and series | World | | | Brazil | | | India | | | Pakistan | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1965 | 1985 | Percent increase | 1965 | 1985 | Percent increase | 1965 | 1985 | Percent increase | 1965 | 1985 | Percent increase |
| All ages: | | | | | | | | | | | | |
| High | 3,308 | 5,032 | 52 | 81 | 150 | 85 | 484 | 864 | 78 | 116 | 241 | 108 |
| Low | | 4,647 | 40 | | 138 | 70 | | 769 | 58 | | 211 | 82 |
| Under 5 years: | | | | | | | | | | | | |
| High | 467 | 742 | 59 | 14 | 28 | 100 | 78 | 148 | 90 | 23 | 51 | 122 |
| Low | | 556 | 19 | | 21 | 50 | | 114 | 46 | | 39 | 69 |
| 5 to 14 years: | | | | | | | | | | | | |
| High | 784 | 1,160 | 48 | 22 | 40 | 82 | 123 | 225 | 83 | 32 | 69 | 118 |
| Low | | 984 | 26 | | 34 | 54 | | 174 | 42 | | 54 | 68 |
| 15 to 34 years: | | | | | | | | | | | | |
| High | 1,033 | 1,629 | 58 | 26 | 48 | 85 | 158 | 274 | 74 | 33 | 75 | 127 |
| Low | | 1,606 | 55 | | 48 | 85 | | 265 | 68 | | 72 | 118 |
| 35 to 64 years | 859 | 1,239 | 44 | 18 | 31 | 72 | 110 | 185 | 68 | 24 | 39 | 62 |
| 65 years and over | 165 | 262 | 58 | 2 | 5 | 121 | 14 | 31 | 117 | 5 | 7 | 42 |

Source: See appendix tables.

*15.3.1 Assumptions for the Two Population Projections.* Projections in the high series are based on the assumption that fertility will remain at present levels. The low series was based on a decline in fertility levels. It was assumed that mortality will decline at the same rate in both series. No attempt was made to measure the impact of possible subsistence crises.

For the high series it was not assumed that birth rates (e.g., births per 1000 total population) will remain constant, but rather, that age-specific fertility, the probability that a woman of a given age will bear a child, will remain constant. Birth rates (and also death rates, when mortality is constant) under these conditions fluctuate according to the age-sex structure of the population.

The level of fertility for the world in 1965 was obtained by assuming that a birth rate of 34 per 1000 population (about equal to that of Taiwan), given in the United Nations, *Demographic Yearbook, 1965*, as the average for 1960–64, applies equally to 1965. A set of female age-specific fertility rates was obtained by slightly modifying a schedule of rates for Taiwan for 1960. These adjusted rates were used to establish birth rates for the high series. For the low series, it was assumed that fertility will decline to 90 percent of the 1965 value by 1970, to 80 percent by 1980, and to 70 percent by 1985.

For the high series for Pakistan a model was constructed to reflect the assumed levels of fertility for East and West Pakistan separately. East Pakistan's birth rate was assumed to be 53 per thousand in 1961 while that for West Pakistan was placed at 50. The expectation of life at birth was assumed to increase about 3.3 years per decade.[27]

For the low series it was assumed that the intensified family planning program introduced in 1965 would be gradually extended throughout the population. It was assumed that maximum effectiveness will be reached by 1972, at which time the fertility rate (sum of age specific fertilities) will have decreased 28 percent. It was assumed that after 1972 the family planning program would expand at the same rate as the population to be served, i.e., the proportion of the population practicing family planning would remain constant. If this proportion continued to rise during the 1970's and 1980's our assumed growth rates for the latter part of the period would be too high.

The Indian high series projections were prepared by the Institute of Applied Manpower Research in New Delhi.[28] The average birth rate during 1961–65 was assumed to be 41 per thousand and the assumed 1965 birth rate was also close to this value. The expectation of lon-

[27] Brackett, J. W., and Akers, D. S., Projections of the population of Pakistan by age and sex, 1965–1986. Washington, U.S. Bureau of the Census, 1965.

[28] Institute of Applied Manpower Research. Manpower aspects of educational development and national population growth perspective. New Delhi, 1965.

gevity at birth was assumed to increase about 7 years per decade. For the low series, the percentage decline in fertility assumed for Pakistan was adopted.

For Brazil, the United Nations Commission for Latin America estimated the birth rate during the period 1959–61 to be in the range of 40 to 43 per thousand. A birth rate of 41 for 1965 was used to establish the level of fertility for the projections. For the low series a modified version of the fertility model developed for Pakistan was used to establish a schedule of fertility rates.

*1.5.3.2 Possible Range of Future Population Size.* The high series projections show a 52 percent increase in the population of the world from 3.31 billion in 1965 to 5.03 billion by 1985. The low series projects a population of 4.65 billion in 1985, an increase of about 40 percent above the 1965 figure. These numbers correspond to average annual growth rates of 2.1 percent and 1.7 percent respectively.

The difference between the high and low figures for the world population in 1985 is only 385 million persons, about the same as the probable range of uncertainty in the projected population of Mainland China in 1985.[29] The difference would be much greater in later decades, if rates of increase were to persist beyond 1985. By the year 2000, for example, an annual rate of increase of 2.4 percent, starting with a population of 5 billion in 1985 would result in a world population of 7.15 billion persons, whereas an annual rate of 1.7 percent and a 1985 population of 4.65 billion would produce a world population of 6 billion by the end of the century.

As Table 3 shows, the proportion of the world population in the reproductive ages would increase slightly under the high projection, and by about 10 percent in the low series. Consequently, the high series would give a slight increase in birth rates, even though age-specific fertilities are assumed constant and the decline in birth rates in the low series would be much less than the assumed decline in age-specific fertility. For the high series, the natural increase rate increases 5 to 6 per 1000 during the projection period (Table 2). For the low series the assumed declines in the birth rate are just about offset by declines in the death rate.

The high series for Brazil, India, and Pakistan show trends similar to those displayed for the world as a whole (Table 2). Growth rates for Brazil and India would increase to more than 3 percent by 1985 while the growth rate for Pakistan would be about 4 percent. For the low series the growth rate for Brazil decreases only slightly and increases for both India and Pakistan. For both the latter countries birth rates decrease during the early part of the period and rise

[29] Aird, J. S., personal communication.

263–888 O—67——4

somewhat thereafter. This pattern stems from our assumed model of fertility reduction.

The proportional difference in population size between our high and low projections for 1985 is greater in India and Pakistan than in the world as a whole; the high value for both countries being about 12.8 percent greater than the low one. The difference in 1980 would be only a little over 9 percent. By the end of the century, if the assumed 1985 rates of increase were to continue, the population of the subcontinent would be nearly 25 percent greater under the high projection than the low. The projected population of over 1800 million persons in the Indian subcontinent under the high projection would be three times the present population of the region and more than half the 1965 population of our entire planet.

### *1.5.4 Population Growth and Food Needs*

In terms of the need to increase food supplies, particularly in the less developed countries, these figures strongly emphasize the urgency of large-scale and effective action. If present trends continue, the possibility of ultimate improvement will be gravely reduced because of the enormously increased magnitude of the problems. By the year 2000, the population of India will have increased to such an extent, even with the low population projection, that the present area harvested for food crops would provide only about three-tenths of an acre per person, about the same as in Egypt today. The most critical situation will occur about 1980, before any decrease in the rate of population growth can have much effect.

*1.5.4.1 Economic Effects of Rapid Rates of Population Growth.* It is clear that no probable reduction in the rate of population growth would be sufficient, during the next 15 to 20 years, to overcome food deficits; but, because economic growth and social development are made much more difficult by rapid population growth, it may be equally true that a reduction in the rate of population growth will be necessary to increase food production.

We have already seen that a high birth rate results in a very high proportion of children in the total population, approximately 45 percent under 15 years old (Table 3), and hence, a heavy dependency burden on the producing adults in a society. Education, health, and other services put an equally great burden on the total national income. A high rate of population growth also means that even a relatively high rate of economic growth results in very little improvement in per capita income and in the ability to save for capital investment. The needed growth in agricultural and industrial production is thus severely inhibited.

In the developed countries, with their low birth rates, there are between two and three adults (persons 20 years of age or older) for each child under 15. In the less developed countries, the number of adults is about equal to the number of children. During the next two decades, the proportion of children in the developed countries will probably diminish, and their absolute numbers will increase by only around 15 percent. In contrast, if fertility remains at present levels in the less developed countries, the proportion of children will rise, and their absolute numbers will about double (Tables 3 and 4). On the other hand, if fertility can be reduced by the amounts we have assumed, the number of children will increase by only one-half to two-thirds of what would occur if fertility remains constant.

These possible differences in number of children have important implications for education. In Pakistan, for example, under the high projection the number of children of primary school age—5 to 14 years—will increase by 118 percent in 20 years (see Table 4, Appendix) or nearly 4 percent per year. This means that with an annual economic growth rate of 5 percent, and a constant fraction of national income going into education, the educational expenditures per child of primary school age can be increased only 1 percent per year, or 22 percent in 20 years. Since less than half the children are now in school, the proportion receiving a primary education in 1985 would still be less than 60 percent. The fraction of national income going into education will need to be doubled to ensure a primary education at the present minimal level for all the children, let alone to improve the quality or lengthen the period of schooling.

With the low projection, the number of children of school age increases only 68 percent, or 2.6 percent per year. With the same economic growth rate of 5 percent, and a constant fraction of national income going into education, the educational expenditure per child could be increased by 62 percent over the 20-year period. By 1985, 80 percent of the children could be given a primary education.

The poverty of the less developed countries gravely constrains not only their total educational expenditures, but also the percentage of income that can be alloted to education.The high proportion of children in the poor nations means that meager educational budgets must be spread very thin. The United States spends more on education each year than the entire national product of India. In England and several other European countries, children of primary school age make up only about 14 percent of the population, half the percentage in Pakistan. By 1985, the proportion of 5 to 14-year olds in the United States will probably be only two-thirds that in Pakistan.

Today's poorly educated children in the less developed countries will be tomorrow's job seekers. India's population in the age group 15 to 34 will increase over the next two decades by 107 to 116 million, Pakistan's by about 41 million, and Brazil's by 22 million, a total of 170 to 180 million (Appendix Tables 1–4). This means jobs must be created for about 100 million young persons entering the labor force for the first time. The total size of the labor force in these three countries will grow by roughly 200 million, or 70 percent. Nearly all this increase will come from persons who are already born; consequently, the magnitude of the employment problem in 1985 will not be much affected by changes in fertility levels during the next 20 years. *If a capital investment of $1,000 is required on the average to create a new job, then the total cumulative investment needed for the three countries by 1985 would be about $200 billion even to maintain the present very low per capita incomes.*

The proportion of the population in the age group 65 and over is low and likely to remain so. Our projections show that these will be only about 4 percent of the population of India, Pakistan, and Brazil in this age group by 1985 compared to 5.6 percent for the world as a whole. More than 9 percent of the U.S. population is 65 or older.

### *1.5.5 Prospective Changes in the Geographic Distribution of the World's Population*

Although population projections for world regions consistent with the projections in Tables 2 and 4 are not available, the United Nations [30] has prepared regional projections. Estimates for 1965 and 1985 for the United Nations "Medium" variant (which corresponds fairly closely to the low series in our Tables 2 and 4) are given in Table 5. The United Nations data show the proportion of the world's population residing in less developed areas will increase from 69 percent in 1965 to 74 percent in 1985. On a regional basis, the percentages in Africa, Asia, and Latin America will increase while those in Europe, North America, and the USSR will decrease.

The United Nations study shows an overall increase in world population of 45 percent by 1985 as compared with 1965. Latin America, with an increase of 78 percent, and Africa, with an increase of 68 percent, are shown as the fastest growing. The United Nations' projected increase for Asia during the 20-year period is based on an assumed annual growth rate of only 2 percent, well below the growth rates we have used in Tables 2 and 4 for two of the three largest Asian countries, India and Pakistan.

[30] United Nations. Department of Social Affairs. Population Division. World population prospects as assessed in 1963. Population Studies No. 41, 1966.

TABLE 5.—*Projected population of world regions according to the United Nations "medium" variant, 1965 and 1985*

| Area | Population (in millions) | | Percent change | Each area as a percent of the world total | |
|---|---|---|---|---|---|
| | 1965 | 1985 | 1965–85 | 1965 | 1985 |
| World | 3,281 | 4,746 | 45 | 100 | 100 |
| More developed [1] | 1,032 | 1,256 | 22 | 31 | 26 |
| Less developed [2] | 2,249 | 3,490 | 55 | 69 | 74 |
| Africa | 306 | 513 | 68 | 9 | 11 |
| Asia | 1,828 | 2,701 | 48 | 56 | 57 |
| Latin America | 245 | 436 | 78 | 7 | 9 |
| Europe | 440 | 492 | 12 | 13 | 10 |
| North America | 213 | 283 | 33 | 7 | 6 |
| Oceania | 17 | 25 | 44 | 1 | 1 |
| U.S.S.R. | 231 | 297 | 28 | 7 | 6 |

[1] Includes Europe, the U.S.S.R., Northern America, Japan, Argentina, Chile, Falkland Islands, Paraguay, Uruguay, Australia, and New Zealand.

[2] Includes Asia (except Japan), Africa, Latin America (except Argentina, Chile, Falkland Islands, Paraguay, and Uruguay), Oceania (except Australia and New Zealand).

SOURCE: United Nations. Department of Social Affairs. Population Division. World population prospects as assessed in 1963. Population Studies No. 41, 1966. Reference on p. 134.

### *1.5.6 How Sharp a Decline in Fertility Can Be Expected in the Less Developed Countries?*

The assumed decline in rates of fertility in the low projections are chosen simply for illustration because they cannot be justified quantitatively with our present level of understanding. There are good reasons to believe that human fertility in most of the less developed countries will decrease during the next few decades, but when and how much cannot be predicted. We are able to identify, however, several of the factors involved.

*1.5.6.1 Factors Affecting Human Fertility.* Fertility rates in nearly all human societies that practice agriculture fall well below the potential of human fecundity; the direct constraints on population growth appear to be social ones, not as Malthus first thought, starvation and disease. Birth rates in the industralized nations began to fall below the levels in primarily agricultural nations about 100 years ago. There was a growing tendency to postpone marriage, to increase celibacy, to resort to abortion, and to practice contraception, in addition to the limitation of population by emigration.

In recent years, rapid decreases in fertility levels have occurred in several developed countries; notably in eastern Europe and in Japan. Fertility rates were lowered by about 40 percent in Hungary between 1954 and 1962, by 36 percent in Rumania between 1955 and 1962, and by 30 percent in Poland between 1955 and 1964. Japan experienced an even sharper decline—the decrease measured from the 1947–49 period

when fertility was exceptional high because of the post-war reaction, amounted to 55 percent. If from 1950, it is 44 percent.

Conditions in these countries differ markedly from those in the less developed areas. Literacy rates were high, fertility was already being controlled by significant segments of the population (fertility levels were about half those of many less developed areas even before the recent declines), and the people were strongly motivated to limit family size. Even Japan, with one of the lowest birth rates in the world, is no model of direct emulation by her Asian neighbors. In terms of industrialization, urbanization, literacy, and rapid social change, Japan differs profoundly from all other countries in Asia.

Surveys of attitudes of husbands and wives concerning the number of children they would like to have show clearly that in the less developed countries there is a desire to limit family size.[31] Many couples want no more children than they already have, and would like to know better ways of preventing further births. The average number of live births per woman in these countries is over 30 percent greater than the desired number of children (Table 6). Only part of this difference can be accounted for directly by the deaths of children, though, as we shall see, high infant and child mortalities are an underlying cause of high reproductive rates. At the same time, these surveys demonstrate that the numbers of children desired by married couples in most of the less developed countries are much higher than in the developed ones. The unweighted average is four children per couple, which, with present and prospective levels of mortality, would double population every 30 to 35 years.

Typically, in developing countries, half to two-thirds of the people want four or more children, while in most developed countries less than 25 percent want four or more. Most people in developed countries want two to four children; in the less developed countries they want three to five. In the developed countries, actual family size is slightly less than desired family size, while the reverse is true in less developed ones (Table 6).

In Japan and Hungary, 95 to 98 percent of parents with four living children do not want more; 92 to 95 percent of those having three and 76 to 85 percent of those having two living children do not want another child.

In Jamaica, India, Ceylon, Taiwan, Thailand, and the Philippines, 66 to 86 percent of women having four living children, 45 to 71 percent of those having three, and 27 to 56 percent of those with two, do not want more. In Turkey, Pakistan, and Indonesia, all Muslim countries, the percentages are smaller; 37 to 62 percent of those with four

[31] Mauldin, W. P., Fertility studies: knowledge, attitude and practice. Population Council Studies in Family Planning No. 7: 1–10. June 1965.

TABLE 6.—*Desired family size and actual fertility*

| Country | (1) Population | (2) Average desired number of children | (3) Percent wanting 4 or more children | (4) Parents with living children not wanting more—number of living children | | | | (5) Average live births per woman | (6) Excess live births, percent of total fertility | (7) Infant mortality per 1,000 live births |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 2 | 3 | 4 | 5 or more | | | |
| Puerto Rico | Urban and rural | 3.0 | 19 | NA | NA | 87 | 93 | 4.9 | 39 | 45-51 |
| Ceylon | Rural | 3.2 | 25 | 29 | 57 | 69 | 88 | 5.5 | 42 | (53) |
| Turkey | Urban and rural | 3.5 | 42 | 5 | 23 | 44 | 66 | 5.8 | 40 | (165) |
| Thailand | Not available | 3.8 | 54 | 48 | 71 | 86 | 96 | 6.0 | 37 | (145) |
| Jamaica | Urban and rural | 3.8 | 48 | 56 | 68 | 80 | 84 | 5.5 | 31 | 50 |
| Taiwan | Urban | 3.9 | 62 | 24 | 54 | 76 | 88 | 5.8 | 33 | (30) |
| Pakistan | Urban | 4.0 | 65 | [1] 22 | [1] 44 | [1] 62 | [1] 68 | 6.4 | 39 | (160) |
| India | Urban and rural | [2] 4.1 | [2] 58 | [3] 27 | [3] 42 | [3] 75 | [3] 85 | 5.4 | 24 | (140) |
| Chile | Urban | 4.1 | 58 | NA | NA | NA | NA | 4.5 | 9 | 111 |
| Indonesia | Rural | 4.3 | 66 | 17 | 23 | 37 | 41 | 5.9 | 27 | 125 |
| South Korea | Rural | 4.4 | 76 | NA | NA | NA | NA | 5.7 | 23 | (100) |
| Philippines | Urban and rural | 5.0 | 71 | 42 | 56 | 68 | 85 | 6.4 | 22 | (73) |
| Ghana | Urban | 5.3 | 88 | NA | NA | NA | NA | 6.6 | 20 | (113) |
| Unweighted average | | 4.0 | 56 | 31 | 48 | 68 | 79 | 5.7 | [6] 32 | 86 |
| 10 European countries [4] | Urban and rural | 2.7 | 18 | [5] 85 | [5] 92 | [5] 95 | [5] 93 | 2.6 | −4 | 25 |
| Japan | Urban and rural | 2.8 | 22 | 76 | 95 | 98 | 97 | 2.0 | −40 | 20 |
| United States | Urban and rural | 3.3 | 40 | NA | NA | NA | NA | [7] 3.3 | 0 | 25 |

[1] Average for East and West Pakistan.

[2] Weighted average of urban and rural surveys in Mysore (1952), an urban/rural sample in Central India (1958) and a rural sample near Delhi (1957-60).

[3] Central India only.

[4] Austria, W. Germany, Czechoslovakia, Hungary, Great Britain, France, Switzerland, Norway, Italy, Netherlands.

[5] Hungary only.

[6] Omitting countries with only an urban sample.

[7] Computed from data given in tables 5 and 17 of Demographic yearbook, 1964. United Nations. Statistical Office.

SOURCES: Columns (1) through (4)—Sample survey results reported in Population Council studies in Family Planning No. 7, June 1965. Column (5)—Cho, L. J., Estimated refined measures of fertility for all major countries of the world. Demography 1(1):359-374. 1964. Column (7)—Our estimates, based on data given in United Nations. Statistical Office. Demographic yearbook, 1964. New York, 1965. Table 19.

living children, 23 to 44 percent of those with three, and 5 to 22 percent of those with two living children do not want another child.

A study of urban versus rural preferences in family size was made in Korea. Here the proportion of people in rural areas wanting five or more children was over four times as high as in urban areas (42 to 45 percent against 10 percent); the proportion wanting four or more was more than twice as high (73 to 80 percent against 35 percent).

The difference in desired family size between the developing and the developed countries can be understood only if we take into account the cultural and social differences between the two groups of nations. Freedman [32] has given a perceptive discussion of the problem. He points out that much of the decline in European fertility resulted from the practice of coitus interruptus, a method of contraception which can be reinvented by each couple that has a strong parental motivation to limit the number of children. This and other "folk" methods of fertility control, for example abortion, were equally available in the less developed areas, and past failure to use them extensively has been at least in part the result of social pressures for high fertility. Individual couples had many children because they wanted or needed them. A non-secular view of nature and a reluctance to interfere with "ways of divine providence" may also have played a role.

High fertility has been an adjustment to high and unpredictable mortality and also has been of central importance in a community life built on family and kinship ties. In most pre-industrial societies, a wide range of activities involves interdependence with relatives and with children. These include economic production, consumption, leisure, assistance in illness and old age, and other activities covered by nonfamily institutions in modern societies.

Emphasis on the importance of male heirs leads to large families. Only one son may be needed for ritual or economic purposes, but it is common to desire at least two for insurance against the death or incapacity of one. Families would have to average about four living children to obtain two sons.

Availability of birth control means is largely irrelevant until the desired number of living children is secured. Favorable attitudes to family limitation are much more common among couples who already have three or four living children. Thus, low infant and child mortality, and public awareness that mortality is low, seems to be one of the necessary conditions for an effective social policy for reducing fertility. The momentum of the traditional social structure may cause large numbers of births to occur long after child mortality has actually fallen.

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[32] Freedman "The Sociology of Human Fertility", Current Social. Vols. 10–11, No. 2 (1961–62).

A recent study in Cairo, Egypt, supports the idea that the experience of infant or child mortality tends to raise fertility.[33] Mothers 45 to 49 years old were subdivided into ten groups according to five levels of educational attainment and according to whether they had experienced the death of one or more of their children. In each of the five educational classes, those women who had experienced one or more child deaths had borne a considerably higher number of children than those who had not experienced such a death. Mothers of all ages who had lost one or more children tended to desire a larger number of children who would be alive when the mother reached age 50 than did mothers who had not lost a child.

The relationship between mortality and fertility in less-developed countries is illustrated by an intra-country comparison of different districts in Ceylon, Mauritius, and British Guiana.[34] In Table 7 the five districts with the highest pre-1950 mortality rates in each country are compared with the five districts having the lowest pre-1950 mortality. In all three countries, those districts with relatively high mortality and a low rate of natural increase prior to 1950 experienced a rise in birth rate in recent years. In Ceylon and Mauritius, the districts with relatively low mortality and a high rate of natural increase prior to 1950 showed a marked decline in the birth rate in 1960 and 1964, respectively. In British Guiana, there are no data after 1955. In that year the birth rate for the low mortality districts was slightly higher than it had been in 1945–49, but the percentage increase of birth rates was much smaller than in the districts where the 1945–49 mortality was relatively high.

Heer and Smith [35] have presented a model which indicates that large-scale reductions in fertility are unlikely in the less developed nations unless these countries see a further substantial reduction in their level of mortality.

In regions where the average mortality of children has been reduced, but is still relatively high, the variance in mortality will also be large and the parents' desire for a high degree of "insurance" that at least one son will grow to manhood may result in the maintenance of high fertility. Consequently, the net reproduction rate and the annual rate of natural increase will be greater than where infant and child mortality are sufficiently low. We are faced with the apparent paradox that a reduction in mortality will reduce rather than raise the rate of population growth.

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[33] Hassan, S., Influence of child mortality on fertility. Paper presented at annual meeting of the Population Association of America, New York City, April 1966.

[34] Frederiksen, H., Determinants and consequences of mortality and fertility trends. Public Health Reports 81(8): 715–727. Aug. 1966.

[35] Heer, D. M., and Smith, D. O., The impact of mortality level upon desired family size. Paper presented at the 134th meeting of the American Association for the Advancement of Science, Washington, D.C., 1966.

TABLE 7.—*Changes in birth rates related to previous death rates, and rates of natural increase in three less developed countries*

| | Ceylon | Mauritius | Guiana |
|---|---|---|---|
| FIVE HIGH MORTALITY DISTRICTS | | | |
| Pre-1950: | | | |
| Birth rate | [1] 35.3 | [3] 39.0 | [3] 36.2 |
| Death rate | [1] 33.4 | [3] 31.3 | [3] 17.0 |
| Natural increase rate | [1] 1.9 | [3] 7.7 | [3] 19.2 |
| Post-1950 birth rate | [2] 46.1 | [4] 39.6 | [5] 42.7 |
| FIVE LOW MORTALITY DISTRICTS | | | |
| Pre-1950: | | | |
| Birth rate | [1] 40.3 | [3] 44.3 | [3] 43.8 |
| Death rate | [1] 21.0 | [3] 25.0 | [3] 13.1 |
| Natural increase rate | [1] 19.3 | [3] 19.3 | [3] 30.7 |
| Post-1950 birth rate | [2] 37.5 | [4] 38.8 | [5] 45.4 |

[1] Average annual rate per thousand for 1930–45.
[2] Average annual rate per thousand for 1960.
[3] Average annual rate per thousand for 1945–49.
[4] Average annual rate per thousand for 1964.
[5] Average annual rate per thousand for 1955.

Source: Frederiksen, H., Determinants and consequences of mortality and fertility trends. Public Health Reports 81(8):715–727. Aug. 1966.

As mortality drops from an intermediate to a low level, the rate of natural increase should decline rapidly. Today, infant and child mortality in most of the less developed nations is at an intermediate level and that of the developed nations at a low level. If, as Heer and Smith assume, parents want a 95 percent certainty that one of their sons will become a man, we can expect little reduction in the rate of population increase until infant and child mortality in the less developed nations approaches the level in the developed ones. On the other hand, it may be possible to create changes in social structure so that parents will no longer feel compelled to seek such a high degree of assurance of the survival of at least one son to their old age.

Even after taking into account the effects of mortality in producing high fertility in underdeveloped areas, it is probably still true that the social norms prescribe a larger number of living children than is true of modern societies. Clan or tribal kinship systems enhance the value placed on children because they contribute to the power or status of the group. Elements of this effect appear in western societies among religious or ethnic minorities. Extended family systems, in which many relatives live together, average higher fertility than the family systems in which fewer social functions are carried out within the family unit.

*1.5.6.2 Fertility Control Programs in the Less Developed Countries.* Declines in fertility in the West resulted from married couples deciding individually to limit the size of their families by resorting to abortion and to "folk" methods of contraception that had been known for centuries. Organized society generally frowned on these practices, laws were passed against the sale and distribution of contraceptive information and supplies, birth control movements were strongly denounced, and leaders of birth control movements were often jailed. Nevertheless, as economies industrialized, as people moved from village to town to city, and as the traditionally subordinate status of women was modified, the small family became the norm. The transition from high to relatively low fertility rates occurred in a much less favorable atmosphere for family planning than exists in the world today. Confronted with high rates of population growth that are a major drag on economic development, the governments of developing countries are now endorsing population control policies at a rate and in a climate of world approval unimaginable even a few years ago.

Among the nations that have officially decided to foster family planning are India, Pakistan, Mainland China, South Korea, Ceylon, Singapore, Hong Kong, Malaysia, Turkey, Egypt, Tunisia, Morocco, and Honduras. Taiwan has no formal policy, but the Government has given full cooperation to an island-wide program that has already reached a substantial part of the population. In many other countries, at least the beginning of governmental interest is visible. These include the Philippines, Thailand, Nepal, Afghanistan, Iran, Kenya, Mauritius, Chile, Colombia, Peru, and Venezuela.

In the field of family planning, governmental programs must be catalytic agents rather than the total effort. Formal policy statements at high governmental levels are neither necessary nor sufficient to achieve a reduction in fertility. In some rapidly developing areas of Asia such as Singapore, Hong Kong, and Taiwan, widespread contraceptive practices predated official policy. The adoption of a birth control program doesn't ensure a reduction of fertility. The role of governments in reducing fertility is to exhort, inform, and provide; decisions and actions must be taken by individual couples acting in accordance with their perceived interests. Even so, the governmental task is large and difficult, requiring a high degree of organization, adequate financial and logistic support, great flexibility in meeting changing conditions, and continuing objective evaluation of results.

Only a small proportion of people in the less developed countries have even moderate knowledge of modern methods of family plan-

ning; the poor and the uneducated need to learn what the well-to-do and the educated already know, that there are a number of safe, reliable, and simple methods of limiting family size. Knowledge of contraceptive methods is much less widespread than the desire not to have more children. In recent surveys in India, only 11 to 15 percent of the people in rural areas near Mysore, and 28 to 43 percent in villages near New Delhi, said they had some knowledge about methods of contraception. In Japan, more than 90 percent of the people know about these methods.

Among urban populations of the less developed countries, 6 to 40 percent of persons interviewed had used some contraceptive method; in rural areas, they were used by 1 to 9 percent of the population.

Among the most widely used contraceptives today are intrauterine devices and pills, methods that have several advantages over those which were available ten years ago. Even these new methods may be inadequate, however, for poorly motivated or illiterate people, and in developing countries, family planning programs may not be as effective as planned. Considerable research and technological effort is going into the development of better birth control methods. This should contribute a good deal to speeding up the adoption of family planning.

Emphasis needs to be placed on birth control education in the less developed countries. The importance of education is not simply in facilitating the dissemination of knowledge about ideas and means of birth control. It is the more basic fact that educated people become involved with modern ideas and institutions. If the individual sees himself as part of a larger non-familial system, he begins to find rewards in social and economic relationships in which a large number of children may be unnecessary or even a hindrance.

Equally fundamental for population control, as we have shown, is a continuation of the decline in mortality that has occurred during the last two decades, particularly a marked decrease in infant and child mortality. Reduction of malnutrition among children as a result of increased quality and quantity of food supplies may be a key factor in solving the population problem of our time.

### *1.5.7 Population Characteristics Affecting Nutrition*

In computing the nutritional requirements of a population, we must consider more than numbers. The age and sex distribution are also important as are average body size of males and females at different ages. The level of physical activity, and the environmental temperature should be taken into account, but differences in these factors among most peoples, at least in the less developed countries, are not highly significant (see Section 1.6.1).

*1.5.7.1 Body Size.* Available data on growth as measured by increases in body weight with age in Latin American and Asian countries answer a few questions—and leave many unanswered, including the basic question of the relative importance of genetic and environmental factors such as nutrition on the mature body size of the people in these countries.

There are marked variations in average body weights among different peoples. The ranking by average body weight of males of ages 25 to 29 years in the seven Latin American countries for which data are available is shown in Table 8. The average Uruguayan man weighs about 20 percent more than the average Northeast Brazilian man. A similar difference exists among the women of these countries. An average Uruguayan woman 25 to 29 years old weighs 60 kg; an average woman from Northeast Brazil weighs 48.8 kg.

Of the six Asian countries for which average body weights are available, Malayan men are the heaviest (55.1 kg.), even though they weigh less on the average than men in any of the Latin American countries. (Table 9.) Between the relatively small Indians and the large Malayans the average difference is nearly 15 percent; while between East and West Pakistan it is even larger, about 20 percent. The total range between Indians and Vietnamese at the small extreme (Table 9) and Uruguayans and Chileans at the large extreme (Table 8) is about 40 percent.

Data on body weight and caloric supply indicate a direct relation between nutrition and growth: the populations which have the high-

TABLE 8.—*Average height and weight of males and females (25–29 years) and estimated daily calorie supplies for seven Latin American countries*

| Country | (1) Males (2) | | (3) Females (4) | | (5) Estimated daily calorie supply 1959–61 |
|---|---|---|---|---|---|
| | Height (cms.) | Weight (kg) | Height (cms.) | Weight (kg) | |
| Uruguay | [1] 168.1 | 70.0 | [1] 155.5 | 60.0 | 3030 |
| Chile | 162.8 | 64.3 | 151.9 | 56.4 | 2610 |
| Venezuela | 164.2 | 62.4 | 152.5 | 53.0 | 2330 |
| Bolivia | 161.3 | 61.0 | 151.0 | 54.0 | 2010 |
| Colombia | [1] 160.1 | 59.6 | [1] 151.2 | 49.4 | 2280 |
| Northeast Brazil | [1] 160.6 | 58.0 | [1] 150.4 | 48.8 | NA |
| Ecuador | [2] 157.7 | 57.5 | [2] 146.3 | 51.3 | 2100 |

[1] Average of 15+ years.
[2] Average of 20+ years.

Source: Columns (1)–(4): U.S. Interdepartmental Committee on Nutrition for National Defense. Surveys for each country. Column (5): World food budget 1970. U.S. Dep. Agr. Foreign Agr. Econ. Rep. No. 19, 105 p. 1964 (except for Northeast Brazil where estimate is average obtained in Interdepartmental Committee on Nutrition for National Defense. Nutritional Survey of Northeast Brazil.) Washington, D.C., 1961.

TABLE 9.—*Height and weight of males and females (25–29 years), and estimated daily calorie supplies for six Asian countries*

| Country | Males | | Females | | Estimated daily calorie supply 1959–61 |
|---|---|---|---|---|---|
| | Height (cms.) | Weight (kg) | Height (cms.) | Weight (kg) | |
| | (1) | (2) | (3) | (4) | (5) |
| Malaya | 161.8 | 55.0 | 150.7 | 47.8 | 2,400 |
| Thailand | 161.0 | 53.2 | 151.0 | 45.8 | 2,120 |
| Pakistan [1] | NA | 50.6 | NA | 43.8 | 2,120 |
| Burma | 161.5 | 49.9 | 150.7 | 45.2 | 2,170 |
| Vietnam | 157.6 | 49.1 | 147.6 | 43.5 | 1,944 |
| India [2] | 163.0 | 48.2 | 150.7 | 42.5 | 2,060 |

[1] Average for West and East Pakistan; both males and females in West Pakistan are on the average about 9 kilograms heavier than in East Pakistan.

[2] Age 20–21.

Source: Columns (1)–(4): U.S. Interdepartmental Committee on Nutrition for National Defense. Surveys for Thailand, Burma, East Pakistan, and South Vietnam; for India a weighted average of rural, semi-urban, and urban measurements was computed from data given by the India Council of Medical Research, "Report of 42d Meeting, Nutrition Advisory Committee," Hyderabad, December 1960. Data for West Pakistan were kindly contributed by Dr. Barbara Underwood, Institute of Nutrition Sciences, Columbia University; for Malaya, average adult weights were given to us by Dr. E. B. Bridgforth, University of Texas, Galveston. Column (5): World food budget 1970. U.S. Dep. Agr. Foreign Agr. Econ. Rep. No. 19, 105 p. 1964 (except for Vietnam, where estimate is based on ICNND Survey).

est mature body weights among the Latin American and Asian countries respectively, also have the highest estimated daily caloric supply. (Tables 8 and 9.) The difference in the body weight-caloric supply relationship *between* the populations of the two groups of countries, however, indicates basic genetic differences between the peoples of the Asian countries and those of the Latin American countries.

A direct effect of nutrition on body size is suggested by a comparison of data for rural, semi-urban and urban India. Urban males 20–21 years old are 5.2 kg heavier than rural males; urban females are 3.75 kg heavier than rural females. These differences in body weight are accompanied by differences in stature at the same age: urban men are 5.60 cms taller than rural ones; urban women are 4.85 cms taller than rural women[36]. The most probable explanation for these differences is the availability of more and better food in the cities, though one must consider the possibility that bigger people have migrated to the cities in greater numbers than smaller people.

That nutrition can be a determining factor in fulfilling genetic potential is strongly suggested by the change in body size of the Japanese people in the twelve year interval from 1948 to 1960; average body weight increased from 39.9 kg to 43.2 kg, average height from

[36] India, Council of Medical Research. Nutrition Advisory Committee. Report. 42nd meeting, Dec. 1960.

137.4 cm to 143.9 cm. Japanese children (1–19 years) increased in height 5.4 cms and in weight 2.5 kg. These increases accompanied an increase in animal protein in the diet from 13 grams to 25 grams per day.[37]

The trend in the developed countries for people to be taller and heavier at maturity is probably largely due to improved nutrition and better medical care in childhood, though hybrid vigor may also be a factor. United States inductees during World War II were 1.7 cms taller and 4.9 kg heavier than the inductees of World War I. Inductees measured during 1957–58 were 1.27 cms taller and over 3.2 kg heavier than World War II inductees, thus making a total increase from 1917–18 to 1957–58 of about 3.05 cms and 8.2 kg.

Another example of the realization of genetic potential associated with improvements in nutrition is that of the steady increase of the heights and weights of 5-, 8-, and 12-year-old children in Great Britain from 1911 to 1953, except when the two World Wars had a retarding effect on growth. The weights of 5-year-old urban boys increased from 17.9 kg to 20.1 kg, that of 8-year-olds from 23.0 kg to 27.3 kg, and that of 12 year olds from 32.7 kg to 39.1 kg.[38]

*1.5.7.2 Sex distribution.* There are more females than males in the developed countries, while the reverse is often true in the less developed countries such as India and Pakistan (see Appendix Tables 3 and 4). In both regions, more boys than girls are born, and there is an excess of males over females among children under 15. But in most developed countries the ratio of males to females diminishes among young adults, and usually becomes less than one to one in persons more than 40 years of age. For the age group over 40 years old, there are 15 percent fewer men than women in the United Kingdom, and 10 percent fewer in the United States.

In contrast, the ratio of males to females for India and Pakistan is larger among adults 15–39 years old than among children, and continues to increase up to about age 50. There are 13 percent more Indian men than women in the age group over 40 years old. For the entire population, India and Pakistan have, respectively, 6 percent and 4 percent more males than females, while the United States and the United Kingdom have, respectively, 3 percent and 6 percent more females than males. Brazil occupies an intermediate position; the ratio of males to females at all ages is close to one to one, but diminishes slightly with age.

At first thought, it would appear that this difference in sex ratios would tend to raise significantly the nutritional requirements of the

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[37] Sukhatme, P. V. Feeding India's growing millions. New York, Asia Publishing House, 1965. 172 p.

[38] Boyne, A. W., Secular changes in the stature of adults and the growth of children. *In:* Tanner, J. M. (ed). Human growth. Oxford, Pergamon Press, 1960. 120 p.

less developed countries relative to the developed ones. Men need more calories per kilogram of body weight than women. Since they are usually about 20 percent heavier than women, the daily caloric requirement of 20-year-old men is 50 percent greater than that for women of the same age and country. The difference decreases with age, but is still over 40 percent for people 60 to 70 years old.

However, the countries that have an excess of males over females are also those in which there is a large proportion of children under 15 whose nutritional requirements are much less than those of adults, and are about the same for both sexes. The higher ratios of children to adults more than compensate for the higher man to woman ratios of the less developed countries in determining average caloric needs.

There is no single explanation for the excess numbers of men over women in India and Pakistan or for the observed relation between male to female and child to adult ratios, but one important factor is probably the relatively high mortality among women of child-bearing age.[39] As we have shown, a large proportion of children in a population results directly from high fertility. Poverty stricken mothers in the poor countries, worn out with child-bearing and child-raising, would be expected to have a lower life expectancy, relative to men of the same age, than the young women of the developed countries, with their smaller number of children and better living conditions.

*1.5.7.3 Income distribution and nutrition.* Qualitative evidence that poor people in the less developed countries eat less and poorer food than richer people is easily found. A survey of nutrition in India from 1946–1958 by the Indian Council of Medical Research describes middle class families as eating satisfactory diets, varied with milk, ghee, vegetables and fruits, and low income groups eating mainly inadequate amounts of cereals.[40] A direct positive correlation between per capita income and the intake of calories and protein was observed in a study of poor, pregnant women in India.[41] The voluminous literature on malnutrition in children in the developing countries [42] is a literature describing the children of the poor.

Quantitative data on the variations of caloric and protein supply with income level in the developing countries are more difficult to find.

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[39] For a discussion of this and other explanations of the high male/female ratio in India, see:

Gordon, J. E., Singh, S., and Wyon, J. B., Causes of death at different ages, by sex and by season, in a rural population of the Punjab, 1957–1959, a field study. Indian J. Med. Res. 53: 906–917. 1965 and

Potter, R. G. and others. A fertility differential in eleven Punjab villages. Milbank Memorial Fund Quart. 48: 185–201. 1965.

[40] Pandit, C. G., and Rao, K. S. Nutrition in India (1946–58). New Delhi, Indian Council of Medical Research, 1960.

[41] Pasricha, S., A survey of dietary intake in a group of poor, pregnant and lactating women. Indian J. Med. Res. 46(4): 605–609. July 1958.

[42] Progress in meeting protein needs of infants and preschool children; proceedings of an international conference. Nat. Res. Council Publ. 843, 569, p. 1961.

In a study of 278 families in Chile [43] with average monthly incomes of about $80, the average daily energy and protein consumption were 2212 calories and 68 grams, respectively. But the poorest 25 percent, with family incomes of less than $64 per month, consumed less than 1770 calories and 50 grams of protein per person per day; the top 25 percent, with monthly incomes greater than $95, had a daily intake of more than 2650 calories and 86 grams of protein. It appears that caloric intake varied almost directly with income, while the quality of the diet, as measured by the ratio of protein to calories, was somewhat higher for the more well-to-do families.

Similar results were obtained in a study in Northeast Brazil of 56 families classified as *very poor*, *poor*, *middle income*, and *well-to-do*. The *very poor* averaged only 1606 calories per day (15 percent below the average of 1886 calories per day for all classes), the *poor*, 1862 calories per day (1.0 percent below the average of all classes), the *middle income*, 2028 (108.0 percent of the average), and the *well-to-do*, 2323 calories per day (123 percent of the average). Northeast Brazil is the poorest region of the country, and the average caloric consumption of 1888 calories per day is itself far below the average for all of Brazil. As in Chile, the protein consumption of the four classes shows a greater inequality with income than caloric intake. The *very poor* consumed 15 percent less than the average of 51 grams of protein per day, while the *well-to-do* consumed 51 percent more than the average.[44]

Data collected in Maharashtra State, India, during a National Sample Survey in 1958 showed that as monthly per capita expenditures on food rose among families from 0–8 rupees to 8–11 and 24–34 rupees, average daily calorie and protein supplies per capita rose from 1120 to 1560 to 2530 calories and from 31 to 45 to 72 grams of protein, respectively.[45] Other Indian data indicate that food represents over 90 percent of the total monthly expenditure for those households with incomes of 100 rupees per month *or less*,[46] and at least in South India (Kerala, Madras, Mysore, and Andhra Pradesh), 77 percent of the rural population during the late 1950's had monthly incomes per household under 50 rupees.[47] If an average household size of 5 to 6 is assumed for rural families, one can estimate from these combined data that about three-fourths of rural households in South India in

[43] U.S. Interdepartmental Committee on Nutrition for National Defense. Chile. Nutrition survey, March–June 1960. Washington, 1961. 357 p.

[44] U.S. Interdepartmental Committee on Nutrition for National Defense. Northeast Brazil. Nutrition survey, March–May 1963. Washington, 1965. 294 p.

[45] Sukhatme, P. V. Feeding India's growing millions. New York, Asia Publishing House, 1965. 172 p.

[46] Food habits in Madras State, Census of India IX (Pt. XIB), Madras, 1964.

[47] Rao, K. S., and others, Protein malnutrition in south India. World Health Organ. Bull. 603, 1959. 20 p.

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the late 1950's had food energy supplies of less than 1600 calories per capita per day, and protein supplies of 45 grams per day or less.

The effect of income level on the quality of the diet is illustrated by data from Madras on the daily consumption of pulses and vegetables as a function of income. At the low end of the scale, families with incomes less than 25 rupees per month (22 percent of all households) consumed an average of 26 grams of pulses per person per day and 48 grams of vegetables; families with monthly incomes of 26–50 rupees (43 percent of all households) consumed 30 grams of pulses and 57 grams of vegetables per person per day; at the more affluent end of the income range, households with over 201 rupees per month (2.8 percent of all households) ate more than 54 grams of pulses and consumed 128 grams of vegetables per person per day.[48]

A detailed study of diet as related to income among urban communities in the city of Vellore, state of Madras, India, during the 1950's, showed that the poorest communities, with household incomes less than 35 rupees per month, obtained an average of 1520 to 1650 calories and 36 to 42 grams of protein per day. The highest income groups (monthly household incomes averaging $156 to $212) consumed about 2270 calories per person per day and 57 grams of protein.[49]

In the less developed countries, as elsewhere, the share of national income received by the poor and by rural people is smaller than their proportion in the population. A 1962 sample survey of all of India [50] showed that rural households, which made up 81 percent of the total population, received only 68 percent of the national income, while the 19 percent of the population who lived in towns or cities received 32 percent. Half the national income (equivalent to 122 rupees per month per average household of 5 persons) was divided among less than a third of the total population, and the other half was spread among more than two-thirds. As a result, 50 percent of the rural families in 1962 had monthly incomes of less than 80 rupees and 25 percent received less than 52 rupees per month. It is apparent that poor families received much less than the average food supply.

## *1.6.0 Nutritional Requirements, Current and Projected*

### *1.6.1 Requirements for Calories*

The current consumption of foods does not represent an adequate intake of calories for the world's population. Inequities in distribution have led to an excess for some people and a deficit for others. Moreover, the current rates of population growth in some countries exceed

[48] Food habits in Madras State. Census of India IX (Pt. XIB), Madras, 1964.

[49] Dakshinamurti, K., and Devadatta, S. C., Studies on the nutrition of urban population groups. Indian Acad. Sci. Proc. 43(2) : 121–133. Feb. 1956.

[50] National Council of Applied Economic Research (India). All India rural household survey, 1962. New Delhi, Publ. 1965. 2 volumes.

the current rates of increase in caloric availability. Evidence of the severity of the caloric deficit among the poorest classes is the occurrence of calorie-protein malnutrition in children of all of the less developed countries. A less severe caloric deficit is evident in the small body heights and weights of the populations of these same regions.

*1.6.1.1 Assumptions. Body weight.* In our estimates of the current caloric needs of India, Pakistan, and Brazil, and of the entire world, the caloric requirements developed by the Second Committee of the Food and Agriculture Organization of the United Nations served as a reference.[51] In attempting to apply FAO standards to the populations of the three selected countries, it became apparent that the adult "reference" male of 65 kg. body weight and the "reference" female of 55 kg. body weight were not representative of the actual body weights available from nutrition surveys or other population statistics. There were similar deviations in body size of children. Hence, it was decided to express the FAO caloric allowances for various age groups for currently observed body weights and for FAO "standard" weights. Caloric allowances per unit of body weight, FAO standard weights and actual weights as determined in India, Pakistan and Brazil are shown in Table 5, Appendix. The standard body weights for children were derived from the FAO-WHO committee report dealing with protein requirements.[52] It is appropriate to acknowledge and to emphasize that the lack of more accurate data on body weights for these countries introduces uncertainties into estimates for caloric needs.

*Energy needs.* Estimates of caloric needs in 1965 for India, Pakistan, and Brazil were calculated at two levels: (a) the energy needs for the FAO reference standard weights (upper level); (b) the energy needs corresponding to actually observed average body weights (lower level). For the world as a whole, only the FAO standard weights were used, because actual measurements are not available for average body size of the populations of most countries. (Tables 6, Appendix).

*Growth rate.* In projecting caloric needs for the future (Tables 7–10, Appendix), the assumption was made that children should be provided with sufficient energy to allow for normal growth based on FAO child weights through the 10 to 14 year age group. For the world as a whole FAO standard weights were also used for older age groups; while for India, Pakistan and Brazil, observed adult weights were used for the 1970 values. On the assumption that the adult populations in India, Pakistan and Brazil would eventually increase in body weight with the above caloric allowance for children, the projections for 1975, 1980 and 1985 in these countries allow for an increase in body weight of adults of

[51] Caloric requirements, FAO Nutritional Studies No. 15, 1957. 68 p.

[52] Protein requirements, report of a joint FAO/WHO expert group. FAO Nutrition Meetings Report Series No. 37, 1965. 71 p.

3 kg. for each 10-year period. Experience in western countries and recent studies in Japan [53] show that, when adequate calories and other nutrients are available during childhood, the height and weight of adults will increase (See Section 1.5.7.1).

In projecting caloric needs for the teenage group (age 15–19 years) in the three selected countries the allowance is 113 percent of that for the adult (age 20–30 years) in the male and 104 percent in the female. This is in accord with the FAO suggested allowances.

*Pregnancy.* The caloric needs used for pregnancy and lactation are those proposed by FAO and are included in the allowances for the infant group. The allowance is based on the assumption that the number of pregnancies in each population is equal to 110 percent of the number of children less than one year old.

*Ambient temperature.* In the country projections, no adjustment has been made for environmental temperature. The FAO caloric allowances are based on an environmental temperature of 10° C. Mean environmental temperatures for much of the population in selected countries (Pakistan, India, Brazil) may be as high as 30° C. The estimates of caloric needs may be as much as 10 percent larger than those proposed by the FAO Committee which indicated that caloric allowances should be *reduced* 0.5 percent for each degree rise in temperature between 10° and 30° C. There is good evidence, however, that the energy cost of work in hot climates is actually increased by as much as 10 or 15 percent.[54] It has therefore been assumed that the lower energy needs during idle or non-work periods in a hot climate are cancelled by the higher energy needs when physical work is being done.

*Age.* Adjustments for age in caloric allowances for the adult populations are in accord with those proposed by FAO.

*Fertility rate.* The projected daily caloric needs at 5-year intervals through 1985 are summarized in Table 10 for India, Pakistan, Brazil and the world. Per capita needs are slightly higher when projected on the assumption that some decreases in the fertility rate will occur (low population projection). This would be expected since such a projection assumes fewer births and hence, a lower proportion of individuals with caloric requirements below the mean. The rise in per capita caloric need in 1975 and 1985 in the three countries is the result of the assumption that the body weight of the adult population will increase an average of 3 kg. per decade if the FAO caloric allowances for children are provided.

*1.6.1.2 Caloric requirements for India.* The estimates of caloric needs with anticipated increases due to population growth are summarized

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[53] Japan. Koshu Eiseikyoku. Eiyoka. Nutrition in Japan. Tokyo, 1964.

[54] National Research Council. Food and Nutrition Board. Recommended dietary allowances. 6th rev. ed. Nat. Res. Council Publ. 1146, 1964. 59 p.

TABLE 10.—*Projections of Caloric Needs of the World and Selected Countries for High and Low Estimates of Population Growth* [1]

| | High projection | | | Low projection | | |
|---|---|---|---|---|---|---|
| | Population (millions) | Caloric needs | | Population (millions) | Caloric needs | |
| | | Kcal/capita/day | Total (billions) | | Kcal/capita/day | Total (billions) |
| World: | | | | | | |
| 1965 | 3,308 | 2,354 | 7,787 | 3,308 | 2,354 | 7,787 |
| 1970 | 3,624 | 2,366 | 8,571 | 3,599 | 2,373 | 8,540 |
| 1975 | 4,005 | 2,364 | 9,468 | 3,911 | 2,385 | 9,330 |
| 1980 | 4,467 | 2,356 | 10,526 | 4,264 | 2,388 | 10,184 |
| 1985 | 5,032 | 2,350 | 11,823 | 4,647 | 2,393 | 11,118 |
| India: | | | | | | |
| 1965 | 484 | 2,351 | 1,138 | 484 | 1,936 | 937 |
| 1970 | 552 | 2,151 | 1,188 | 542 | 2,168 | 1,175 |
| 1975 | 636 | 2,206 | 1,404 | 602 | 2,247 | 1,352 |
| 1980 | 739 | 2,202 | 1,627 | 677 | 2,241 | 1,517 |
| 1985 | 864 | 2,264 | 1,955 | 769 | 2,297 | 1,765 |
| Pakistan: | | | | | | |
| 1965 | 116 | 2,284 | 264 | 116 | 1,836 | 212 |
| 1970 | 137 | 2,069 | 283 | 134 | 2,087 | 279 |
| 1975 | 164 | 2,133 | 349 | 153 | 2,177 | 334 |
| 1980 | 198 | 2,131 | 421 | 178 | 2,171 | 387 |
| 1985 | 241 | 2,171 | 523 | 211 | 2,203 | 464 |
| Brazil: | | | | | | |
| 1965 | 81 | 2,330 | 189 | 81 | 2,164 | 176 |
| 1970 | 94 | 2,299 | 216 | 93 | 2,306 | 215 |
| 1975 | 109 | 2,346 | 256 | 107 | 2,369 | 252 |
| 1980 | 128 | 2,342 | 299 | 122 | 2,376 | 289 |
| 1985 | 150 | 2,399 | 360 | 138 | 2,446 | 339 |

[1] For the world as a whole the current and projected caloric needs are based on FAO caloric requirements and FAO standard body weights. For India, Pakistan, and Brazil the projections (1970–85) are also based on FAO standards for children but on actual weights for adults with some increase in body weight anticipated as explained in the text. The current lower level (1965) estimates of caloric need for these countries are based on body weights as determined in these countries and FAO caloric allowances corresponding to these body weights. The higher current estimates are based on FAO standard body weights. Derivation of caloric needs is given on pages 46-49, and in appendix tables 5–10.

in Table 10. The high projection (1970–85) assumes that the present fertility rate will prevail whereas the low projection assumes a decline in fertility by 28 percent, as indicated in Tables 2, 3, and 4 and Appendix Tables 1 and 3. The upper projection exceeds the lower by 190 billion kilocalories daily by 1985, a difference of nearly 12 percent.

The difference between the two estimates of caloric needs for 1965 emphasizes the impact of affording caloric allowances in accord with FAO standard weights as opposed to the estimated body weights. The high estimate can be partly justified if it is assumed that children provided with sufficient calories will grow at a rate equal to that of children in the developed countries. The low estimate is based on a caloric need for the average body weights determined by the Nutrition Research Laboratories in India. This low estimate (1936 kilocalories per capita per day) is in close agreement with the FAO calculations

of current caloric availability in the Far East.[55] The FAO survey placed caloric availability at the retail level at 2060 kilocalories per capita per day and assumed a loss of less than 10 percent between retail level and actual consumption. If the lower estimate of current (1965) caloric need in India is accepted, we can calculate from Table 10 that by 1985, the need will rise by 108 percent if no decline in fertility occurs and by 88 percent if the assumed decline in fertility occurs.

*1.6.1.3 Caloric requirements for Pakistan.* The projected caloric needs for Pakistan are summarized in Table 10. If present fertility rates persist, Pakistan's population will more than double by 1985 and current caloric needs (212 billion kilocalories per day) will increase by 146 percent. With decline in fertility rates assumed in Tables 2, 3 and 4, projected caloric needs in 1985 will still exceed current needs by as much as 118 percent. Our estimate for the present caloric need of 1836 kilocalories per capita per day for Pakistan is about 5 percent below that for India. The difference is directly related to lower body weights utilized in the estimate for Pakistan. The validity of the difference, of course, rests upon the validity of the available data on body weights.[56]

A recent survey in East Pakistan reveals an average caloric intake of 1777 kilocalories for the urban population and 2251 for the rural population.[57] In over 50 percent of the rural population however, the average caloric intake was only 1996 kilocalories per capita per day. These data are in close agreement with our estimate of current caloric need.

*1.6.1.4 Caloric requirements for Brazil.* Recent estimates of caloric *availability* in Northeast Brazil range downward from 2000 kilocalories per capita per day.[58] Our low estimate (corresponding to the most probable value of average body weights) of current caloric need for Brazil as a whole is shown in Table 10 as 2164 kilocalories per capita per day. A recent careful study showing that *average* caloric *availability* for the whole of Brazil at present is 2650 kilocalories per capita per day [59] emphasizes that food distribution is of major importance in estimating caloric availability for population groups.

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[55] Food and Agriculture Organization of the United Nations. Third World food survey. Freedom from Hunger Campaign, Basic Study No. 11, 1963. 102 p.

[56] Our own estimates indicate that adult body weights in India (see Table 9) are about the same as the average for Pakistan and approximately 5 kg. less than the official Indian figures. However, because of uncertainties in the data, we have used the latter in calculating caloric and protein needs.

[57] East Pakistan, Nutrition Survey, March 1962–January 1964, OIR–NS, NIH, Bethesda, Maryland, 1966.

[58] U.S. Interdepartmental Committee on Nutrition for National Defense. Northeast Brazil. Nutrition survey, March–May 1963. Washington, 1965. 294 p.

[59] Food and Agriculture Organization of the United Nations. Third world food survey. Freedom from Hunger Campaign, Basic Study No. 11, 1963. 102 p.

Assuming no change in fertility, the caloric needs of Brazil will increase 104 percent between 1965 and 1985. With our postulated decline in fertility, the projected increase will be 92 percent. The magnitude of the increase in caloric supplies required to meet these needs will depend on whether or not a more equitable distribution of calories is achieved within the country.

*1.6.1.5 Caloric requirements for the world.* There is no precise method for estimating the body size of a representative individual in any age group in the world's population. In estimating *current* global caloric needs we have assumed that adult males weigh 65 kg., adult females 55 kg., and that children weigh as much as the FAO standards. The validity of these assumptions can be challenged but no better baseline is available. *Projections* based on FAO standards are at least partly justified by the fact that much of the current world's population is suffering impairment of physical growth due to inadequate intake of calories and protein.

With no change in the fertility rate in the world's population and no change in average body weights, the *caloric need by 1985 will increase about 52 percent.* With reduction in fertility rate, the increased need is estimated at 43 percent.

The current need for calories is 2354 kilocalories per capita per day or a total of 7,787 billion kilocalories per day. The FAO Third World Food Survey places current caloric availability (retail level) at 2420 kilocalories per capita per day, a value that agrees closely with our estimates of current need.

If we remember that poor people in the less developed countries obtain far less food than the average for the population, that food is distributed unevenly among countries, and that losses between retail availability and consumption are at least 10 percent, the close agreement between caloric needs and supply allows only two conclusions, if we accept the validity of the FAO estimates of availability: (1) world caloric needs are less than our calculations indicate; or, (2) a considerable portion of the world's population is seriously undernourished. We know the second conclusion is correct from other evidence, but we are inclined to believe from the scanty data on body weights in Asia and South America (Tables 8 and 9) that the first is also.

Before more accurate estimates of caloric needs of the world's population can be made, it will be necessary to obtain adequate statistical information from detailed surveys of structured samples of all ethnic groups in all countries.

Caloric needs of individuals are, to a major extent, dependent upon physical activity. The FAO caloric requirement for the adult male

assumes that the day consists of rest in bed, non-occupational activity, and working activity each for 8 hours daily. The assumed caloric expenditures during these three periods are 1.05, 3.13 and 2.50 kilocalories per minute, respectively. The overall rate of 2.5 kilocalories per minute during work assumes moderately light work in a standing position with occasional bursts of heavy manual labor.

Again, before more accurate projections of caloric needs are possible, data must be obtained on the energy cost of specific occupations and the distribution of the working population in various occupations.

*1.6.2 Requirements for Protein*

Foods currently available on a world basis furnish inadequate calories and barely adequate quantities of protein for the world as a whole, but due largely to inequities in distribution, vulnerable population groups in less developed countries have a high incidence of protein deficiency. Impaired growth and development and kwashiorkor are found in large numbers of children. It has been estimated, with limited evidence, that at least one-quarter and perhaps one-third of the populations of less developed countries are protein deficient.[60] In planning to meet the food needs of an expanding world population, high priority must be given to increased production and more equitable distribution of food sources of protein. With most present national food patterns, protein needs can be met if caloric sources are adequate and the composition of the diet corresponds to the national average. Neither of these conditions usually holds for the poorest groups in the population.

*1.6.2.1 Assumptions.* In this section, an estimate is made of the protein needs for the world and for India, Pakistan and Brazil, now and at projected five-year intervals until 1985. These estimates have been derived by procedures proposed by the Joint FAO–WHO Expert Group on Protein Requirements.[61] Protein needs vary with age and body weight, as well as with the quality or essential amino acid content of dietary proteins. Our estimates are derived first in terms of high quality protein (i.e., egg, the FAO "reference" protein). These values are then equated to the protein in food sources found in the national food supply. This is done by determining the net protein utilization (NPU) of these diets. The NPU is an index of digestibility of protein and the biologic value of the amino acid mixture absorbed from the intestine.

Information on the quality of the protein in the food supplies of the world was derived from material incorporated in Table 2 of "The

[60] Sukhatme, P. V., The world's food supplies. Roy. Statist. Soc. J. Ser. A 129 (Part 2): 222–241. 1966.

[61] Protein requirements, report of a joint FAO/WHO expert group. FAO Nutrition Meetings Report Series No. 37, 1965. 71 p.

World Food Budget, 1970"; Tables 5 and 9 in ERS Foreign 88, "Food Balances for 12 Countries in the Far East and Oceania, 1959–61," and Table 8 of ERS Foreign 86, "Food Balances for 24 Countries of the Western Hemisphere, 1959–61". Data on NPU values for various food proteins have been listed in "Protein Requirements", FAO Nutrition Meetings Report Series #37, 1965. Based on these, the approximate NPU of various commodity groups was taken as: Cereals, 56; potatoes, cassava, etc., 71; peanuts, 48; pulses, 46; vegetables, fruits, 70; fish, 83; milk, and cheese, 75; eggs, 100; and meat, 82.

The weighted average NPU of the various countries was then calculated according to the following formula:

$$\frac{\text{Sum of (gms protein from each commodity x NPU)}}{\text{Sum of (gms protein from these sources)}} = \text{weighted av. NPU}$$

The protein contribution of the commodity groups in the world food supply was not listed in "The World Food Budget, 1970" as it had been in the food balances for individual countries. Accordingly, this was approximated to derive a weighted average NPU value for the world protein supply.

It must be remembered that a weighted average NPU only approximates the NPU that would be obtained from a mixture of these proteins. It must also be remembered that this mixture of proteins is not likely to be representative of the diet of any particular segment of these populations. It represents only the national food availability, not food consumed, nor the proportions found in specific diet patterns.

Dietary proteins must contain an adequate amount of each of the essential amino acids to meet daily needs. Table 11 records the requirements of young adults for these amino acids. These requirements are met by approximately 19.5 gm of the FAO reference protein (150 gm of egg). Table 11 also shows the minimal requirements of infants for essential amino acids.

In assessment of protein needs of populations, it is necessary that requirements for the essential amino acids be met for all population segments. This is usually accomplished if protein intakes are adequate and if a significant proportion is derived from animal sources. When dietary protein is obtained largely from one cereal or vegetable source, it may be necessary to consider other mechanisms for providing essential amino acids, particularly for nutritionally vulnerable groups. When a diet affords protein derived largely from wheat, the content of the amino acid, lysine, is limited. Similarly, a rice diet may contain too little lysine and methionine. In corn, tryptophan is found in limited amount. Under such conditions, fortification of the chief food sources with essential amino acids may be desirable to extend the physiologic

TABLE 11.—*Minimum requirements of essential amino acids*

| Essential amino acid | Young men gm/day [1] | Young women gm/day [1] | Provided by 19.5 gm FAO protein | Infants mg/kg/day [2] |
|---|---|---|---|---|
| Leucine | 1.10 | 0.62 | 1.72 | 150 |
| Isoleucine | .70 | .45 | 1.28 | 119 |
| Lysine | .80 | .50 | 1.39 | 103 |
| Threonine | .50 | .31 | .77 | 87 |
| Trypophan | .25 | .16 | .38 | 22 |
| Valine | .80 | .65 | 1.29 | 105 |
| Methionine | 1.10 | .29 | .56 | 45 |
| Cystine | (3) | .25 | .45 | (3) |
| Phenylalanine | 1.10 | .22 | .96 | 90 |
| Tyrosine | (4) | .90 | .60 | (4) |
| Histidine | | | | 34 |

[1] Taken from: Swendseid, M. E., and Tuttle, S. G., Essential amino acid requirements of adult man. Nat. Res. Council Publ. 843:323-330. 1961. Reference on p. 327.

[2] Holt, L. E. and Snyderman, S. E., The amino acid requirements of infants. Amer. Med. Ass. J. 175(2): 100-103. Jan. 14, 1961.

[3] Spares methionine.

[4] Spares phenylalanine.

utilization of the available protein. The details of fortification are discussed elsewhere (see Chapter 5).

The protein requirement is expressed as grams of protein per kilogram of body weight for individuals of different ages from birth through adulthood and allows for individual variation in requirements so that needs will be met for all but a very small fraction of the population (2.5 percent).

The added requirements for protein during pregnancy were not evaluated by FAO procedures which estimate the number of pregnant women as 110 percent of the number of infants less than one year of age and allow 6 grams of protein per day for six months of pregnancy. Instead, the needs during pregnancy and lactation were added by increasing protein allowance for infants from the FAO figure of 1.7 gm/kg to 2.0 gm/kg. The protein needs of the age group 0–1 year in the accompanying tables therefore, include not only the requirements of infants who are not breast-fed but also the *additional protein requirements of women who are either pregnant* or *lactating*.

Precise and satisfactory body weight data are not available on a world basis nor for the countries selected for determination of protein needs. Two types of reference body weights have been used. One is the standard adopted by the FAO group which for children was derived from data on Iowa children. The other represents average weights measured and estimated for the respective countries. The projections of future protein needs are based on FAO standard weights in early childhood but actual or estimated weights are used for older children and adults. The projections, in addition, anticipate at maturity an

average gain in body weight of three kilograms per decade, from 1965 to 1985 for the populations of India, Pakistan and Brazil.

In all analyses, two estimates of population growth are used (high and low projections—see pages 26–28). The high projection represents an estimate of the *maximal* future needs for protein, while the low indicates the lesser quantities required by a smaller population of somewhat older average age.

*1.6.2.2 Protein requirements for India.* The estimates of protein needs of India with anticipated increases due to population growth in the period up to 1985 are given in Tables 12 and 13. The high projection of population growth anticipates an increase in population from 483 million in 1965 to 864 million in 1985, a gain of 78 percent. The low projection represents a population growth of 59 percent.

In Table 12 the total protein required by the population of India at five year intervals at the high and low rates of population growth is

TABLE 12.—*Projection of protein needs in terms of FAO reference protein (1965–85)*

| | Protein (gms/capita/day) | | Total protein needs (metric tons/day) | |
|---|---|---|---|---|
| | High population estimate | Low population estimate | High population estimate | Low population estimate |
| World: [2] | | | | |
| 1965 | 35.2 | 35.2 | 116,370 | 116,370 |
| 1970 | 35.4 | 35.5 | 128,295 | 127,922 |
| 1975 | 35.4 | 35.9 | 141,853 | 140,288 |
| 1980 | 35.3 | 36.0 | 157,628 | 153,638 |
| 1985 | 35.1 | 36.2 | 176,640 | 168,640 |
| Pakistan: | | | | |
| 1965 | [2] 33.1 | [3] 25.7 | [2] 3,829 | [3] 2,974 |
| 1970 | 28.3 | 28.7 | 3,883 | 3,837 |
| 1975 | 29.5 | 30.4 | 4,832 | 4,657 |
| 1980 | 29.4 | 30.3 | 5,807 | 5,416 |
| 1985 | 30.3 | 31.2 | 7,283 | 6,565 |
| India: | | | | |
| 1965 | [2] 34.4 | [3] 27.6 | [2] 16,647 | [3] 13,332 |
| 1970 | 30.1 | 30.4 | 16,641 | 16,484 |
| 1975 | 31.4 | 32.2 | 19,976 | 19,363 |
| 1980 | 31.3 | 32.2 | 23,112 | 21,819 |
| 1985 | 32.4 | 33.4 | 27,985 | 25,659 |
| Brazil: | | | | |
| 1965 | [2] 33.9 | [3] 31.4 | [2] 2,757 | [3] 2,551 |
| 1970 | 33.1 | 33.2 | 3,107 | 3,097 |
| 1975 | 34.6 | 34.9 | 3,765 | 3,720 |
| 1980 | 34.3 | 35.2 | 4,391 | 4,271 |
| 1985 | 35.4 | 36.5 | 5,317 | 5,060 |

[1] Protein needs were derived by consideration of protein requirements of various age and sex groups for each population. See Appendix Tables 11–14.

[2] All World Data and 1965 High Projections for Countries are related to FAO Standard Weights.

[3] In 1965 Low Projections are related to average weight of various age-sex groups in these countries. Later estimates relate to FAO Standard Weight in childhood and actual average weight of adults, with an estimated 3 kg increase in weight per decade.

TABLE 13.—*Projection of protein needs in terms of food proteins consumed*[1] *(1965–85)*

| | Gms/capita/day | | Total protein needs metric tons/day | |
|---|---|---|---|---|
| | High population estimate | Low population estimate | High population estimate | Low population estimate |
| World:[2] | | | | |
| 1965 | 56.7 | 56.7 | 187,693 | 187,693 |
| 1970 | 57.1 | 57.3 | 206,928 | 206,326 |
| 1975 | 57.1 | 57.9 | 228,795 | 226,271 |
| 1980 | 56.9 | 58.1 | 254,239 | 247,804 |
| 1985 | 56.6 | 58.4 | 284,903 | 272,000 |
| Pakistan: | | | | |
| 1965 | 55.4[3] | 42.9[3] | 6,832[3] | 4,956[3] |
| 1970 | 47.3 | 47.7 | 6,471 | 6,394 |
| 1975 | 49.2 | 50.6 | 8,053 | 7,761 |
| 1980 | 49.0 | 50.6 | 9,679 | 9,026 |
| 1985 | 50.4 | 52.0 | 12,138 | 10,942 |
| India: | | | | |
| 1965 | 60.4[3] | 48.3[3] | 29,206[3] | 23,391[3] |
| 1970 | 52.9 | 53.3 | 29,195 | 28,819 |
| 1975 | 55.0 | 56.5 | 35,029 | 33,970 |
| 1980 | 54.9 | 56.6 | 40,548 | 38,279 |
| 1985 | 56.8 | 58.6 | 49,097 | 45,015 |
| Brazil: | | | | |
| 1965 | 52.2[3] | 48.3[3] | 4,245[3] | 3,924[3] |
| 1970 | 50.8 | 51.1 | 4,781 | 4,765 |
| 1975 | 53.0 | 53.7 | 5,792 | 5,722 |
| 1980 | 52.9 | 54.1 | 6,756 | 6,571 |
| 1985 | 54.5 | 56.2 | 8,180 | 7,783 |

[1] The NPU of the protein in foods available is assumed to be 62 for the world, 60 for Pakistan, 57 for India and 65 for Brazil.

[2] All World Data and 1965 Higher Projections for countries are related to FAO Standard Weights.

[3] 1965 Lower Projections are related to average weight of various age-sex groups in these countries. Later estimates relate to FAO Standard Weight in childhood and actual average weight of adults, with an estimated 3 Kg increase in weight per decade.

recorded in terms of quantities of FAO reference protein. Present needs are estimated at 13,332 metric tons per day, based on actual body weights, or 16,647 metric tons based on FAO standard body weights which are substantially greater than those of average Indians. The estimated needs by 1985 would be 27,985 metric tons per day for the high and 25,659 metric tons per day for the low projection, increases of 110 percent and 93 percent, respectively, above the requirements in 1965 based on average body weights used by the Nutrition Research Laboratories of the Indian Government (see footnote on page 48). The table also presents estimates in terms of grams of protein needed per capita per day. The higher values in 1975 and 1985 reflect increases in projected body weights.

Table 13 presents similar projections based on food protein derived largely from cereal and pulse sources, with an estimated NPU of 57, an appropriate value for protein provided by the present food supply in India. On this basis, the daily protein needs will increase from

23,391 metric tons in 1965 to 49,097 or 45,015 metric tons per day in 1985 depending on population projection. The per capita needs for protein which in 1965 were 48.3 gm/capita/day are expected to increase to 56.8 gm/capita/day with the high population projection or to 58.6 gm/capita/day with the low projection by the year 1985.

The detailed tables, including the data whereby these estimates were derived for various age groups of populations of India for the years 1965, 1970, 1975, 1980 and 1985, are found in Table 12, Appendix.

The values derived in these estimates can be compared with other observations. Food balances indicate a per capita supply of protein in India of 55.6 gm per day in the period 1959–61, with 7.2 gm derived from animal food sources.[62] This value is well in excess of the estimate of per capita protein need of 48.3 gm/day in this report. The supply value does not allow for food losses from retail level to consumption or for inequitable distribution. Sukhatme[63] in a study of 866 households in one area of India (Maharastra) found that in 27 percent of the households the intake of protein was less than 29 gm of FAO reference protein per person per day. The actual prevalence of protein malnutrition in households is probably higher because of uneven distribution within the household. The value reported by Sukhatne, 29 gm, approximates the value of 27.6 gm per capita per day of reference protein derived in the present studies of protein needs in India. Other indirect evidence of the probable existence of widespread protein malnutrition in India is afforded by the infant mortality rate of about 140 per 1,000 live births (Table 6).

*1.6.2.3 Protein requirements for Pakistan.* The population projections for Pakistan anticipate an increase from 116 million in 1965 to between 241 and 211 million in 1985. On these bases, the estimated present protein need of 2,973 metric tons per day in terms of FAO reference protein would increase to 7,283 or 6,565 metric tons daily by the year 1985 (Table 12, Pakistan). For dietary protein sources with an NPU of 60, the requirements are 4,956 metric tons per day in 1965 and 12,138 or 10,942 metric tons in 1985 (Table 13, Pakistan). The per capita requirement for protein would increase from 42.9 gm/day in 1965 to 50.4 gm or 52.0 gm per day in 1985 for the high and low population projections respectively.

The detailed data for population components by age and sex at five year intervals are recorded in Table 13 (Pakistan), Appendix.

Recent estimates of food supplies in Pakistan[64] indicate an avail-

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[62] U.S. Department of Agriculture. Economic Research Service. Foreign Regional Analysis Division. Food balances for 12 countries in the Far East and Oceania, 1959–1961. U.S. Dep. Agr. Econ. Res. Serv. ERS–Foreign 88, 14 p. Aug. 1964.

[63] Sukhatme, P. V., The world's food supplies. Roy. Statist. Soc. J. Ser. A 129 (Part 2): 222–241. 1966.

[64] U.S. Department of Agriculture. Economic Research Service. Foreign Regional Analysis Division. Food balances for 12 countries in the Far East and Oceania, 1959–1961. U.S. Dep. Agr. Econ. Res. Serv. ERS–Foreign 88, 14 p. Aug. 1964.

ability of 55.7 gms protein per capita per day with 10.9 gms from animal protein.

A nutrition survey indicated that per capita availability for protein was 57.5 gm per day in rural areas and 49.5 gm per day in urban areas of East Pakistan.[65] These observations do not take household food losses or uneven distribution into account. Other evidence demonstrates a high prevalence of protein malnutrition in Pakistan. Infant mortality rates are probably at least 160 per thousand live births (Table 6).

*1.6.2.4 Protein requirements for Brazil.* The population of Brazil was estimated to be 81 million in 1965. With the high projection of population growth, it will increase to 150 million in 1985 and with the low, to 138 million. Accordingly, it is projected that present needs for protein which are 2,551 metric tons per day will increase to 5,317 metric tons or to 5,060 metric tons by 1985 (Table 12). These values are in terms of the FAO "reference" protein. When expressed in terms of the usual sources of protein in the national food supply in Brazil, current total protein needs are 3,924 metric tons per day. This value would increase to 8,180 metric tons per day (high estimate) or 7,783 metric tons per day (low estimate) in 1985. The corresponding increase in per capita protein requirement would be from 48.3 gm per day in 1965 to 54.5 gm or 56.2 gm per day, respectively, in 1985. Detailed calculations of protein needs of Brazil are found in Table 14, Appendix.

Most estimates of food availability in Brazil indicate that they could meet present protein needs. The U.S. Department of Agriculture estimated that 1959–61 supplies of protein were 65 gm per capita per day.[66] But there is a highly inequitable distribution of available food. Caloric and protein supplies are particularly short for the population of northeast Brazil. A nutrition survey in that part of the country in 1963 [67] indicated an average protein intake of 51.4 gm per capita per day, but in some sections consumption was as little as 37.8 gms per capita. The existence of protein malnutrition is evident in the high prevalence of kwashiorkor and retarded growth of children in this part of Brazil. There are no acceptable data for present infant death rates in Brazil but in the early 1950's the infant mortality was probably 170 per thousand live births.

*1.6.2.5 Protein requirements for the world.* The 1965 world population is estimated at 3.3 billion persons. With sustained rates of population

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[65] Nutrition Survey of East Pakistan—March 1962–January 1964, U.S. Department of Health, Education and Welfare, Public Health Service, May, 1966.

[66] U.S. Department of Agriculture. Economic Research Service. Foreign Regional Analysis Division. Food balances for 24 countries of the Western Hemisphere, 1959–1961. U.S. Dep. Agr. Econ. Res. Serv. ERS–Foreign 86, 29p. Aug. 1964.

[67] U.S. Interdepartmental Committee on Nutrition for National Defense. Northeast Brazil. Nutrition survey, March–May 1963. Washington, 1965. 294p.

growth the total will reach 5.0 billion by 1985 or 4.6 billion if there is a reduced rate of growth. On the basis of FAO standard body weights for children and adults, current FAO reference protein needs for the world are 116,370 metric tons per day. The needs for the two population projections are 176,640 and 168,640 metric tons per day in 1985 (Table 12, World). When expressed in terms of protein supplies with an NPU of 62, current needs are 187,693 metric tons per day (56.7 gm per capita per day) and would increase to 284,903 or 272,000 metric tons in 1985. The projected need in 1985 would be 56.6 gm or 58.4 gm per capita per day on the basis of the high and low populations respectively (Table 13). These data which assume no changes in average body weights indicate that world protein requirements will increase approximately 50 percent in the next twenty years. This is clearly a minimum estimate since as we have seen from our projections for Pakistan, India, and Brazil, the increase in the less developed countries is likely to be as much as 100 to 150 percent.

The projections of protein needs derived in this report differ from other projections. The FAO Third World Food Survey [68] developed short term nutritional targets for 1975 for calories, total protein, and animal protein. The targets for total protein were derived on the basis of a quantity of protein equivalent to 12 percent of caloric standards. On this basis, the target was 69 gm per capita per day for "low calorie" countries, and 75 gm per capita per day for the world as a whole, values much greater than the physiological needs for patterns indicated in our calculations. The USDA in its 1970 World Food Budget [69] suggests a reference standard of 60 gm protein per person per day, presumably to be supplied at retail level, indicating that it allows for loss and waste of food between the retail level and consumption. In several studies, such losses have varied from 10 to 25 percent.

Our projections of protein needs for the World, India, Pakistan, and Brazil represent best judgments derived from consideration of physiological requirements for food protein actually *consumed*. They do not represent requirements for protein *supplies*. The estimates do not allow for loss of protein in production, storage, and preparation of foods, for wastage on the plate, or inadequate utilization of protein when caloric sources are insufficient. Where these losses are large, as they are likely to be in most less developed countries, proportionately larger quantities of additional protein must be made available. Calculations of requirements for protein supplies based on our estimates of physiological requirements must also take into account inevitable inequities in distribution among households at different income levels, and within households.

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[68] Food and Agriculture Organization of the United Nations. Third world food survey. Freedom from Hunger Campaign, Basic Study No. 11, 1963. 102p.

[69] World food budget 1970. U.S. Dep. Agr. Foreign Agr. Econ. Rep. No. 19, 105p, 1964.

### *1.6.3. Requirements for Vitamins and Minerals*

Recommendations for dietary intakes of four vitamins: thiamine, riboflavin, niacin and vitamin A, and for one mineral, calcium, have been developed by Joint Expert Committees of FAO and WHO.[70] [71] Current and projected needs for these nutrients have been estimated for the world and for three countries, India, Pakistan and Brazil for the two population projections. The values for body weights used for estimation of vitamin and mineral requirements are the same as those given in Tables 5 through 14 in the appendix.

The recommended intakes for thiamine, riboflavin and niacin are directly related to caloric requirements [70] since all three of these vitamins function in energy metabolism. The assumptions made for calculations of caloric needs are also applicable to the calculations of vitamin requirements.

*1.6.3.1 Thiamine.* The thiamine intake recommended by the Expert Committee of FAO–WHO is 0.4 milligrams per 1,000 kilocalories which includes an excess of 20 percent above minimum needs to allow for individual variation. In countries where the dietary supply of thiamine is more than 0.4 mg per 1,000 calories, little or no thiamine deficiency has been observed.[72] It is desirable to maintain this level for all segments of the population.

Thiamine in the diets of persons in many of the less developed countries is furnished primarily by cereal grains. Since thiamine content can be reduced by processing, it is important to consider methods of conserving thiamine in cereal products, or, if necessary, to enrich with thiamine after processing or cooking.

Since thiamine needs are based on estimates of caloric requirements, the relative increase in needs during the next 20 years will be the same magnitude as for calories (Table 14). In all cases, the per capita intake is slightly higher when the fertility rate is decreased since the resulting population has fewer children and higher caloric requirements. The estimate of thiamine need on a world basis indicates per capita levels approximately 10 percent higher than those in India and Pakistan. This is due to the small body size in these countries and the higher percentage of the population under the age of 15.

*1.6.3.2 Riboflavin*

Estimation of requirements is based on data from nutrition surveys and on depletion-repletion studies in which the intake of riboflavin has been related to urinary excretion and to the development of clinical

[70] "Vitamin Requirements", Report of a joint FAO/WHO expert group, 6–17 September 1965—FAO Headquarters, Rome.

[71] Those for the vitamins, thiamine, riboflavin, niacin and vitamin A have not received final approval; however, they represent the most suitable values for the present report.

[72] Summary of Reports of Interdepartmental Committee on Nutrition for National Defense, (presently Nutrition Section, OIR–NIH) 1956–1964.

deficiency. In general urinary excretion tends to be low when the intake of riboflavin is less than 0.44 milligrams per 1,000 kilocalories.

The intake of riboflavin recommended by the FAO–WHO committee is 0.55 milligrams per 1,000 kilocalories which is 20 percent above minimum needs. No increase in riboflavin is recommended for pregnancy or lactation except as related to caloric increases.

Riboflavin is widely distributed in the foods consumed in both less developed and developed countries. Legumes are an important source of riboflavin. Cereal products which are eaten in relatively large amounts in the less developed countries do not contain high concentrations of this vitamin. Since milling of grains reduces the riboflavin content, fortification of milled cereal products should be considered if other dietary sources of riboflavin are in short supply. Milk, eggs, meat and enriched cereal products are the major sources of riboflavin. Vegetables and fish are good sources, also.

Riboflavin requirements will increase appreciably in the three selected countries and in the world during the next 20 years. By 1985, the total daily need, if there is no effective population control, will be approximately 8 percent greater than if control plans are sucessful. The largest percentage increase during the 20-year period will be in Pakistan (Table 15).

*1.6.3.3 Niacin.* The requirement for niacin is complicated by the fact that while niacin is available as such in many food products, man is capable of meeting part of his requirement by conversion of the amino acid, tryptophan, to niacin. In addition, the availability of niacin in certain foods is limited. It is essential to determine whether the niacin determined by chemical methods is biologically available to man.

TABLE 14.—*Projections of thiamine needs, 1965–85* [1]

| Population projections (year) | India | | Pakistan | | Brazil | | World | |
|---|---|---|---|---|---|---|---|---|
| | Mg/capita/day | Total kg/day | Mg/capita/day | Total kg/day | Mg/capita/day | Total kg/day | Mg/capita/day | Total kg/day |
| 1965 | 0.77 | 375 | 0.73 | 85 | 0.87 | 70 | 0.94 | 3,115 |
| 1970: | | | | | | | | |
| High | .86 | 475 | .83 | 113 | .92 | 84 | .95 | 3,428 |
| Low | .87 | 470 | .83 | 112 | .92 | 86 | .95 | 3,416 |
| 1975: | | | | | | | | |
| High | .88 | 561 | .85 | 140 | .94 | 103 | .95 | 3,787 |
| Low | .90 | 541 | .87 | 133 | .95 | 101 | .95 | 3,732 |
| 1980: | | | | | | | | |
| High | .88 | 651 | .85 | 168 | .94 | 120 | .94 | 4,210 |
| Low | .90 | 607 | .87 | 155 | .95 | 116 | .96 | 4,074 |
| 1985: | | | | | | | | |
| High | .91 | 782 | .87 | 209 | .96 | 144 | .94 | 4,729 |
| Low | .92 | 706 | .88 | 186 | .98 | 135 | .96 | 4,447 |

[1] Projections are based on FAO thiamine requirements of 0.4 mg per 1,000 calories.

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TABLE 15.—*Projections of riboflavin needs, 1965–85* [1]

| Population projections (year) | India | | Pakistan | | Brazil | | World | |
|---|---|---|---|---|---|---|---|---|
| | Mg/capita/day | Total kg/day | Mg/capita/day | Total kg/day | Mg/capita/day | Total kg/day | Mg/capita/day | Total kg/day |
| 1965 | 1.1 | 515 | 1.0 | 117 | 1.2 | 97 | 1.3 | 4,283 |
| 1970: | | | | | | | | |
| High | 1.2 | 654 | 1.1 | 156 | 1.3 | 119 | 1.3 | 4,714 |
| Low | 1.2 | 646 | 1.1 | 154 | 1.3 | 118 | 1.3 | 4,697 |
| 1975: | | | | | | | | |
| High | 1.2 | 772 | 1.2 | 192 | 1.3 | 141 | 1.3 | 5,207 |
| Low | 1.2 | 744 | 1.2 | 183 | 1.3 | 139 | 1.3 | 5,131 |
| 1980: | | | | | | | | |
| High | 1.2 | 895 | 1.2 | 232 | 1.3 | 165 | 1.3 | 5,789 |
| Low | 1.2 | 834 | 1.2 | 213 | 1.3 | 159 | 1.3 | 5,601 |
| 1985: | | | | | | | | |
| High | 1.2 | 1,075 | 1.2 | 287 | 1.3 | 198 | 1.3 | 6,503 |
| Low | 1.3 | 971 | 1.2 | 255 | 1.3 | 186 | 1.3 | 6,115 |

[1] Projections based on FAO riboflavin requirements of 0.55 mg. per 1,000 calories.

The FAO Expert Committee has accepted the term, *niacin equivalent*, for expressing requirements and has further indicated that one niacin equivalent is equal to either one milligram of niacin or 60 milligrams of tryptophan.

The estimated requirement for niacin has been based primarily on experimental diets where niacin equivalents of 4.4 milligrams per 1,000 kilocalories or less have been fed, either as niacin or a combination of niacin and tryptophan. Deficiency symptoms have been reported when intakes of less than 4.4 mg. niacin equivalents per 1,000 kilocalories have been consumed [73] [74] or when the total daily intake of adults was less than 9.0 mg.

A minimum requirement of 5.5 mg. niacin equivalents per 1,000 kilocalories has been accepted with the recommended intake being 6.6 mg. niacin equivalents per 1,000 kilocalories. Calculation of actual niacin intakes in populations is not possible because good information on the tryptophan content of many foods is not available. In general, it is assumed that tryptophan intake can be related to dietary protein, although there are some proteins that are low in tryptophan. No added requirement for niacin has been indicated for either pregnancy or lactation other than that associated with the increased caloric requirement.

Factors affecting the availability of niacin in cereal products have been studied in several laboratories. Corn contains a bound form of niacin which is not available under many conditions. In parts of the

[73] Horwitt, M. K., and others. Tryptophan-niacin relation in man. J. Nutr. 60 (Suppl. 1) : 43pp. 1956.

[74] Goldsmith, G. A., and others. Studies of niacin requirement in man. 3. Comparative effects of diets containing lime-treated and untreated corn in the production of experimental pellagra. J. Clinical Nutr. 4 : 151–160. 1956.

world where corn is processed with lime, such as Latin America, niacin becomes available and pellagra, which is due to niacin deficiency, is not a problem. Bound forms of niacin also occur in wheat and rice. An additional problem arises when the total amount of protein in the diet is less than that required for other metabolic functions. In such instances, it is doubtful that conversion of tryptophan to niacin is a significant source of this vitamin.

Niacin is extremely stable under most conditions and even with prolonged cooking relatively little is lost. There is no evidence that tryptophan is lost during storage so food proteins can be considered as sources of niacin.

The estimates for niacin requirements indicate that these will increase relative to caloric needs during the next 20 years. (Table 16.) It can be assumed that if protein needs are met or exceeded, there will be an adequate supply of niacin from the conversion of tryptophan.

*1.6.3.4 Vitamin A.* Hypovitaminosis A is a major problem in parts of Latin America, Africa, the Near East, and Asia. Studies in Brazil, Jordan, India, and Pakistan have documented vitamin A deficiency as a major cause of blindness in children less than 5 years old. Symptoms of this deficiency are frequently associated with protein-calorie malnutrition.

The lowest vitamin A intakes have been reported for the Near East, but values in Asia and the Far East are only slightly higher. The average vitamin A intakes in the United States and Western Europe are from 2 to 18 times greater than those in some areas of the Near East and Africa.

Dietary sources of vitamin A differ in the less developed and developed countries. In the latter,. animal products containing pre-formed

TABLE 16.—*Projections of Niacin Needs 1965–85* [1]

| Population projections (year) | India | | Pakistan | | Brazil | | World | |
|---|---|---|---|---|---|---|---|---|
| | Mg/capita/day | Total kg/day | Mg/capita/day | Total kg/day | Mg/capita/day | Total kg/day | Mg/capita day | Total kg/day |
| 1965 | 12.8 | 6,183 | 12.1 | 1,401 | 14.3 | 1,161 | 15.5 | 51,393 |
| 1970: | | | | | | | | |
| High | 14.2 | 7,843 | 13.7 | 1,870 | 15.2 | 1,426 | 15.6 | 56,569 |
| Low | 14.3 | 7,755 | 13.8 | 1,844 | 15.2 | 1,420 | 15.7 | 56,361 |
| 1975: | | | | | | | | |
| High | 14.6 | 9,265 | 14.1 | 2,304 | 15.5 | 1,692 | 15.6 | 62,488 |
| Low | 14.8 | 8,922 | 14.4 | 2,202 | 15.6 | 1,666 | 15.7 | 61,577 |
| 1980: | | | | | | | | |
| High | 14.5 | 10,739 | 14.1 | 2,778 | 15.5 | 1,975 | 15.6 | 69,470 |
| Low | 14.8 | 10,011 | 14.3 | 2,557 | 15.7 | 1,906 | 15.8 | 67,214 |
| 1985: | | | | | | | | |
| High | 14.9 | 12,904 | 14.3 | 3,450 | 15.8 | 2,376 | 15.5 | 78,035 |
| Low | 15.2 | 11,650 | 14.5 | 3,062 | 16.1 | 2,235 | 15.8 | 73,379 |

[1] Projections based on FAO niacin requirements of 6.6 mg. per 1,000 calories.

vitamin A and vitamin A fortified foods, such as margarines and milk, are available. In the less developed countries, vitamin A is obtained primarily from fruits and vegetables in the form of carotenes which are precursors of vitamin A.

Vitamin A reqirements have been proposed in the FAO report in terms of retinol (vitamin A alcohol); the recommended allowance for adults is 750 micrograms of retinol per day. No increase in intake during pregnancy is recommended but a daily intake of 1,200 micrograms retinol is recommended during lactation. This increased allowance for the mother is recommended to provide for the needs of the infant during the first 5 months of life. In childhood, recommended intakes range from 300 micrograms of retinol per day (ages 6 to 12) to 750 micrograms per day after the age of 16. In general, requirements are approximately 12 micrograms of retinol per kilogram of body weight per day for adults. For infants of 3 months of age, intakes of about 65 micrograms per kilogram per day are recommended.

Since the dietary vitamin A intake in India, Pakistan, Brazil, and in most sections of the world is primarily derived from carotene, two calculations have been made in projecting needs. The first is based on retinol requirements and the second on requirements if the dietary sources of vitamin A furnish approximately 10 percent retinol and 90 percent beta carotene.

Requirements for vitamin A in India, Pakistan and Brazil will approximately double during the next 20 years if there is no reduction in rate of population growth and will increase 80 percent or more if population growth rate decreases. (Table 17.) Since vitamin A-containing foods are not widely used in these and other less developed countries, means of adding vitamin A to existing foods, such as cereal products, must be considered.

It is probable that fortification of foods must be undertaken to meet vitamin A needs. Vitamin A can be used in the form of natural foods rich in this vitamin, such as red palm oil, but in order to ensure controlled addition, synthetic vitamin A may be preferable. Emphasis should be given to development of vitamin A fortified foods that can be produced on a commerical or semi-commercial basis in less developed countries and that have wide acceptance. In most countries, edible oil products are not suitable carriers for vitamin A since they are used in small quantities and are produced on a restricted basis. Wheat flour, can be fortified with vitamin A which can be obtained in powder-like form. There is need for research on incorporation of this vitamin into other cereal foods.

*1.6.3.5 Calcium.* Calcium intake varies considerably throughout the world but there is no good evidence that calcium deficiency constitutes

TABLE 17.—*Projections of Vitamin A Needs 1965–85* [1]

| Population projections (year) | India dietary needs | | | | Pakistan dietary needs | | | | Brazil dietary needs | | | | World dietary needs | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Retinol | | B-Carotene 90 percent Retinol 10 percent | | Retinol | | B-Carotene 90 percent Retinol 10 percent | | Retinol | | B-Carotene 90 percent Retinol 10 percent | | Retinol | | B-Carotene 90 percent Retinol 10 percent | |
| | Mcg/capita day | Total gm/day | Mcg/capita day [2] | Total gm/day [2] | Mcg/capita day | Total gm/day | Mcg/capita day [2] | Total gm/day [2] | Mcg/capita day | Total gm/day | Mcg/capita day [2] | Total gm/day [2] | Mcg/capita day | Total gm/day | Mcg/capita day [2] | Total gm/day [2] |
| 1965 | 606 | 294 | 2,402 | 1,163 | 586 | 68 | 2,316 | 268 | 601 | 49 | 2,381 | 194 | 621 | 2,057 | 2,468 | 8,164 |
| 1970: | | | | | | | | | | | | | | | | |
| High | 605 | 334 | 2,368 | 1,308 | 583 | 80 | 2,305 | 316 | 602 | 57 | 2,384 | 224 | 625 | 2,267 | 2,483 | 8,999 |
| Low | 610 | 331 | 2,422 | 1,313 | 590 | 79 | 2,335 | 313 | 604 | 56 | 2,440 | 228 | 627 | 2,260 | 2,494 | 8,976 |
| 1975: | | | | | | | | | | | | | | | | |
| High | 603 | 384 | 2,390 | 1,521 | 581 | 95 | 2,296 | 376 | 601 | 66 | 2,381 | 260 | 626 | 2,508 | 2,484 | 9,951 |
| Low | 620 | 373 | 2,456 | 1,478 | 595 | 91 | 2,357 | 361 | 609 | 65 | 2,355 | 257 | 633 | 2,479 | 2,517 | 9,848 |
| 1980: | | | | | | | | | | | | | | | | |
| High | 602 | 445 | 2,384 | 1,761 | 579 | 114 | 2,284 | 451 | 600 | 77 | 2,374 | 303 | 623 | 2,786 | 2,472 | 11,047 |
| Low | 623 | 422 | 2,473 | 1,674 | 602 | 108 | 2,385 | 426 | 612 | 74 | 2,269 | 276 | 636 | 2,714 | 2,527 | 10,779 |
| 1985: | | | | | | | | | | | | | | | | |
| High | 600 | 519 | 2,379 | 2,055 | 575 | 139 | 2,268 | 546 | 598 | 90 | 2,368 | 355 | 620 | 3,121 | 2,460 | 12,379 |
| Low | 620 | 477 | 2,460 | 1,891 | 595 | 125 | 2,354 | 496 | 615 | 85 | 2,441 | 338 | 638 | 2,968 | 2,539 | 11,799 |

[1] Requirements are given in 2 ways: (1) in terms of FAO reference vitamin A or Retinol, and (2) in terms of a diet which furnishes 90 percent of vitamin A as B-carotene (provitamin A) and 10 percent as retinol.

[2] Expressed as mcg. B-carotene. Mcg=microgram

a serious health problem, particularly when the supply of vitamin D is adequate. Dietary sources of calcium also vary widely. Milk and milk products are a good source for all age groups. In less developed countries, milk products are not widely used, and except for nursing infants, calcium is obtained from cereals, leafy vegetables, and to a small extent from animal products. An Expert Committee of FAO has developed an extensive report on calcium requirements.[75] The report takes into consideration the different intakes of calcium among population groups and the ability of man to adapt to low intakes with no apparent undesirable effects.

One health problem that is related to calcium is osteomalacia. Low calcium intake in association with repeated pregnancies is considered to be a major factor in this disease although evidence to support this conclusion is meager. Calcium deficiency occurs in infants, but is more often related to malabsorption secondary to diseases of the intestinal tract.

Estimation of calcium requirements on a national or world basis is difficult due to wide differences in calcium intake found in populations of apparent good health. Many investigations of calcium requirements are based on metabolic balance studies and there is evidence to suggest that these studies are influenced markedly by past calcium intake. Thus, balance studies in developed countries indicate much higher requirements than in developing countries. While mean requirements may not be applicable to all segments of the world population, the FAO Expert Committee has developed some "practical allowances" which permit estimation of total calcium requirements. Allowances are given as a range of acceptable intakes for various age groups. Allowances for infants are 500 to 600 milligrams per day from birth to 12 months of age and increase to 600 to 700 milligrams per day for adolescents between the ages of 10 and 15. Allowances then decrease to 500–600 milligrams for the 16 to 19 year age group and to 400 to 500 milligrams for adults. Intakes for pregnancy and lactation are estimated to be between 1,000 and 1,200 milligrams per day. These amounts should be provided during the latter third of pregnancy and throughout lactation.

Calculations for India, Pakistan and Brazil are based on the lower allowance suggested by FAO to give a more realistic estimate of calcium requirements. (Table 18.) The values for the three countries increase about the same percent as that for other nutrients. Calcium requirements in 1985 in Pakistan, for example, will be 2.1 times requirements in 1961 with the low population projection and 2.4 times with the high projection.

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[75] Calcium Requirements. Report of an FAO–WHO Expert Group. FAO Nutrition Report Series No. 30. Rome, Italy, 1962.

TABLE 18.—*Projection of Calcium Needs 1965–85* [1]

| Population projection (year) | India | | Pakistan | | Brazil | | World | |
|---|---|---|---|---|---|---|---|---|
| | Gm/capita day | Total metric tons/day | Gm/capita day | Total metric tons/day | Gm/capita day | Total metric tons/day | Gm/capita day | Total metric tons/day |
| 1965 | 0.44 | 215 | 0.45 | 52 | 0.45 | 36 | 0.44 | 1,462 |
| 1970: | | | | | | | | |
| High | .45 | 245 | .45 | 61 | .45 | 43 | .44 | 1,607 |
| Low | .45 | 241 | .45 | 60 | .45 | 42 | .44 | 1,596 |
| 1975: | | | | | | | | |
| High | .45 | 283 | .45 | 73 | .45 | 49 | .44 | 1,774 |
| Low | .45 | 269 | .45 | 69 | .45 | 48 | .44 | 1,735 |
| 1980: | | | | | | | | |
| High | .45 | 329 | .45 | 89 | .45 | 57 | .44 | 1,973 |
| Low | .45 | 302 | .45 | 80 | .45 | 54 | .44 | 1,884 |
| 1985: | | | | | | | | |
| High | .45 | 385 | .45 | 108 | .45 | 67 | .44 | 2,219 |
| Low | .44 | 340 | .45 | 94 | .45 | 62 | .45 | 2,083 |

[1] Requirement is the lower value of the range of practical allowances of FAO.

In countries where cereals are the principal source of calories, calcium intake is adequate if considerable amounts of pulses and nuts are consumed also. The ability to meet calcium requirements in the coming years will be associated closely with the ability to meet caloric and protein requirements. In some of the less developed countries, careful selection of the limited variety of foods may be necessary to meet even the lower FAO practical allowances.

*1.6.3.6 Other Vitamins and Minerals. Vitamin C.* Deficiency of this vitamin is a problem only in isolated segments of the population for a few countries.[76, 77] There is a wide difference of opinion as to the amount of vitamin C that should be included in the diet for the maintenance of health. The minimum amount of this vitamin that will prevent scurvy (vitamin C deficiency) is about 10 mg. daily. Vitamin C has many important metabolic functions some of which may be deranged long before the development of clinical deficiency. Some investigators have suggested that vitamin C intake should be sufficient to maintain approximate saturation of the tissues which requires an intake of 60 to 100 mg. a day. Recommended dietary allowances for vitamin C that have been adopted by various countries range from 20 mg. to 70 mg. daily.

Vitamin C containing foods are available in most countries of the world. Although fruit, particularly citrus fruit, is generally considered the most important source of this vitamin, many vegetables,

[76] Summary of Reports of Interdepartmental Committee on Nutrition for National Defense (Presently Nutrition Section, OIR–NIH) 1956–1964.

[77] Schaefer, A. E., Observations from exploring needs in national nutrition programs. Amer. J. Public Health 56(7): 1088–1096. July 1966.

including potatoes and members of the cabbage family, are good sources of vitamin C. Fortification of food products or supplementation of diets with the synthetic vitamin may be desirable at times.

*Vitamin D.* It is not practical to estimate vitamin D requirements for population groups. For infants and children, 300 to 400 International Units of vitamin D per day will prevent the development of rickets. Few studies have been carried out on requirements of adults. In most countries, an insignificant amount of vitamin D is consumed in food products. The vitamin is provided mainly by the action of sunlight on 7-dehydrocholesterol in the skin.

Rickets due to vitamin D deficiency has not been reported as a major world health problem in recent years. Isolated cases are found in almost every country and are frequently associated with cultural patterns which do not permit children to be exposed to sufficient sunlight.

*Iodine.* Endemic goiter (thyroid enlargement due to iodine deficiency) is a major health problem in many parts of the world. Iodine intakes of 100 to 150 micrograms per day are recommended although evidence suggests that goiter is not a problem in areas where iodine intake exceeds 75 micrograms per day. The relatively few dietary sources of iodine make it difficult to propose changes sufficient to prevent goiter. Seafoods are good sources but are generally eaten in only limited amounts. When iodine is included in the ration of animals, products such as milk and eggs can be good sources, but in the less developed countries these foods are consumed in small quantities. The public health measure used most often in the prevention of goiter is the iodization of salt. In some countries, there are technical problems related to the iodization of salt, including the type of salt available and the means by which salt production can be controlled. Certain types of crude salt, or partially processed salt, are difficult to use as a carrier. In the United States one part of iodine per 10,000 is added in the form of potassium iodide.

*Iron.* The amount of iron required for growth and the maintenance of health can be defined in terms of *absorbed* iron but is difficult to estimate in terms of *dietary* iron. More information is needed on the amount of iron absorbed from food, iron loss under normal conditions and iron loss associated with parasitic infestation. The latter loss is a significant problem in many less developed countries. Iron absorption is influenced by the kinds of food in the diet and is increased when body stores of iron are depleted.

Nutrition surveys in many less developed countries indicate that the iron content of diets exceeds by several times the proposed dietary allowances for iron in the United States (10 to 15 mg per day for adults). Recent studies in Africa report average iron intakes ranging

from 30 to 120 milligrams of iron per day [78] and in Latin America intakes range from of 25 to 60 milligrams per day. The amount of iron absorbed from these diets is not known. It is somewhat surprising to find that anemia is a major problem in most of these countries and in many instances seems to be due to iron deficiency. Most reports on anemia are based on hemoglobin levels and few data are available on the concentration of iron in tissues. Recently, the World Health Organization has undertaken a comprehensive evalution of iron nutriture; information obtained should be of great value.

*Other Nutrients.* Requirements for minerals and vitamins, other than those discussed above, cannot be estimated at the present time for the world or for specific countries. Dietary needs for vitamin $B_6$ are about 1.5 to 2 milligrams per day for adults, but more information must be obtained on needs and dietary sources before recommendations for intakes by population groups can be developed.

Daily diets that contain 3 to 5 micrograms of vitamin $B_{12}$ (if 1 to 1.5 micrograms is absorbed) will satisfy minimum requirements. Vitamin $B_{12}$ is found in foods of animal origin. Since diets in most of the less developed countries are low in animal products, intakes may be less than adequate. More information on the vitamin $B_{12}$ content of diets in these countries is needed. Some of the anemias that are known to be prevalent in less developed areas may be due to lack of vitamin $B_{12}$.

Data are insufficient to recommend a dietary allowance of folacin (folic acid). Folic acid compounds are present in many animal and vegetable products but information on the folic acid content of foods is meager. Folic acid intake appears to be inadequate in some segments of the population in many less developed countries. Deficiency causes macrocytic anemia, glossitis and diarrhea and occurs commonly during pregnancy. Deficiency of both vitamin $B_{12}$ and folic acid can be due not only to dietary inadequacy, but also to malabsorption syndromes of varied etiology.

Knowledge of requirements for pantothenic acid, vitamin E and vitamin K is incomplete. This is also the case for minerals such as copper, selenium, magnesium and zinc. It seems probable that many of these nutrients may be consumed in less than required amounts in less developed countries. This is an area for future research.

## *1.7.0 Nutritional Requirements Translated into Terms of Food and Food into Agricultural Commodities*

### *1.7.1 Some General Conclusions*

The caloric and protein needs for various countries and the world have been translated into quantities of types of food that are equiva-

[78] Summary of Reports of Interdepartmental Committee on Nutrition for National Defense (Presently Nutrition Section, OIR–NIH) 1956–1964.

lent to the projected needs. These data bring out and highlight some urgent problems to be faced in the world food supply in the years ahead and suggest priorities for action programs to anticipate these problems.

Clearly, calories constitute the most limiting need for countries, regions, or the world as a whole, but not for some segments of the population. Meeting caloric needs with current national food supply patterns will for the population as a whole result in an adequate *quantity* of protein despite its overall poor *quality;* however, this average fails to show that in young children the quantity and quality of dietary protein must be better than the average represented by such a statistic. We must also recognize that national food supply patterns may deteriorate in the attempt to meet the caloric needs of a rapidly growing population. It will be less difficult to increase the overall volume of calories than to increase the volume of milk, eggs, meat, fish, and other traditional sources of high quality protein. Improvement or even maintenance of dietary protein quality and quantity may require shifts to other sources of protein and changes in food habits. In efforts to increase protein availability, a critical challenge is that of introducing improvements which will benefit the population groups that are in greatest need.

Amino acid fortification of foods, the combination of cereal and soybean products in foods, or the use of protein concentrates from oil seeds or fish may yield small benefits to the bulk of the population, but would be highly beneficial to vulnerable groups such as preschool children. For example, wheat in India contributes about 14 percent of the protein in the national food supply. If as much as 50 percent of this wheat could be fortified to raise its net protein utilization (NPU) to 75, approximating the NPU of milk, it would raise the average NPU of dietary proteins in India as a whole from approximately 56.6 only to 58.1. This would have the effect of lowering the total protein needs of India by about 2.5 percent, but it might contribute significantly to vulnerable segments who largely utilized wheat for their energy and protein requirements.

The real problem then is to bring the tremendous benefits that programs to improve protein quality can achieve to the segments of population for whom protein *quality* and *quantity* are truly critical. Fortification programs, for example, can achieve great benefits for small groups, but *only if the programs affect these persons.* At the same time, it should be recognized that protein may merely serve to meet energy needs if caloric requirements are inadequately met.

In planning action programs, we must recognize that, for the short term, *family planning* will not solve the food supply problem. Only a 6 to 11 percent reduction of food needs by 1985 is indicated in the

projections for the three countries selected or for the world as a whole through successful family planning programs. (Table 20.) As we have shown in an earlier section, such programs are needed now, not only for benefit in the more distant future, but also to slow down rapid rates of population growth which seriously interfere with economic and social development.

For the next two decades, production is the key to meeting the food problem of the expanding population. India will need at least twice as large a food supply in 1985 as was available in 1960, if similar foods are consumed. Pakistan will need an even greater scale-up in food supply. The world as a whole will need more than half again as much food in 1985 as is now available (Table 20).

The increases in food supplies shown in Table 20 for India, Pakistan, and Brazil are minimal for several reasons. They do not include an allowance for losses between retail level and consumption or for improvements in diets associated with rising per capita incomes (which are essential if agricultural productivity is to rise) and they assume an even distribution of food among all income groups and a distribution according to physiological needs within households. The world figures should be increased because of these factors and because of the implicit assumptions that average body weights of the world population will not rise and that food supplies will be distributed according to the calculated needs among the rich and the poor countries.

*Distribution* is now and will continue to be a key factor in meeting the protein-calorie needs of very large segments of the population. This study has emphasized critical problems in distribution between countries, within countries, and within the family. Because of maldistribution, the true situation is far more disturbing than the figures in Tables 20–27 would indicate.

### *1.7.2 Methodology Used in Converting Caloric and Protein Needs to Foods and Commodities*

The quantities of foods needed to fulfill physiological requirements for calories and protein are based on projections of population growth, changes in population characteristics, and increase in body size, with and without changes in fertility rate, but are *not* adjusted for changes in income or for the much larger quantities of foods which must actually be produced to compensate for losses from harvest to consumption.

The basic source of data for food consumption patterns was the study "World Food Budget" [79] and publication on detailed analyses of food balances in the Western Hemisphere [80] and in the far East and

[79] World food budget 1970. U.S. Dep. Agr. Foreign Agr. Econ. Rep. No. 19, 105p. 1964.

[80] U.S. Department of Agriculture. Economic Research Service. Foreign Regional Analysis Division. Food balances for 24 countries of the Western Hemisphere, 1959–1961. U.S. Dep. Agr. Econ. Res. Serv. ERS—Foreign 86, 29p. Aug. 1964.

Oceania.[81] The 1959–61 per capita caloric and protein contributions from the total available food supplies are listed in these publications, as are population figures on which they were based.

The scale-up of different food quantities required to meet projected physiological needs for calories (Table 20) in different years represents the ratio of the projected caloric needs (Table 10) to the 1959–61 caloric availability. Projected food quantities (Tables 21–24) were derived by multiplying the tons of various food groups available in the base period (summarized in Table 19) by the appropriate ratio from Table 20. The 1965 figures thus represent quantities of foods needed rather than amounts currently available; actual availability is likely to be quite similar, however.

The projected amounts of protein available for consumption if caloric needs are met (Table 25) were derived in a similar manner by multiplying the figures for protein in the national food supplies in 1959–61 by the scale-up ratios for caloric needs. (Table 20). Projected "protein surpluses" (Table 26) represent the excess of these projected availabilities over amounts required to meet physiological needs (Table 13-Protein) on an annual basis. It is assumed in projecting these "surpluses" that all the food available could be consumed.

This procedure obviated need to work with protein and caloric contributions of individual food groups beyond that which already had gone into the USDA-ERS study.

The food groups used in the tables are reported on the following bases:[82]

*Wheat* is shown as grain.

*Rice* as paddy or rough rice.

*Other cereals* include corn, barley, oats, rye, millet, and sorghum, as well as minor products such as buckwheat, quinoa, spelt and teff.

*Other starchy crops* include potatoes, sweet potatoes, yams, cassava, and similar tropical root crops. This group of commodities also includes bananas and plantains in countries which produce such crops abundantly.

*Pulses and nuts* include beans, peas, lentils, chickpeas, and similar dry leguminous seeds. It also includes peanuts and soybeans in countries where they are used for food.

*Sugar* is basically raw cane and beet sugar.

*Vegetables and fruits* exclude commodities classified as other starchy crops.

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[81] U.S. Department of Agriculture. Economic Research Service. Foreign Regional Analysis Division. Food balances for 12 countries in the Far East and Oceania, 1959–1961. U.S. Dep. Agr. Econ. Res. Serv. ERS—Foreign 88, 14p. Aug. 1964.

[82] For detailed definitions see: World food budget 1970. U.S. Dep. Agr. Foreign Agr. Econ. Rep. No. 19, 105p. 1964. References on p. 88–89.

*Fats and oils* include butter (fat content), edible animal fats, marine oils, and vegetable oils which may be used for food.

*Meat, fish, and eggs* include poultry meat and game, in addition to other kinds of meat. Production of meat is generally on a carcass-weight basis. Production of fish is generally on landed-weight basis. Egg products are usually converted to shell-egg equivalent.

*Milk products* include milk and milk products other than butter.

### *1.7.3 Limitations in Interpretation of Data (Tables 19 Through 27)*

The food projections are based on estimates of caloric and protein needs of various populations. Appreciable uncertainties exist in population numbers and population characteristics. These in turn contribute uncertainty to caloric needs, and levels of physical activity add further uncertainty in estimating caloric requirements. Protein needs involve many similar unavoidable uncertainties.

Extrapolation of these nutrient requirements to foods and commodities introduces additional limitations in the data. Some commodity groups can be determined with fair accuracy, but others may be pure guesses as to amounts available. This is most obvious for fruits and vegetables. Furthermore, the projections of minimum food quantities to meet *physiological* needs of various countries or the world represent simple straight line projections of foods available in 1959–61. Obviously, food patterns will not remain static. Foods consumed will shift with increasing population pressure on the land, improving

TABLE 19.—*Total gross food balances (1000 m. tons) for 1959–61 for Brazil, India Pakistan, and the World (these figures represent food supplies available at retail* [1]).

| | Brazil | India | Pakistan | World |
|---|---|---|---|---|
| Wheat | 2,153 | 11,030 | 4,370 | 168,381 |
| Corn | 2,380 | | | |
| Millets | | 13,758 | | |
| Rice | 4,146 | 44,924 | 14,053 | 217,015 |
| Other cereals | 57 | 5,774 | 1,138 | 124,775 |
| Sugar | 2,955 | [2] 7,463 | [2] 1,278 | 57,868 |
| Starchy foods | 7,097 | 7,253 | 700 | 271,484 |
| Pulses, nuts | 2,006 | 12,601 | 1,027 | 40,905 |
| Vegetables | 952 | 12,951 | 2,778 | 244,982 |
| Fruit | 6,074 | 8,305 | 3,704 | |
| Meat | 2,032 | 600 | 580 | 107,115 |
| Fish | 290 | 2,585 | 1,320 | |
| Eggs | 264 | 126 | 35 | |
| Milk products | 3,963 | 20,979 | 4,164 | 199,836 |
| Fats, oils | 497 | 1,560 | 326 | 25,468 |

[1] Sources: "World Food Budget 1970," USDA For. Agr. Econ. Rept. 19, Oct. 1964; "Food Balances for 24 Countries of the Western Hemisphere, 1959–61," USDA-ERS For. 86, Aug. 1964; "Food Balances for 12 Countries in the Far East and Oceania, 1959–61," USDA-ERS For. 88, Aug. 1964.

[2] Includes $\frac{\text{cane sugar}}{10}$ to bring to "sugar" basis.

TABLE 20.—*Projected food quantities to meet physiological needs for calories as compared to 1959–61 food supplies. Projections at retail for Brazil, India, Pakistan, and the World.*

[These figures represent ratios of projected national needs for calories (Table 10, text) to 1959–61 availability (as derived from per capita data for caloric availability and population estimates.[1])]

| | Year | Brazil | India | Pakistan | World |
|---|---|---|---|---|---|
| High population projection | 1965 | 0.920 | 1.053 | 1.081 | 1.096 |
| | 1970 | 1.130 | 1.336 | 1.443 | 1.206 |
| | 1975 | 1.341 | 1.578 | 1.778 | 1.332 |
| | 1980 | 1.565 | 1.830 | 2.144 | 1.481 |
| | 1985 | 1.883 | 2.199 | 2.663 | 1.664 |
| Low population projection | 1965 | 0.920 | 1.053 | 1.081 | 1.096 |
| | 1970 | 1.126 | 1.321 | 1.423 | 1.202 |
| | 1975 | 1.310 | 1.520 | 1.699 | 1.313 |
| | 1980 | 1.511 | 1.706 | 1.974 | 1.433 |
| | 1985 | 1.771 | 1.985 | 2.363 | 1.564 |

[1] Source: "World Food Budget 1970", USDA For. Agr. Econ. Rept. 19, Oct. 1964; "Food Balances for 24 Countries of the Western Hemisphere, 1959–61", USDA-ERS For. 86, Aug. 1964; "Food Balances for 12 Countries in the Far East and Oceania, 1959–61", USDA-ERS For. 88, Aug. 1964.

agricultural productivity, rising consumer income, and even with a change in population makeup (such as in increasing percentage of older people). Unless agricultural productivity can be rapidly increased, the proportion of vegetables, fruits and animal products is likely to diminish because of the need for increasing the harvest of cereals, starchy foods and pulses to provide energy for rapidly growing populations.

In looking at consumption statistics and estimates of food gaps, we must remember that there is an important uncertainty in our estimate of the foods many people eat in many countries. This uncertainty is in the food from home production, barter, payment for work, and foraging. Such foods account for a sizable, if not the entire, amount available for those living in some traditional village economies. This uncertainty is minor in such countries as India and Pakistan where the land taxes are partly based on the size and composition of the harvest, regardless of how it is used, and consequently, farm food production is carefully estimated. But it may be more serious in other countries. In addition to the nonpurchased food in rural areas, there is evidence that on the outskirts and even within large cities, home-produced food is an important factor in the diets of the people.[83] An attempt is made to take this into account in the consumption statistics but there is a lack of research data from which reliable adjustments can be developed.

Most of the published statistics on food consumption are, more accurately speaking, food availability. For example, USDA food

[83] Money value of food used by households in the United States, spring 1965. U.S. Dep. Agr., Agr. Res. Serv. Food Consumption Survey, 1965–66, Prelim. Rep., 11p. Sept. 1966.

balance sheets are estimates of food at retail, not at home. There are few useful data on the losses due to microbiological spoilage, insects, and rodents that must occur between retail and the home from lack of refrigeration and storage facilities. Especially where foods do not go through commercial channels but are processed by rural households, large but unknown losses may occur because of poor facilities for storage in the home. Future requirements for food supplies (the quantities given in Tables 21 through 24) must be increased by an unknown amount because our estimates based on caloric and protein needs are at the *individual consumption* level and there is no satisfactory way of accurately adjusting these upward to account for losses from the time of harvest, through storage, transportation, marketing, preparation in the home, and plate waste. Still another uncertainty is introduced by the variable or unknown nutrient composition of foods within the food groups.

Finally, it is well to remind the reader again of the need for *caution in the interpretation of averages.* Data on average food supplies are

TABLE 21.—*Projected annual gross food quantities needed to meet physiological needs for calories, for Brazil, 1965–1985*

[These figures (1000 m. tons) assume food patterns similar to foods available in Brazil 1959–61 (Table 19)]

| | 1965 | 1970 | 1975 | 1980 | 1985 |
|---|---|---|---|---|---|
| High population estimates: | | | | | |
| Wheat | 1,980 | 2,433 | 2,887 | 3,369 | 4,054 |
| Corn | 2,190 | 2,689 | 3,192 | 3,725 | 4,482 |
| Rice | 3,814 | 4,685 | 5,560 | 6,488 | 7,807 |
| Other cereals | 52 | 64 | 76 | 89 | 107 |
| Sugar | 2,719 | 3,339 | 3,963 | 4,625 | 5,564 |
| Starchy foods | 6,529 | 8,020 | 9,517 | 11,107 | 13,364 |
| Pulses, nuts | 1,846 | 2,267 | 2,690 | 3,139 | 3,777 |
| Vegetables | 876 | 1,076 | 1,277 | 1,490 | 1,793 |
| Fruit | 5,588 | 6,864 | 8,145 | 9,506 | 11,437 |
| Meat | 1,869 | 2,296 | 2,725 | 3,180 | 3,826 |
| Fish | 267 | 328 | 389 | 454 | 546 |
| Eggs | 243 | 298 | 354 | 413 | 497 |
| Milk products | 3,646 | 4,478 | 5,314 | 6,202 | 7,462 |
| Fats, oils | 457 | 562 | 666 | 778 | 936 |
| Low population estimates: | | | | | |
| Wheat | 1,980 | 2,424 | 2,820 | 3,253 | 3,813 |
| Corn | 2,190 | 2,680 | 3,118 | 3,596 | 4,215 |
| Rice | 3,814 | 4,668 | 5,431 | 6,265 | 7,343 |
| Other cereals | 52 | 64 | 75 | 86 | 101 |
| Sugar | 2,719 | 3,327 | 3,871 | 4,465 | 5,233 |
| Starchy foods | 6,529 | 7,991 | 9,297 | 10,724 | 12,569 |
| Pulses, nuts | 1,846 | 2,259 | 2,628 | 3,031 | 3,553 |
| Vegetables | 876 | 1,072 | 1,247 | 1,438 | 1,686 |
| Fruit | 5,588 | 6,839 | 7,957 | 9,178 | 10,757 |
| Meat | 1,869 | 2,288 | 2,662 | 3,070 | 3,599 |
| Fish | 267 | 327 | 380 | 438 | 514 |
| Eggs | 243 | 297 | 346 | 399 | 468 |
| Milk products | 3,646 | 4,462 | 5,192 | 5,988 | 7,018 |
| Fats, oils | 457 | 560 | 651 | 751 | 880 |

TABLE 22.—*Projected annual gross food quantities needed to meet physiological needs for calories, for India, 1965 to 1985*

[These figures (1000 m. tons) assume food patterns similar to foods available in India in 1959–61 (Table 19)]

| | 1965 | 1970 | 1975 | 1980 | 1985 |
|---|---|---|---|---|---|
| High population estimates: | | | | | |
| Wheat | 11,615 | 14,736 | 17,405 | 20,185 | 24,254 |
| Millets | 14,487 | 18,381 | 21,710 | 25,177 | 30,254 |
| Rice | 47,305 | 60,018 | 70,890 | 82,211 | 98,788 |
| Other cereals | 6,080 | 7,714 | 9,111 | 10,566 | 12,697 |
| Sugar | 7,859 | 9,971 | 11,777 | 13,657 | 16,411 |
| Starchy foods | 7,637 | 9,690 | 11,445 | 13,273 | 15,949 |
| Pulses, nuts | 13,269 | 16,835 | 19,884 | 23,060 | 27,710 |
| Vegetables | 13,637 | 17,303 | 20,437 | 23,700 | 28,479 |
| Fruit | 8,745 | 11,095 | 13,105 | 15,198 | 18,263 |
| Meat | 632 | 802 | 947 | 1,098 | 1,319 |
| Fish | 2,722 | 3,454 | 4,079 | 4,731 | 5,684 |
| Eggs | 133 | 168 | 199 | 231 | 277 |
| Milk products | 22,091 | 28,028 | 33,105 | 38,392 | 46,133 |
| Fats, oils | 1,643 | 2,084 | 2,462 | 2,855 | 3,430 |
| Low population estimates: | | | | | |
| Wheat | 11,615 | 14,571 | 16,766 | 18,817 | 21,895 |
| Millets | 14,487 | 18,174 | 20,912 | 23,471 | 27,310 |
| Rice | 47,305 | 59,345 | 68,284 | 76,640 | 89,174 |
| Other cereals | 6,080 | 7,627 | 8,776 | 9,850 | 11,461 |
| Sugar | 7,859 | 9,859 | 11,344 | 12,732 | 14,814 |
| Starchy foods | 7,637 | 9,581 | 11,025 | 12,374 | 14,397 |
| Pulses, nuts | 13,269 | 16,646 | 19,154 | 21,497 | 25,013 |
| Vegetables | 13,637 | 17,108 | 19,686 | 22,094 | 25,708 |
| Fruit | 8,745 | 10,971 | 12,624 | 14,168 | 16,485 |
| Meat | 632 | 793 | 912 | 1,024 | 1,191 |
| Fish | 2,722 | 3,415 | 3,929 | 4,410 | 5,131 |
| Eggs | 133 | 166 | 192 | 215 | 250 |
| Milk products | 22,091 | 27,713 | 31,888 | 35,790 | 41,643 |
| Fats, oils | 1,643 | 2,061 | 2,371 | 2,661 | 3,097 |

useful for general comparisons and to indicate priority problems in national food needs. For example, the figures point to the need for national efforts in *food* production and distribution rather than merely seeking new sources of certain nutrients. But the averages do not reflect the actual incidence, numbers, or proportions of the populations that are undernourished or malnourished. Throughout the world, within regions, within individual countries, and even in individual families, some eat better than the average, some worse. Sometimes this is a result of the unavailability of foods, local custom, or taboo, but in most poor countries it is chiefly due to lack of purchasing power.

Latin America is a particularly good example of this. According to the food balances[84] developed for this region by the USDA for 1959–61, calories available at retail levels were about adequate but this

[84] U.S. Department of Agriculture. Economic Research Service. Foreign Regional Analysis Division. Food balances for 24 countries of the Western Hemisphere, 1959–1961. U.S. Dep. Agr. Econ. Res. Serv. ERS-Foreign 86, 29p. Aug. 1964.

included a range from a high of 3220 per capita per day in Argentina (higher than the USA) to a low of 1970 calories in Guatemala. Latin America as a whole averaged 66.1 grams of protein available per capita per day, primarily because of the very high consumption in Argentina and Uruguay. Within the Latin American area, Brazil, as a whole, had an adequate national daily food supply, 2710 calories and 65 grams of protein (⅓ of the protein from animal sources); but within Brazil the problems of maldistribution are quite evident. People in the southern part of the country are relatively well fed like those in the River Plate countries, Argentina, and Uruguay, but diets are clearly inadequate in Northeast Brazil. The problem is compounded by the sizable proportion of foods high in calories but low in protein. For example, Table 19 shows that the food supply of Brazil included 10 million tons of sugar and starchy foods while that of India included only a little more (14.7 million tons) despite a six-fold greater population.

TABLE 23.—*Projected annual gross food quantities needed to meet physiological needs for calories, for Pakistan, 1965 to 1985*

[These figures (1000 m. tons) assume food patterns similar to foods available in Pakistan in 1959–61 (Table 19)]

| | 1965 | 1970 | 1975 | 1980 | 1985 |
|---|---|---|---|---|---|
| High population estimates: | | | | | |
| Wheat | 4,724 | 6,306 | 7,770 | 9,369 | 11,637 |
| Rice | 15,191 | 20,278 | 24,986 | 30,130 | 37,423 |
| Other cereals | 1,230 | 1,642 | 2,023 | 2,440 | 3,030 |
| Sugar | 1,382 | 1,844 | 2,272 | 2,740 | 3,403 |
| Starchy foods | 757 | 1,010 | 1,245 | 1,501 | 1,864 |
| Pulses, nuts | 1,110 | 1,482 | 1,826 | 2,202 | 2,735 |
| Vegetables | 3,003 | 4,009 | 4,939 | 5,956 | 7,398 |
| Fruit | 4,004 | 5,345 | 6,586 | 7,941 | 9,864 |
| Meat | 627 | 837 | 1,031 | 1,244 | 1,545 |
| Fish | 1,427 | 1,905 | 2,347 | 2,830 | 3,515 |
| Eggs | 38 | 50 | 62 | 75 | 93 |
| Milk products | 4,501 | 6,009 | 7,404 | 8,928 | 11,089 |
| Fats, oils | 352 | 470 | 580 | 699 | 868 |
| Low population estimates: | | | | | |
| Wheat | 4,724 | 6,219 | 7,425 | 8,626 | 10,326 |
| Rice | 15,191 | 19,997 | 23,876 | 27,741 | 33,207 |
| Other cereals | 1,230 | 1,619 | 1,933 | 2,246 | 2,689 |
| Sugar | 1,382 | 1,819 | 2,171 | 2,523 | 3,020 |
| Starchy foods | 757 | 996 | 1,189 | 1,382 | 1,654 |
| Pulses, nuts | 1,110 | 1,461 | 1,745 | 2,027 | 2,427 |
| Vegetables | 3,003 | 3,953 | 4,720 | 5,484 | 6,564 |
| Fruit | 4,004 | 5,271 | 6,293 | 7,312 | 8,753 |
| Meat | 627 | 825 | 985 | 1,145 | 1,371 |
| Fish | 1,427 | 1,878 | 2,243 | 2,606 | 3,119 |
| Eggs | 38 | 50 | 59 | 69 | 83 |
| Milk products | 4,501 | 5,925 | 7,075 | 8,220 | 9,840 |
| Fats, oils | 352 | 464 | 554 | 644 | 770 |

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TABLE 24.—*Projected annual gross food quantities needed to meet physiological needs for calories, for the World, 1965-1985*

[These figures (1000 m. tons) assume food patterns similar to foods available in the World in 1959–61 (Table 19)]

| | 1965 | 1970 | 1975 | 1980 | 1985 |
|---|---|---|---|---|---|
| High population estimates: | | | | | |
| Wheat | 184,546 | 203,067 | 224,283 | 249,372 | 280,186 |
| Rice | 237,848 | 261,720 | 289,064 | 321,399 | 361,113 |
| Other cereals | 136,753 | 150,479 | 166,200 | 184,792 | 207,626 |
| Sugar | 63,423 | 69,789 | 77,080 | 85,702 | 96,292 |
| Starchy foods | 297,546 | 327,410 | 361,617 | 402,068 | 451,749 |
| Pulses, nuts | 44,832 | 49,331 | 54,485 | 60,580 | 68,066 |
| Vegetables, fruit | 268,500 | 295,448 | 326,316 | 362,818 | 407,650 |
| Meat, fish, eggs | 117,398 | 129,181 | 142,677 | 158,637 | 178,239 |
| Milk products | 219,020 | 241,002 | 266,182 | 295,957 | 332,527 |
| Fats, oils | 27,912 | 30,714 | 33,923 | 37,718 | 42,379 |
| Low population estimates: | | | | | |
| Wheat | 184,546 | 202,394 | 221,084 | 241,290 | 263,348 |
| Rice | 237,848 | 260,852 | 284,941 | 310,982 | 339,411 |
| Other cereals | 136,753 | 149,980 | 163,830 | 178,803 | 195,148 |
| Sugar | 63,423 | 69,557 | 75,981 | 82,925 | 90,506 |
| Starchy foods | 297,546 | 326,324 | 356,458 | 389,037 | 424,601 |
| Pulses, nuts | 44,832 | 49,168 | 53,708 | 58,617 | 63,975 |
| Vegetables, fruit | 268,500 | 294,468 | 321,661 | 351,059 | 383,152 |
| Meat, fish, eggs | 117,398 | 128,752 | 140,642 | 153,496 | 167,528 |
| Milk products | 219,020 | 240,203 | 262,385 | 286,365 | 312,544 |
| Fats, oils | 27,912 | 30,613 | 33,439 | 36,496 | 39,832 |

TABLE 25.—*Total protein availability per day in 1959–61 and projected protein quantities if calorie needs are met, for Brazil, India, Pakistan, and the world, 1965-1985.*

[These figures (in m. tons per day) assume food patterns similar to foods available in 1959–61 and in amounts adequate to meet calorie needs (Tables 21–24)] [1]

| | Year | Brazil | India | Pakistan | World |
|---|---|---|---|---|---|
| Available | 1959–61 | 4,586 | 24,003 | 5,158 | 192,735 |
| Projected: | | | | | |
| High population projection | 1965 | 4,219 | 25,275 | 5,576 | 211,238 |
| | 1970 | 5,182 | 32,067 | 7,443 | 232,439 |
| | 1975 | 6,150 | 37,876 | 9,171 | 256,723 |
| | 1980 | 7,177 | 43,925 | 11,058 | 285,441 |
| | 1985 | 8,635 | 52,782 | 13,735 | 320,712 |
| Low population projection | 1965 | 4,219 | 25,275 | 5,576 | 211,238 |
| | 1970 | 5,164 | 31,707 | 7,340 | 231,668 |
| | 1975 | 6,007 | 36,484 | 8,763 | 253,061 |
| | 1980 | 6,929 | 40,948 | 10,182 | 276,190 |
| | 1985 | 8,121 | 47,645 | 12,188 | 301,438 |

[1] Source: Protein in 1959–61 supplies from "World Food Budget 1970", USDA For. Agr. Econ. Rept. 19, Oct. 1964; "Food Balances for 24 Countries of the Western Hemisphere, 1959–61", USDA-ERS For. 86, Aug. 1964; "Food Balances for 12 Countries in the Far East and Oceania, 1959–61", USDA-ERS For. 88, Aug. 1964.

TABLE 26.—*Projected annual protein surpluses (1000 tons), if calorie needs are met with food patterns similar to foods available in 1959–61 for Brazil, India, Pakistan, and the world.*

[These figures represent the amounts the projected national protein supplies exceed needs for protein of similar NPU (Table 13) per annum]

| | Year | Brazil | India | Pakistan | World |
|---|---|---|---|---|---|
| High population projection | 1965 | 107 | 688 | 226 | 8,594 |
| | 1970 | 147 | 1,048 | 355 | 9,312 |
| | 1975 | 130 | 1,039 | 408 | 10,194 |
| | 1980 | 154 | 1,233 | 503 | 11,389 |
| | 1985 | 166 | 1,345 | 583 | 13,070 |
| Low population projection | 1965 | 107 | 688 | 226 | 8,594 |
| | 1970 | 146 | 1,018 | 345 | 9,250 |
| | 1975 | 104 | 918 | 366 | 9,778 |
| | 1980 | 131 | 974 | 422 | 10,361 |
| | 1985 | 123 | 960 | 455 | 10,745 |

TABLE 27.—*Projected protein surpluses as percent of requirements for Brazil, India, Pakistan, and the world (These figures assume caloric needs will be met with foods similar to foods available in 1959–61)*

| | Year | Brazil | India | Pakistan | World |
|---|---|---|---|---|---|
| High population projection | 1965 | 8 | 8 | 13 | 13 |
| | 1970 | 8 | 10 | 15 | 12 |
| | 1975 | 6 | 8 | 14 | 12 |
| | 1980 | 6 | 8 | 14 | 12 |
| | 1985 | 6 | 8 | 13 | 13 |
| Low population projection | 1965 | 8 | 8 | 13 | 13 |
| | 1970 | 8 | 10 | 15 | 12 |
| | 1975 | 5 | 7 | 13 | 12 |
| | 1980 | 5 | 7 | 13 | 11 |
| | 1985 | 4 | 6 | 11 | 11 |

### *1.7.4 Some Possible Action Programs*

Possibilities for action programs include:

1. Fortification of specific foods with nutrients known to be insufficient in the food supply of important segments of populations. This could involve, for example, amino acid fortification, vitamin A fortification, or addition of iodide.

2. Intensive efforts to produce legumes and more nutritious cereals.

3. In addition to the possibility of fortification of processed foods, countries should be encouraged to increase production of foods high in vitamin A which are already accepted in local food habits. These could include carrots, sweet potatoes and yams, papaya, and mangoes. In other countries, acceptance and pro-

duction of high Vitamin A foods should be encouraged through educational programs which will demonstrate their value.

### *1.8.0 Nutrition Programs in Developing Countries*

A national nutrition program is the primary responsibility of the government of the country. Consultation, where necessary and requested, with international or foreign national agencies does not change this responsibility. Nutrition planning must include development of education, research and action programs.

It should be emphasized that the child in its home is a member of a community and his state of health is influenced by the actions and events taking place there. Relief of malnutrition is, therefore, largely a social problem and the solution depends not only on government action, but also on the efforts of the people themselves. An essential prerequisite to planning any proper program is an understanding of the local situation. Preliminary investigations of the food producing potential, manpower, cutomary methods of communication, local opinion and beliefs, and medical, agricultural, and educational resources should be carried out. Intermediate and long-term aims should be outlined and plans made for measuring and assessing progress.

The first step in a nutrition program, if the area is capable of food production, may be to encourage an increase and improvement of crops, including reduction of waste, that will make more suitable foods available, or will increase income from sale of cash crops so that proper foods may be purchased. If immediate improvement of agriculture is not feasible, foods must be imported or processed food mixtures can be used as supplements.

#### *1.8.1 Current Nutrition Programs*

Nutrition programs have been initiated in many less developed countries with the assistance of international agencies, particularly FAO, WHO and UNICEF, governments of the United States and of other developed countries, foundations, and voluntary agencies. Programs have included efforts to increase national, local and home food production, to improve distribution of food and to enhance nutrition knowledge through education and training. Major emphasis has been placed on provision of low cost foods for prevention of protein-calorie malnutrition in pre-school children. Such protein-rich food mixtures as Incaparina in Central America, Pro-nutro in South Africa, Fortifex in Brazil and Multiple Purpose Food in India have been prepared. Processing of oil seed meals for use as protein supplements has received considerable attention. The development of fish protein concentrates is under investigation in the United States, Chile and Scandinavia. Supplementary feeding programs, including provision of school lunches, have been initiated in many areas.

FAO [85, 86] through its Freedom from Hunger campaign, World Food Program and many other activities has reported on the magnitude of the problem of malnutrition and has contributed to nutrition knowledge through expert committees, conferences and seminars and preparation of educational materials. They have participated in action programs by providing advice to governments and services of staff members and collaborating with UNICEF and WHO in applied nutrition programs.

The activities of WHO in nutrition from 1948 to 1964 have been reviewed in a recent publication.[87] Assistance has been given in development of national programs, in surveys and in training and education. Applied projects have been aided by providing advisors and fellowships and organizing seminars.[88] The WHO professional staff numbers 69 of which 58 are involved full or part time in planning and implementation of projects. A number of short-term consultants are also provided yearly. In the past 18 years, WHO has sponsored 652 fellowships. During the years 1961–65, the average per year has been 45, largely for training in public health nutrition and applied nutrition projects. Since 1958, twelve meetings and seminars relating to applied programs have been sponsored by WHO, most of them in cooperation with FAO.

UNICEF initiated nutrition programs in developing areas about 15 years ago, the major interest being the development and use of protein-rich foods to combat malnutrition in childhood.[89] The FAO-UNICEF Joint Policy Committee in its Fifth Session outlined prerequisites for developing, planning, and evaluating applied programs.[90] These programs have been established in 56 countries under joint sponsorship of UNICEF, WHO, and FAO; some are just starting and some have been in action for about six years.

In 1966, UNICEF initiated an evaluation of these programs and a consultant visited five representative countries, the Philippines, India, the Ivory Coast, Colombia and Trinidad.[91] The programs are planned for rural areas and combine home food production, which includes raising poultry and small animals and development of vegetable gardens, with feeding, education and demonstration activities.

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[85] The work of the nutrition division, general statement. Food and Agriculture Organization of the United Nations, April 15, 1966.

[86] Indicative world plan for agricultural development 1965–1975–1985. Food and Agriculture Organization of the United Nations, April 15, 1966.

[87] WHO activities in nutrition, 1948–1964, World Health Organization, Geneva, 1965.

[88] Assessment of applied nutrition projects. Addendum 3: WHO Assistance to the Applied Nutrition Projects. United Nations Children Fund, U.N. Economic and Social Council. December 1966.

[89] Tepley, L. J., Protein-rich foods, research: development and testing. Protein Advisory Group (WHO, FAO, UNICEF) Geneva, August 1966.

[90] FAO–UNICEF Joint Policy Committee, 5th Session, Prerequisites for the development, planning and evaluation programs, March 1965.

[91] Assessment of applied nutrition program, James M. Hundley. Document prepared for United Nations Childrens Fund Executive Board, Dec. 1966.

The national executive agency for the program differs among the countries; the Ministry of Education or of Health, the Community Development Agency (in India) or an autonomous independent agency (National Institute of Nutrition in Colombia). UNICEF has allocated a total of $19.5 million to the projects from 1958 to 1966. In the past year, about $2.5 million was expended. These funds have been used for supplies and equipment, vehicles for transport, fellowships, costs for within-country training, remuneration for key national staff and provision of international experts as consultants or advisors to the project.

It was the consultant's opinion [91] that the applied nutrition programs were capable of engendering serious, sustained and coordinated local interest and national action on nutrition problems.

Agreement had not been reached on the type of baseline survey for establishment of needs to guide program design and evaluate progress. Inadequate financing was a great problem, as were lack of coordination and cooperation in some areas. Staffing was inadequate at times. In some instances, feeding programs gravitated to a "stomach filling" operation to the neglect of the primary purpose, that of education and demonstration projects designed to improve food production and consumption in the home. Village people were not sufficiently involved. International experts were used as project executives rather than advisors. Food production activities were not properly linked to normal agricultural production and commercial development schemes. In spite of difficulties, only two projects in the 56 countries were classified as failures, although some others were considered very weak.

The present applied nutrition programs were so small that only a very small fraction of the population has been reached. They must be redesigned for urban areas. Some countries are not ready for the program at their present stage of governmental development or their resources are too meager and there is a shortage of qualified personnel. It was suggested that international agencies develop a small, flexible, mobile, reserve of potential project experts for programs in each country. Such agencies should also conduct or sponsor a cost-benefit analysis of the various components of the program.

Training of personnel has increased as the result of the programs, both within a country for intermediate and low level training, and regionally for higher level training. Exchange of personnel among projects would be useful for additional training. Emphasis should be given to the development of voluntary groups such as mother's clubs, 4–H Clubs, farmers clubs, cooperatives and similar organizations. Foods produced as one phase of the program could be used not only in schools but in rehabilitation centers or in other programs in which mothers helped with cooking and feeding.

An applied nutrition program is part of the national policy in India and has been provided for in the new 5-year plan. There is evidence, although incomplete, that applied nutrition programs have an impact on food habits, beliefs and practices. Part of the strength of the program in India is due to the Community Development Organization which is the coordinating agency. The country is divided into 5,222 blocks of which 222 now have applied nutrition programs. The program is evaluated periodically. Failures have occurred in some areas.

A national system of institutions to train people to carry out applied nutrition programs has been established in India and about 28,000 persons have been trained. Three months certificate courses for agriculture, animal husbandry, home science and related types of work are scheduled to begin in the Nutrition Laboratory at Hyderabad. These and a comparable course for medical personnel, already in operation, should alleviate much of the need for out-of-country training. The Nutrition Laboratory hopes to establish and test a model, state-level nutrition unit as one means of meeting future needs.

In the Ivory Coast, the applied nutrition program is built around food production, school feeding, nutrition education and demonstration projects including school gardens and poultry units. Food production is a bright spot in the program but the school feeding, nutrition education and demonstration aspects are weak.

In Colombia, the applied nutrition program began in 1960 but little progress was made until 1963 when it was reorganized under the National Nutrition Institute. The program is in operation in three states and is being extended into six of the other 20 states in the country. Baseline nutrition surveys are being or have been conducted. Promotion of the protein supplement, Incaparina, is one aspect of the program. Better approaches are needed to reach the preschool child in rural areas. From July 1964 to June 1965, some type of training in food and nutrition was given to more than 40,000 persons. (In some instances this was only one demonstration.)

The need for expansion of applied nutrition programs can be illustrated in the Philippines where three rural health units with a staff of four and only one vehicle serve a population of 60,000 people.

The United States government and governments of other developed countries are cooperating in nutrition projects in various parts of the world. United States activities have been carried out through the Department of Agriculture, the Food for Peace Program, the Agency for International Development and the Nutrition Section of the Office of International Research, National Institutes of Health.

The Nutrition Section of OIR, formerly the Interdepartmental Committee on Nutrition for National Defense (ICNND) has car-

ried out nutrition surveys in 32 countries. Findings have been evaluated and reports made to the governments of the respective countries with suggestions for remedial action. Nutrition programs (both research and applied) are currently underway under the direction of the Nutrition Section of OIR, either alone or in collaboration with AID, in a number of countries (Equador, Chile, Peru, Brazil, Taiwan, Philippines, Jordan, Egypt, Nigeria, and most of the Central American countries).

Under Food for Peace, $2.5 billion of United States agricultural commodities have been distributed annually to less developed areas. In the recipient countries, only 2 percent of the preschool children and 15 percent of the 7–14 year age group have received any of this assistance. Preschool recipients total about 5 million and recipients in the school feeding program about 65 million. The number of children age 0–14 estimated to be suffering from malnutrition is 269 million. No attempt has been made to evaluate the impact of these feeding programs on malnutrition and this should be done. The estimated cost would be $50,000 per country per year.

The nutrition programs that have been initiated throughout the world thus far have been grossly inadequate to meet the needs of the population. The number of nutrition workers needed for a world wide program of significant impact would be many hundred or thousand times those currently available.

### *1.8.2 Suggestions for National Nutrition Programs in Developing Countries*

*1.8.2.1 Organization and Action Programs.* 1. Nutrition should be included in the overall planning for economic and agricultural development. Creation of a Food and Nutrition Section within the Ministry of Health or in some other ministry is desirable for initiating, planning and coordinating a nutrition program. Councils on food and nutrition to advise the secretaries and administrators of agriculture, health, education, commerce and economic development and to coordinate activities can be useful. National *nutrition* policies should be developed in association with *food* and *agricultural* policies. Local nutrition programs should operate in conjunction with health, educational and agricultural extension activities. In countries where there are food industries, the government should enlist their cooperation in nutrition programs. Food standards should be established by the government so the nutritional adequacy of products can be evaluated.

2. Nutrition surveys, local, regional or national, may be needed to define problem areas and to assess the potentialities for action. To develop realistic goals and to plan for food and nutrition programs for children, it is necessary to know present and projected size, age, and sex structure of the population, average family size,

average income of different family groups, present levels and patterns of food consumption, distribution of food within the family unit, nutritional requirements for these persons, and local environmental and economic conditions pertinent to meeting nutritional needs. Initiation of action programs should not be held up for years, however, pending completion of surveys or definition of a detailed national policy. As a matter of fact, pilot project activities may help develop and improve national food and nutrition polices.

3. Nutrition clinics should be established in connection with health services. Preschool feeding programs can often be planned in association with health centers. Nutrition and child care programs should go hand in hand with programs for the control of diseases, environmental sanitation and food hygiene and studies on suitability and acceptability of new foods and diets.

4. School lunch programs may be valuable in furnishing needed foods and in teaching the essentials of an adequate diet. It is recognized that in many areas there are no schools and a majority of the population is illiterate. Under these circumstances, community feeding and education programs must be devised.

5. Special projects for supplementary feeding of young children can be organized such as establishment of nutritional rehabilitation centers in urban or rural areas where mothers can participate and learn proper feeding practices.

6. The applied nutrition programs of UNICEF can be expanded and adapted to urban as well as rural areas.

7. The importance of family planning should be stressed and appropriate programs should be initiated to improve the chances of a good nutritional start for each child, to protect the health of the mother, and to best utilize the resources of each country.

*1.8.22 Programs of Nutrition Education and Training.* The importance of nutrition in overall planning should be stressed. This can be done by advisors of international or other agencies associated with technical assistance programs in developing countries. Education and training programs should be initiated for professional and auxiliary personnel and for the general public. There is need for nutrition training at all levels: physicians, biochemists, public health nutritionists, nurses, social workers, technicians, agricultural extension agents, rural health personnel, school teachers and mothers, fathers, and children in the community.

1. Food and nutrition research institutes should be organized in countries or regions to provide information, training and advice.

2. Nutrition departments should be established in universities, agricultural colleges and other institutions of higher learning.

Curricula should be organized and supported for training of physicians, nurses, dietitians, agricultural extension agents, social workers, technicians, public health personnel and teachers in primary and secondary schools.

3. Food technology laboratories should be established in one or more agricultural colleges.

4. Programs should be supported for training in food sanitation, quality control, research and demonstration. Emphasis should be placed on the production, conservation and processing of high quality protein foods for the prevention of protein-calorie malnutrition in early childhood.

5. Scholarships should be made available by international agencies, governments and foundations for doctorate and post doctorate training in nutrition. In some less developed countries, there are *no* professional personnel with nutrition training. In most instances, training of candidates at the doctoral level will have to be carried out in the developed countries or at regional centers in various parts of the world. A considerable amount of professional training at intermediate and lower levels can be given in national and regional centers in the less developed countries. Training programs will require extensive support through international, bilateral and multilateral agreements. The assistance of universities in the United States and other developed countries must be obtained and their activities supported by long-term commitments.

6. Nutrition education for the consumer should be planned largely for mothers and housewives. This can be done in health centers for child care, when such exist, and combined with programs for the control of disease. When schools are available, they can be used for training. In some areas, agricultural extension workers, social workers and public health nurses, who are working at the village or rural level, can do much to promote nutrition knowledge if they have been properly indoctrinated. Some type of community organization may be used and simple educational materials must be prepared. The use of tape recordings, motion pictures and television should be considered as one means of reaching large numbers of people with limited personnel and resources available.

7. Personnel for assisting in nutrition programs at the local level should be sought from many sources including international volunteers. Young people with a good education (not necessarily trained in nutrition) such as the Peace Corps in the United States, national volunteers, preferably recruits from the community, and national para-auxiliary workers, that is, persons who can be

trained to do simple tasks under supervision are excellent candidates. For many of these volunteers, nutrition would be only one of their community responsibilities.

National or regional teams can be established in conjunction with a nutrition laboratory or institute to plan, guide and evaluate rural and urban community programs.

8. International training units should be developed to provide short courses in the developing countries or in regional training centers which could be established in Central and South America, Africa, and Asia. Two training centers that are currently functioning are the Central Food Technological Research Institute in Mysore, India and the Institute of Nutrition for Central America and Panama in Guatemala City. These are large multi-disciplinary centers for food and nutrition research. A number of other centers have potentialities for national or regional research and training centers if additional financial and technical assistance is provided. Some of these, as suggested in a recent report [92] are: Food Technology Department, Agricultural College, University of Sao Paulo, in cooperation with the Institute of Technology, Campinas, Sao Paulo, Brazil; Institute of Food Science and Technology, Santiago, Chile; Department of Food Science and Nutrition, University of Ghana, Accra, Ghana; Department of Food Technology, American University, Beirut, Lebanon; Instituto Mexicana de Investigaciones Technologicas, Mexico City; Agrarian University, La Molina, Peru; Taiwan National University in Taiwan; Regional Research Laboratory, Lahore, Pakistan.

A partial survey of nutrition training in Latin America in 1961 [93] pointed out the importance and urgency of improving the training in nutrition for both professional and auxiliary personnel. Of 91 medical schools in Latin America at that time, less than five had nutrition units. Few schools offered university level training in Home Economics. There were eight schools for dietitians and only one for nutritionists. Nutrition was taught in all eleven schools of Public Health but the quality of the curriculum varied considerably. The Institute of Nutrition for Central America and Panama offered a three-month special training course in nutrition, but could accommodate only a limited number of people. Little nutrition was taught in nursing schools and such training was also needed for social workers. Every country in Latin

[92] Scrimshaw, N. S., Increasing the production and human use of protein. Advisory Committee on the Application of Science and Technology to Development, 6th Session, Oct. 1966.

[93] Trulson, M. F., and Bengoa, J. M., Nutrition training in the Americas. FAO–WHO–UNICEF, 1961.

America has one or more schools of agriculture but they have done little to include training in human nutrition. Assistance is needed in the form of equipment, teaching materials, and personnel. Training in nutrition should be included in primary and secondary schools. Most countries in Latin America have no personnel trained in food technology. Information on improvements in nutrition training in these countries since 1961 is not available. The situation is undoubtedly much worse in Africa.

*1.8.2.3 Nutrition Research Programs.* The opportunities and needs for nutrition research in developing countries are numerous. Research and action programs can often be woven together with proper planning and coordination.

1. In all of the developing countries, there is need for more complete and accurate census data and vital statistics, for better estimates of crop and livestock production, and for more accurate estimates of food losses and non-food uses.

2. The nutritional status of the population of the developing areas has not been determined with accuracy. Even such simple information as height and weight for various ages is not available.

3. Data on food composition, especially food grown in tropical areas, must be obtained.

4. Information is lacking on food consumption of regions, villages, individual families, and members of families. More needs to be learned about relationships of food consumption to income.

5. Search should be continued to elucidate the etiology and extent of nutritional disorders. Improved methods are needed for determining nutritional adequacy and for early recognition of nutritional deficiencies.

6. Knowledge of relationships among morbidity, mortality, and nutrition should be increased. Investigation of specific health problems and their relation to nutrition will be desirable in all of the developing areas. Some problems which require further study are nutrition during pregnancy and lactation, the etiology of anemias and infant diarrhea which are extremely prevalent, and the relationships of nutrition to infection and parasitic infestation.

7. Investigation of relationships of nutrition to mental development should receive high priority in research in developing areas. In these areas there is an opportunity, also, to study the effects of urbanization and industrialization on health and nutrition.

8. The physiological effects of different nutritional levels have been insufficiently delineated and information about physiological adaptation to various levels of nutrition is limited. More data are

needed on caloric and specific nutrient requirements for different occupations, in different climates and under varying states of nutrition.

9. Research in educational methods is essential to develop techniques and media for influencing nutritional improvement in areas of high illiteracy.

10. Factors affecting the acceptability of different foods and the many determinants of food habits require exploration.

*1.8.3 United States Assistance in Nutrition Programs in Developing Countries*

In the United States, the importance of nutrition has not been appreciated in recent years. Food is abundant and of wide variety and most population groups have sufficient income to purchase adequate amounts. Deficiency diseases were essentially eradicated about 25 years ago and since then we have become complacent. No comprehensive evaluation of nutritional status in the United States has been conducted. The limited information available indicates that certain segments of the population suffer from, or are potentially vulnerable to, pathologic states related to nutrient deficiencies, e.g. anemia, goiter, underweight, retarded physical growth, increased susceptibility to infections, or health problems in pregnancy. Obesity is a serious problem and relationships of nutrition to degenerative diseases are receiving increased recognition. More attention should be given to nutrition in this country for our own interests, as well as for the welfare of developing areas.

1. The United States should assume leadership in a world program to combat malnutrition. In our international programs for development and technical assistance in developing countries, *nutrition* should receive increased emphasis.

2. The number of professional personnel trained in nutrition in the United States is not sufficient to meet the needs for expansion of nutrition training in the medical schools, agricultural colleges, and universities of this country. With expansion of international nutrition programs, shortage of personnel will become acute. Immediate steps should be taken to stimulate career development in nutrition for international service. This activity should be sponsored by long-term commitments to permit competition with other career development fields. Training should be provided in medical nutrition, nutritional biochemistry, dietetics, food technology, and all aspects of public health nutrition.

3. In the developing countries, the need for persons trained in nutrition exists at all levels. Plans should be made, first, for fellowships in the United States or other developed countries to train outstanding persons who can return as leaders to their respective areas. Special funds should be made available for this training by the United States,

and other developed countries, international agencies, and foundations. More regional training centers in nutrition should be developed in various parts of the world with assistance of the United States, other countries and international agencies.

4. The universities in the United States should develop more collaborative programs with the developing countries for training, research, and action programs in nutrition. Many universities are participating currently in programs related to food and agriculture in developing nations but the number of programs which include nutrition components is relatively small. An effort should be made to identify and coordinate these international nutrition activities. University participation will require federal funding and other support on a long-term basis.

5. Consideration should be given to the organization of nutrition teams either in the United States or in international organizations that could be made available to developing countries for assistance in planning, training, and setting up action programs. It will be difficult, perhaps impossible, to meet requests until more trained personnel are available.

6. Comprehensive planning for a total program to relieve malnutrition in any given country has never been undertaken. It is almost impossible to project total needs. The extent of the problem has not been delineated and reliable sources on availability of personnel, funds, production potential, educational and community facilities, and many other aspects of the problem are not available. Estimates of the scope and cost of a program for a country, likewise, have not been attempted. But for a pilot project in a small country, or a project in one area of a large country, a budget of about $1.0 million yearly could provide the following:

*a.* A baseline nutrition-health survey and periodic evaluation, $80,000 per year.

*b.* Studies on nutrient composition of native foods, $100,000 per year.

*c.* Operation of pre-school rehabilitation centers, $100,000 per year. The cost assumes that a center for 30–40 children, with mothers learning at the same time, in six-week feeding programs, could be operated for $10,000 per year, if local staple foods are available at low cost and a native dietitian operates the center. Ten such centers are proposed per country, each handling eight classes per year.

*d.* Development and dissemination of information, $30,000 per year. This envisions an office staff of four people who would develop tapes for radio and elementary materials for a semi-literate population, primarily mothers.

*e.* Training of indigenous personnel in the United States, 15 per year at the cost of $10,000 per trainee, $150,000 per year.

*f.* Support of a country nutrition council, office, institute, or agency, $100,000 per year. Such an office is essential for success. This level of funding would permit establishment of an office with a director, supporting personnel, and operating budget including costs of convening inter-agency personnel for national planning.

*g.* Support for universities in the United States to effect adequate guidance and supervision. $500,000 per year. For the program outlined above, there will be need for direct United States university counterpart involvement if any real progress is to be made. The amount allotted envisions that at least one university faculty member will be assigned in the counterpart country for each of the above activities. There would likewise be need for counterpart personnel from the country for assignment in the United States. It will be necessary, also, to assign United States personnel to the universities of the country for in-country research and training. The $500,000 would support 15–20 faculty members or their counterparts.

If the United States developed pilot projects as just described in 10 countries, the annual cost would approximate $10 million.

7. The cost of supplementary feeding programs in developing countries should be emphasized, namely, 5 to 10 cents per child per day. In a moderate-sized country such as Nigeria with about 25 million children, the annual cost would be $450 to $900 million. India has a pre-school population of over 78 million and a school population (to age 19) of over 170 million. It has been estimated that food costs for supplementation of only 10 per cent of the vulnerable pre-school children, with currently available formulated food, to supply 10 gm of protein per day, would be more than $500 million per year.

8. The operation of a number of nutrition projects in various parts of the world will require a central clearing house of information for coordination and implementation of programs. This could be done with a budget of $100,000 to $200,000 yearly.

9. Regional seminars should be sponsored periodically to exchange information so that knowledge and experience gained in one area can be applied to another to resolve common problems. If three such seminars were held each year the cost would be about $150,000.

10. Nutrition research is a vital part of a world-wide program to combat malnutrition. The future costs cannot be estimated but it would be highly desirable to allocate at least $1 to $2 million yearly for this aspect of the problem.

## 1.9.0 Appendix—Tables 1–14

TABLE 1.—*Estimated and projected population of the world, by age and sex: selected years, 1965–85*

[In millions]

| Age and series | 1965 | | | 1970 | | | 1975 | | | 1980 | | | 1985 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Both sexes | Male | Female | Both sexes | Male | Female | Both sexes | Male | Female | Both sexes | Male | Female | Both sexes | Male | Female |
| All ages: | | | | | | | | | | | | | | | |
| High | 3,308 | 1,654 | 1,654 | 3,624 | 1,815 | 1,808 | 4,005 | 2,010 | 1,995 | 4,467 | 2,247 | 2,220 | 5,032 | 2,536 | 2,496 |
| Low | | | | 3,599 | 1,803 | 1,796 | 3,911 | 1,962 | 1,949 | 4,264 | 2,143 | 2,121 | 4,647 | 2,340 | 2,307 |
| Under 1 year: | | | | | | | | | | | | | | | |
| High | 98 | 50 | 48 | 109 | 56 | 53 | 123 | 63 | 60 | 147 | 78 | 69 | 162 | 83 | 79 |
| Low | | | | 100 | 51 | 49 | 106 | 54 | 52 | 119 | 63 | 56 | 116 | 59 | 57 |
| 1 to 4 years: | | | | | | | | | | | | | | | |
| High | 369 | 188 | 181 | 380 | 193 | 187 | 437 | 223 | 214 | 496 | 250 | 246 | 580 | 296 | 284 |
| Low | | | | 365 | 186 | 179 | 384 | 196 | 188 | 411 | 207 | 204 | 440 | 224 | 216 |
| 5 to 9 years: | | | | | | | | | | | | | | | |
| High | 416 | 211 | 205 | 445 | 227 | 218 | 468 | 239 | 229 | 539 | 275 | 264 | 624 | 319 | 305 |
| Low | | | | | | | 445 | 227 | 218 | 472 | 241 | 231 | 515 | 263 | 252 |
| 10 to 14 years: | | | | | | | | | | | | | | | |
| High | 368 | 187 | 181 | 408 | 207 | 201 | 438 | 223 | 215 | 463 | 237 | 226 | 536 | 274 | 262 |
| Low | | | | | | | | | | 440 | 225 | 215 | 470 | 240 | 230 |
| 15 to 19 years: | | | | | | | | | | | | | | | |
| High | 309 | 158 | 151 | 361 | 183 | 178 | 403 | 205 | 198 | 434 | 221 | 213 | 462 | 236 | 226 |
| Low | | | | | | | | | | | | | 439 | 224 | 215 |
| 20 to 24 years | 259 | 132 | 127 | 303 | 155 | 148 | 356 | 181 | 175 | 399 | 203 | 196 | 433 | 221 | 212 |
| 25 to 29 years | 244 | 124 | 120 | 252 | 129 | 123 | 295 | 151 | 144 | 347 | 176 | 171 | 391 | 199 | 192 |
| 30 to 34 years | 222 | 113 | 109 | 238 | 121 | 117 | 247 | 126 | 121 | 290 | 148 | 142 | 344 | 175 | 169 |
| 35 to 39 years | 203 | 102 | 101 | 215 | 109 | 106 | 231 | 117 | 114 | 241 | 123 | 118 | 286 | 146 | 140 |
| 40 to 44 years | 174 | 86 | 88 | 195 | 98 | 97 | 208 | 105 | 103 | 225 | 114 | 111 | 236 | 120 | 116 |
| 45 to 49 years | 144 | 71 | 73 | 167 | 82 | 85 | 189 | 94 | 95 | 202 | 102 | 100 | 219 | 110 | 109 |
| 50 to 54 years | 133 | 64 | 69 | 136 | 66 | 70 | 159 | 77 | 82 | 180 | 89 | 91 | 193 | 97 | 96 |
| 55 to 59 years | 114 | 55 | 59 | 123 | 59 | 64 | 126 | 60 | 66 | 148 | 71 | 77 | 169 | 83 | 86 |
| 60 to 64 years | 92 | 43 | 49 | 102 | 48 | 54 | 110 | 52 | 58 | 113 | 53 | 60 | 134 | 63 | 71 |
| 65 to 69 years | 69 | 31 | 38 | 78 | 36 | 42 | 88 | 41 | 47 | 96 | 44 | 52 | 99 | 45 | 54 |
| 70 years and over | 96 | 40 | 56 | 111 | 46 | 65 | 127 | 53 | 74 | 145 | 61 | 84 | 162 | 68 | 94 |

Source: The two series differ only with respect to fertility. The high series assumes that fertility will remain constant at the level estimated for 1965. The low series assumes that fertility will decline to 90 percent of the high series by 1970, to 80 percent by 1980, and to 70 percent by 1985. Both series assume declining mortality. To establish the level of fertility in 1965, an estimate of the total number of births in the world was obtained by applying a birth rate of 34 per 1000, given in the United Nations, *Demographic Yearbook 1965* as the average rate for the period 1960–64, to the estimated world population in 1965. A set of age-specific fertility rates consistent with that number of births was obtained by adjusting slightly the fertility rates for Taiwan for 1960. These adjusted rates were then used to estimate births for the high series.

The age-sex structure for the 1965 population and for the survivors at later dates of persons already alive in 1965 were obtained by summing projections by age and sex for world regions. For Africa, Latin America, and Oceania the projected age-sex structure was based on distributions given in the United Nations, *Provisional Report on World Population Prospects, as Assessed in 1963*. For Asia the distribution was obtained by summing projections for China (Mainland), Pakistan, and Japan prepared by the Bureau of the Census, and projections for India prepared by the Institute of Applied Manpower Research, New Delhi. The resulting distribution was adjusted to reflect the population of Asia as a whole. Projections for North America were based on projections for the United States prepared by the Bureau of the Census; those for Europe were based on projections for western European countries appearing in Organization for European Economic Co-operation, *Demographic Trends 1956–76 in Western Europe and the United States*, and projections for East European countries prepared by the Bureau of the Census. The figures for the U.S.S.R. were prepared by the Bureau of the Census.

263-888 O—67——8

TABLE 2.—*Estimated and projected population of Brazil, by age and sex: Selected years, 1965–85*

[In thousands]

| Age and series | 1965 | | | 1970 | | | 1975 | | | 1980 | | | 1985 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Both sexes | Male | Female | Both sexes | Male | Female | Both sexes | Male | Female | Both sexes | Male | Female | Both sexes | Male | Female |
| All ages: | | | | | | | | | | | | | | | |
| High | 81,301 | 40,518 | 40,783 | 93,970 | 46,957 | 47,013 | 109,267 | 54,737 | 54,530 | 127,770 | 64,153 | 63,617 | 150,104 | 75,534 | 74,570 |
| Low | | | | 93,306 | 46,618 | 46,688 | 106,527 | 53,337 | 53,190 | 121,540 | 60,970 | 60,570 | 138,456 | 69,579 | 68,877 |
| Under 1 year: | | | | | | | | | | | | | | | |
| High | 3,037 | 1,542 | 1,495 | 3,508 | 1,795 | 1,713 | 4,116 | 2,108 | 2,008 | 4,838 | 2,480 | 2,358 | 5,691 | 2,920 | 2,771 |
| Low | | | | 3,227 | 1,651 | 1,576 | 3,581 | 1,834 | 1,747 | 3,967 | 2,034 | 1,933 | 4,325 | 2,219 | 2,106 |
| 1 to 4 years: | | | | | | | | | | | | | | | |
| High | 10,660 | 5,394 | 5,266 | 12,342 | 6,292 | 6,050 | 14,548 | 7,427 | 7,121 | 17,248 | 8,817 | 8,431 | 20,447 | 10,466 | 9,931 |
| Low | | | | 11,959 | 6,097 | 5,862 | 12,978 | 6,625 | 6,353 | 14,565 | 7,445 | 7,120 | 16,298 | 8,342 | 7,956 |
| 5 to 9 years: | | | | | | | | | | | | | | | |
| High | 11,636 | 5,862 | 5,774 | 13,171 | 6,661 | 6,510 | 15,337 | 7,816 | 7,521 | 18,170 | 9,270 | 8,900 | 21,626 | 11,046 | 10,580 |
| Low | | | | | | | 14,702 | 7,492 | 7,210 | 16,125 | 8,227 | 7,898 | 18,151 | 9,271 | 8,880 |
| 10 to 14 years: | | | | | | | | | | | | | | | |
| High | 9,842 | 4,915 | 4,927 | 11,510 | 5,799 | 5,711 | 13,053 | 6,601 | 6,452 | 15,223 | 7,756 | 7,467 | 18,059 | 9,210 | 8,849 |
| Low | | | | | | | | | | 14,592 | 7,434 | 7,158 | 16,027 | 8,174 | 7,853 |
| 15 to 19 years: | | | | | | | | | | | | | | | |
| High | 8,274 | 4,109 | 4,165 | 9,723 | 4,856 | 4,867 | 11,392 | 5,739 | 5,653 | 12,939 | 6,541 | 6,398 | 15,113 | 7,696 | 7,417 |
| Low | | | | | | | | | | | | | 14,487 | 7,377 | 7,110 |
| 20 to 24 years | 6,931 | 3,444 | 3,487 | 8,120 | 4,030 | 4,090 | 9,567 | 4,775 | 4,793 | 11,238 | 5,656 | 5,582 | 12,796 | 6,462 | 6,334 |
| 25 to 29 years | 5,855 | 2,907 | 2,948 | 6,775 | 3,364 | 3,412 | 7,964 | 3,948 | 4,015 | 9,413 | 4,692 | 4,721 | 11,089 | 5,575 | 5,514 |
| 30 to 34 years | 5,149 | 2,545 | 2,604 | 5,719 | 2,838 | 2,880 | 6,640 | 3,295 | 3,345 | 7,830 | 3,879 | 3,951 | 9,281 | 4,622 | 4,659 |
| 35 to 39 years | 4,360 | 2,181 | 2,179 | 5,019 | 2,479 | 2,540 | 5,595 | 2,774 | 2,821 | 6,518 | 3,231 | 3,287 | 7,708 | 3,815 | 3,893 |
| 40 to 44 years | 3,767 | 1,869 | 1,898 | 4,234 | 2,114 | 2,120 | 4,893 | 2,412 | 2,481 | 5,472 | 2,709 | 2,763 | 6,395 | 3,165 | 3,230 |
| 45 to 49 years | 3,158 | 1,565 | 1,593 | 3,628 | 1,793 | 1,835 | 4,095 | 2,037 | 2,058 | 4,752 | 2,334 | 2,418 | 5,332 | 2,631 | 2,701 |
| 50 to 54 years | 2,578 | 1,276 | 1,302 | 3,002 | 1,478 | 1,524 | 3,467 | 1,703 | 1,764 | 3,930 | 1,943 | 1,987 | 4,577 | 2,236 | 2,341 |
| 55 to 59 years | 2,053 | 1,011 | 1,042 | 2,402 | 1,177 | 1,225 | 2,814 | 1,372 | 1,442 | 3,267 | 1,590 | 1,677 | 3,722 | 1,824 | 1,898 |
| 60 to 64 years | 1,581 | 770 | 811 | 1,852 | 899 | 953 | 2,184 | 1,054 | 1,129 | 2,576 | 1,238 | 1,338 | 3,009 | 1,443 | 1,566 |
| 65 to 69 years | 1,141 | 545 | 596 | 1,352 | 646 | 706 | 1,600 | 762 | 839 | 1,904 | 901 | 1,003 | 2,265 | 1,067 | 1,198 |
| 70 years and over | 1,279 | 583 | 696 | 1,613 | 736 | 877 | 2,002 | 914 | 1,088 | 2,452 | 1,116 | 1,336 | 2,994 | 1,356 | 1,638 |

Source: Prepared by the Foreign Demographic Analysis Division, Bureau of the Census, U.S. Department of Commerce. The high series assumes that fertility will remain constant at the level assumed for 1965. The low series assumes that fertility will decline. Both series assume that mortality will decline.

TABLE 3.—*Estimated and projected population of India, by age and sex: selected years, 1965–85*

[In thousands]

| Age and series | 1965 | | | 1970 | | | 1975 | | | 1980 | | | 1985 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Both sexes | Male | Female | Both sexes | Male | Female | Both sexes | Male | Female | Both sexes | Male | Female | Both sexes | Male | Female |
| All ages: | | | | | | | | | | | | | | | |
| High | 483,852 | 249,442 | 234,410 | 552,371 | 284,864 | 267,507 | 636,283 | 328,304 | 307,979 | 738,811 | 381,405 | 357,406 | 863,722 | 446,091 | 417,631 |
| Low | | | | 542,086 | 279,591 | 262,495 | 601,727 | 310,520 | 291,207 | 676,701 | 349,343 | 327,358 | 768,586 | 396,887 | 371,699 |
| Under 1 year: | | | | | | | | | | | | | | | |
| High | 17,757 | 9,096 | 8,661 | 20,990 | 10,771 | 10,219 | 24,179 | 12,471 | 11,708 | 28,296 | 14,628 | 13,668 | 33,253 | 17,188 | 16,065 |
| Low | | | | 17,190 | 8,821 | 8,369 | 18,521 | 9,553 | 8,968 | 22,015 | 11,381 | 10,634 | 25,305 | 13,080 | 12,225 |
| 1 to 4 years: | | | | | | | | | | | | | | | |
| High | 61,410 | 31,375 | 30,035 | 71,258 | 36,513 | 34,745 | 82,505 | 42,433 | 40,072 | 97,113 | 50,113 | 47,000 | 114,889 | 59,398 | 55,491 |
| Low | | | | 64,773 | 33,190 | 31,583 | 63,364 | 32,589 | 30,775 | 75,068 | 38,737 | 36,331 | 88,924 | 45,974 | 42,950 |
| 5 to 9 years: | | | | | | | | | | | | | | | |
| High | 66,381 | 33,735 | 32,646 | 75,345 | 38,676 | 36,669 | 88,702 | 45,652 | 43,050 | 103,513 | 53,470 | 50,043 | 122,573 | 63,508 | 59,065 |
| Low | | | | | | | 78,945 | 40,630 | 38,315 | 79,394 | 41,011 | 38,383 | 94,871 | 49,155 | 45,716 |
| 10 to 14 years: | | | | | | | | | | | | | | | |
| High | 55,537 | 28,333 | 27,204 | 65,367 | 33,274 | 32,093 | 74,437 | 38,267 | 36,170 | 87,862 | 45,273 | 42,589 | 102,736 | 53,118 | 49,618 |
| Low | | | | | | | | | | 78,197 | 40,293 | 37,904 | 78,799 | 40,742 | 38,057 |
| 15 to 19 years: | | | | | | | | | | | | | | | |
| High | 47,737 | 24,533 | 23,204 | 54,694 | 27,936 | 26,758 | 64,529 | 32,893 | 31,636 | 73,664 | 37,911 | 35,753 | 87,129 | 44,935 | 42,194 |
| Low | | | | | | | | | | | | | 77,545 | 39,992 | 37,553 |
| 20 to 24 years | 41,276 | 21,255 | 20,021 | 46,743 | 24,050 | 22,693 | 53,680 | 27,459 | 26,221 | 63,551 | 32,434 | 31,117 | 72,765 | 37,487 | 35,278 |
| 25 to 29 years | 36,464 | 18,746 | 17,718 | 40,253 | 20,768 | 19,485 | 45,708 | 23,561 | 22,147 | 52,710 | 27,002 | 25,708 | 62,628 | 32,005 | 30,623 |
| 30 to 34 years | 32,605 | 16,816 | 15,789 | 35,344 | 18,255 | 17,089 | 39,292 | 20,321 | 18,971 | 44,835 | 23,153 | 21,682 | 51,895 | 26,627 | 25,268 |
| 35 to 39 years | 28,346 | 14,837 | 13,509 | 31,422 | 16,278 | 15,144 | 34,410 | 17,815 | 16,595 | 38,474 | 19,931 | 18,543 | 44,066 | 22,789 | 21,277 |
| 40 to 44 years | 23,790 | 12,660 | 11,130 | 27,128 | 14,241 | 12,887 | 30,457 | 15,799 | 14,658 | 33,567 | 17,393 | 16,174 | 37,680 | 19,536 | 18,144 |
| 45 to 49 years | 19,764 | 10,580 | 9,184 | 22,533 | 12,001 | 10,532 | 26,078 | 13,686 | 12,392 | 29,490 | 15,291 | 14,199 | 32,642 | 16,907 | 15,735 |
| 50 to 54 years | 16,151 | 8,640 | 7,511 | 18,414 | 9,842 | 8,572 | 21,365 | 11,354 | 10,011 | 24,934 | 13,056 | 11,878 | 28,334 | 14,659 | 13,675 |
| 55 to 59 years | 12,705 | 6,757 | 5,948 | 14,676 | 7,816 | 6,860 | 17,092 | 9,093 | 7,999 | 20,037 | 10,597 | 9,440 | 23,524 | 12,257 | 11,267 |
| 60 to 64 years | 9,489 | 4,967 | 4,522 | 11,109 | 5,865 | 5,244 | 13,170 | 6,962 | 6,208 | 15,535 | 8,199 | 7,336 | 18,345 | 9,624 | 8,721 |
| 65 to 69 years | 6,578 | 3,360 | 3,218 | 7,824 | 4,053 | 3,771 | 9,440 | 4,934 | 4,506 | 11,371 | 5,947 | 5,424 | 13,532 | 7,061 | 6,471 |
| 70 years and over | 7,862 | 3,752 | 4,110 | 9,271 | 4,525 | 4,746 | 11,239 | 5,604 | 5,635 | 13,859 | 7,007 | 6,852 | 17,731 | 8,992 | 8,739 |

Source: The high series for India was taken from *Manpower Aspects of Educational Development: National Population-Growth Perspective*, Institute of Applied Manpower Research, New Delhi, 1965. The low series was obtained by assuming that Indian fertility will decline by the same proportion as that assumed for the Series D projections for Pakistan given in U.S. Department of Commerce, Bureau of the Census, *Projections of the Population of Pakistan, by Age and Sex: 1965–1985*, by James W. Brackett and Donald S. Akers, Washington, 1965.

TABLE 4.—*Estimated and projected population of Pakistan, by age and sex: selected years, 1965–85*

[In thousands]

| Age and series | 1965 | | | 1970 | | | 1975 | | | 1980 | | | 1985 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Both sexes | Male | Female | Both sexes | Male | Female | Both sexes | Male | Female | Both sexes | Male | Female | Both sexes | Male | Female |
| All ages: | | | | | | | | | | | | | | | |
| High | 115,563 | 58,908 | 56,655 | 136,893 | 69,781 | 67,112 | 163,665 | 83,405 | 80,260 | 197,555 | 100,642 | 96,913 | 240,717 | 122,590 | 118,127 |
| Low | | | | 133,898 | 68,251 | 65,647 | 153,272 | 78,098 | 75,174 | 178,477 | 90,902 | 87,575 | 210,615 | 107,225 | 103,390 |
| Under 1 year: | | | | | | | | | | | | | | | |
| High | 5,147 | 2,631 | 2,516 | 6,160 | 3,151 | 3,009 | 7,462 | 3,819 | 3,643 | 9,204 | 4,714 | 4,490 | 11,409 | 5,846 | 5,563 |
| Low | | | | 5,046 | 2,581 | 2,465 | 5,719 | 2,927 | 2,792 | 7,164 | 3,669 | 3,495 | 8,687 | 4,451 | 4,236 |
| 1 to 4 years: | | | | | | | | | | | | | | | |
| High | 17,504 | 8,928 | 8,576 | 20,727 | 10,578 | 10,149 | 25,239 | 12,884 | 12,355 | 31,169 | 15,915 | 15,254 | 38,922 | 19,878 | 19,044 |
| Low | | | | 18,846 | 9,618 | 9,228 | 19,376 | 9,891 | 9,485 | 24,105 | 12,308 | 11,797 | 30,134 | 15,390 | 14,744 |
| 5 to 9 years: | | | | | | | | | | | | | | | |
| High | 17,224 | 8,750 | 8,474 | 21,172 | 10,791 | 10,381 | 25,338 | 12,922 | 12,416 | 31,075 | 15,852 | 15,223 | 38,684 | 19,738 | 18,946 |
| Low | | | | | | | 22,551 | 11,500 | 11,051 | 23,847 | 12,164 | 11,683 | 29,956 | 15,285 | 14,671 |
| 10 to 14 years: | | | | | | | | | | | | | | | |
| High | 14,582 | 7,419 | 7,163 | 16,924 | 8,595 | 8,329 | 20,848 | 10,623 | 10,225 | 24,997 | 12,744 | 12,253 | 30,721 | 15,667 | 15,054 |
| Low | | | | | | | | | | 22,251 | 11,344 | 10,907 | 23,576 | 12,023 | 11,553 |
| 15 to 19 years: | | | | | | | | | | | | | | | |
| High | 10,548 | 5,445 | 5,103 | 14,407 | 7,332 | 7,075 | 16,730 | 8,498 | 8,232 | 20,619 | 10,507 | 10,112 | 24,739 | 12,611 | 12,128 |
| Low | | | | | | | | | | | | | 22,020 | 11,226 | 10,794 |
| 20 to 24 years | 7,767 | 4,026 | 3,741 | 10,417 | 5,380 | 5,037 | 14,219 | 7,238 | 6,981 | 16,505 | 8,383 | 8,122 | 20,334 | 10,357 | 9,977 |
| 25 to 29 years | 7,335 | 3,809 | 3,526 | 7,659 | 3,972 | 3,687 | 10,265 | 5,302 | 4,963 | 14,000 | 7,126 | 6,874 | 16,240 | 8,244 | 7,996 |
| 30 to 34 years | 7,125 | 3,701 | 3,424 | 7,219 | 3,749 | 3,470 | 7,534 | 3,907 | 3,627 | 10,092 | 5,212 | 4,880 | 13,759 | 7,000 | 6,759 |
| 35 to 39 years | 5,705 | 2,988 | 2,717 | 6,998 | 3,635 | 3,363 | 7,088 | 3,681 | 3,407 | 7,395 | 3,834 | 3,561 | 9,902 | 5,111 | 4,791 |
| 40 to 44 years | 5,037 | 2,639 | 2,398 | 5,583 | 2,922 | 2,661 | 6,846 | 3,553 | 3,293 | 6,930 | 3,594 | 3,336 | 7,227 | 3,741 | 3,486 |
| 45 to 49 years | 4,177 | 2,184 | 1,993 | 4,892 | 2,554 | 2,338 | 5,421 | 2,827 | 2,594 | 6,645 | 3,436 | 3,209 | 6,724 | 3,475 | 3,249 |
| 50 to 54 years | 3,516 | 1,822 | 1,694 | 4,002 | 2,076 | 1,926 | 4,688 | 2,429 | 2,259 | 5,193 | 2,689 | 2,504 | 6,364 | 3,270 | 3,094 |
| 55 to 59 years | 2,850 | 1,452 | 1,398 | 3,284 | 1,677 | 1,607 | 3,742 | 1,915 | 1,827 | 4,392 | 2,248 | 2,144 | 4,870 | 2,494 | 2,376 |
| 60 to 64 years | 2,257 | 1,117 | 1,140 | 2,560 | 1,273 | 1,287 | 2,959 | 1,479 | 1,480 | 3,383 | 1,698 | 1,685 | 3,935 | 2,005 | 1,980 |
| 65 to 69 years | 1,741 | 825 | 916 | 1,903 | 909 | 994 | 2,171 | 1,045 | 1,126 | 2,525 | 1,227 | 1,298 | 2,907 | 1,423 | 1,484 |
| 70 years and over | 3,048 | 1,172 | 1,876 | 2,986 | 1,187 | 1,799 | 3,115 | 1,283 | 1,832 | 3,431 | 1,463 | 1,968 | 3,930 | 1,730 | 2,200 |

Source: Obtained by adding together data for East and West Pakistan given in U.S. Department of Commerce, Bureau of the Census, *Projections of the Populations of Pakistan, by Age and Sex: 1965–1985. A Measure of the Potential Impact of a Family Planning Program*, by James W. Brackett and Donald S. Akers, Washington, 1965, pp. 36–39 and 48–50. The high series assumes that fertility will remain constant. The low series assumes that a government sponsored family planning program will succeed in lowering fertility. Both series assume declining mortality.

TABLE 5.—*Derivation of Calorie needs*

| Age (years) | FAO | | India | | Pakistan | | Brazil | |
|---|---|---|---|---|---|---|---|---|
| | Body weight [1] (kg.) | Caloric allowance [2] kcal/kg/day | Body weight [3] (kg.) | Caloric allowance kcal/kg/day | Body weight [4] (kg.) | Caloric allowance kcal/kg/day | Body weight [5] (kg.) | Caloric allowance kcal/kg/day |
| 0 to 1 | 9 | [6] 128 | 7 | [6] 128 | 7 | [6] 128 | 7 | [6] 128 |
| 1 to 4 | 13 | 105 | 10 | 105 | 10 | 105 | 12 | 105 |
| 5 to 9 | 24 | 82 | 17 | 82 | 17 | 82 | 20 | 82 |
| 10 to 14: | | | | | | | | |
| Male | 40 | 68 | 28 | 68 | 30 | 68 | 32 | 68 |
| Female | 40 | 64 | 28 | 64 | 30 | 64 | 32 | 64 |
| 15 to 19: | | | | | | | | |
| Male | 60 | 60 | 48 | 66 | 46 | 65 | 50 | 72 |
| Female | 50 | 48 | 42 | 49 | 42 | 50 | 48 | 50 |
| 20 to 29: | | | | | | | | |
| Male | 65 | 49 | 55 | 51 | 50 | 53 | 62 | 49 |
| Female | 55 | 42 | 45 | 44 | 45 | 44 | 55 | 42 |
| 30 to 39: | | | | | | | | |
| Male | 65 | 48 | 55 | 50 | 50 | 51 | 62 | 48 |
| Female | 55 | 41 | 45 | 43 | 45 | 43 | 55 | 41 |
| 40 to 49: | | | | | | | | |
| Male | 65 | 46 | 55 | 48 | 50 | 50 | 62 | 46 |
| Female | 55 | 39 | 45 | 42 | 45 | 42 | 55 | 39 |
| 50 to 59: | | | | | | | | |
| Male | 65 | 43 | 55 | 45 | 50 | 46 | 62 | 43 |
| Female | 55 | 36 | 45 | 38 | 45 | 38 | 55 | 36 |
| 60 to 69: | | | | | | | | |
| Male | 65 | 39 | 55 | 41 | 50 | 42 | 62 | 39 |
| Female | 55 | 33 | 45 | 35 | 45 | 35 | 55 | 33 |
| 70 and up: | | | | | | | | |
| Male | 65 | 34 | 55 | 36 | 50 | 36 | 62 | 34 |
| Female | 55 | 29 | 45 | 31 | 45 | 31 | 55 | 29 |

[1] WHO Tech. Report Series No. 301, Protein Requirements.

[2] FAO Nutritional Series No. 15, Calorie Requirements.

[3] Body weights as determined in India by the Nutrition Research Laboratory.

[4] Body weights as determined in Pakistan, ICNND Nutrition Survey of East Pakistan, and personal data of Dr. Barbara Underwood.

[5] Body weights are the average weights for 7 Latin American countries listed in Table 8.

[6] Includes the FAO allowance for pregnancy and lactation.

TABLE 6.—*Caloric needs in 1965 of populations by age and sex*

WORLD—(1965) ESTIMATE OF CURRENT CALORIC NEEDS BASED ON FAO REFERENCE BODY WEIGHTS AND CALORIC NEEDS [1]

| Age (years) | Population (millions) | Body weight [2] (kilograms) | Caloric allowance [3] (Kcal per kilograms per day) | Caloric need in Kcal per day (billions) |
|---|---|---|---|---|
| 0 to 1 | 98 | 9 | [4] 128 | 113 |
| 1 to 4 | 369 | 13 | 105 | 503 |
| 5 to 9 | 416 | 24 | 82 | 819 |
| 10 to 14: | | | | |
| Male | 187 | 40 | 68 | 508 |
| Female | 180 | 40 | 64 | 463 |
| 15 to 19: | | | | |
| Male | 158 | 60 | 60 | 568 |
| Female | 151 | 50 | 48 | 363 |
| 20 to 29: | | | | |
| Male | 256 | 65 | 49 | 815 |
| Female | 246 | 55 | 42 | 569 |
| 30 to 39: | | | | |
| Male | 215 | 65 | 48 | 669 |
| Female | 210 | 55 | 41 | 474 |
| 40 to 49: | | | | |
| Male | 156 | 65 | 46 | 467 |
| Female | 162 | 55 | 39 | 347 |
| 50 to 59: | | | | |
| Male | 120 | 65 | 43 | 334 |
| Female | 127 | 55 | 36 | 252 |
| 60 to 69: | | | | |
| Male | 75 | 65 | 39 | 189 |
| Female | 86 | 55 | 33 | 156 |
| 70 up: | | | | |
| Male | 40 | 65 | 34 | 88 |
| Female | 56 | 55 | 29 | 90 |
| Sum | 3,308 | | | 7,788 |

[1] See Table 5 for information on derivation of caloric needs.
[2] WHO Tech. Report Series No. 301, Protein Requirements.
[3] FAO Nutritional Series No. 15, Calorie Requirements.
[4] Includes the FAO allowance for pregnancy and lactation.

TABLE 6.—*Caloric needs in 1965 of populations by age and sex*—Continued

INDIA—(1965) ESTIMATES OF CURRENT CALORIC NEEDS BASED ON FAO REFERENCE BODY WEIGHTS (UPPER ESTIMATE) AND ON BODY WEIGHTS AS DETERMINED IN INDIA (LOWER ESTIMATE)

| Age (years) | Population (thousands) | Body weight (kilograms) | (Upper) caloric allowance Kcal per kilogram per day | Caloric need, Kcal per day (billions) | Body weight (kilograms) | (Lower) caloric allowance, Kcal per kilogram per day | Caloric need, Kcal per day (billions) |
|---|---|---|---|---|---|---|---|
| 0 to 1 | 17,757 | 9 | 128 | 20 | 7 | 128 | 16 |
| 1 to 4 | 61,410 | 13 | 105 | 84 | 10 | 105 | 64 |
| 5 to 9 | 66,381 | 24 | 82 | 131 | 17 | 82 | 92 |
| 10 to 14: | | | | | | | |
| Male | 28,333 | 40 | 68 | 77 | 28 | 68 | 54 |
| Female | 27,204 | 40 | 64 | 70 | 28 | 64 | 49 |
| 15 to 19: | | | | | | | |
| Male | 24,533 | 60 | 60 | 88 | 48 | 66 | 78 |
| Female | 23,204 | 50 | 48 | 56 | 42 | 49 | 48 |
| 20 to 29: | | | | | | | |
| Male | 40,001 | 65 | 49 | 127 | 55 | 51 | 112 |
| Female | 37,739 | 55 | 42 | 87 | 45 | 44 | 75 |
| 30 to 39: | | | | | | | |
| Male | 31,653 | 65 | 48 | 99 | 55 | 50 | 87 |
| Female | 29,298 | 55 | 41 | 66 | 45 | 43 | 57 |
| 40 to 49: | | | | | | | |
| Male | 23,240 | 65 | 46 | 69 | 55 | 48 | 61 |
| Female | 20,314 | 55 | 39 | 44 | 45 | 42 | 38 |
| 50 to 59: | | | | | | | |
| Male | 15,397 | 65 | 43 | 43 | 55 | 45 | 38 |
| Female | 13,459 | 55 | 36 | 27 | 45 | 38 | 23 |
| 60 to 69: | | | | | | | |
| Male | 8,327 | 65 | 39 | 21 | 55 | 41 | 19 |
| Female | 7,740 | 55 | 33 | 14 | 45 | 35 | 12 |
| 70 up: | | | | | | | |
| Male | 3,752 | 65 | 34 | 8 | 55 | 36 | 7 |
| Female | 4,110 | 55 | 29 | 7 | 45 | 31 | 6 |
| Sum | 483,852 | | | 1,137 | | | 936 |
| Kcal per capita per day | | | | 2,352 | | | 1,936 |

See footnote 1 on page 96.

TABLE 6.—*Caloric needs in 1965 of populations by age and sex*—Continued

PAKISTAN—(1965) ESTIMATES OF CURRENT CALORIC NEEDS BASED ON FAO REFERENCE BODY WEIGHTS (UPPER ESTIMATE) AND ON BODY WEIGHTS AS DETERMINED IN PAKISTAN (LOWER ESTIMATE)

| Age (years) | Population (thousands) | Body weight (kilograms) | (Upper) caloric allowance Kcal per kilogram per day | Caloric need, Kcal per day (billions) | Body weight (kilograms) | (Lower) caloric allowance, Kcal per kilogram per day | Caloric need, Kcal per day (billions) |
|---|---|---|---|---|---|---|---|
| 0 to 1 | 5,147 | 9 | 128 | 6 | 7 | 128 | 5 |
| 1 to 4 | 17,503 | 13 | 105 | 24 | 10 | 105 | 18 |
| 5 to 9 | 17,224 | 24 | 82 | 34 | 17 | 82 | 24 |
| 10 to 14: | | | | | | | |
| Male | 7,419 | 40 | 68 | 20 | 30 | 68 | 15 |
| Female | 7,163 | 40 | 64 | 18 | 30 | 64 | 14 |
| 15 to 19: | | | | | | | |
| Male | 5,445 | 60 | 60 | 20 | 46 | 65 | 16 |
| Female | 5,103 | 50 | 48 | 12 | 42 | 50 | 11 |
| 20 to 29: | | | | | | | |
| Male | 7,835 | 65 | 49 | 25 | 50 | 53 | 21 |
| Female | 7,267 | 55 | 42 | 17 | 45 | 44 | 14 |
| 30 to 39: | | | | | | | |
| Male | 6,689 | 65 | 48 | 21 | 50 | 51 | 17 |
| Female | 6,141 | 55 | 41 | 14 | 45 | 43 | 12 |
| 40 to 49: | | | | | | | |
| Male | 4,823 | 65 | 46 | 14 | 50 | 50 | 12 |
| Female | 4,391 | 55 | 39 | 9 | 45 | 42 | 8 |
| 50 to 59: | | | | | | | |
| Male | 3,274 | 65 | 43 | 9 | 50 | 46 | 8 |
| Female | 3,092 | 55 | 36 | 6 | 45 | 38 | 5 |
| 60 to 69: | | | | | | | |
| Male | 1,942 | 65 | 39 | 5 | 50 | 42 | 4 |
| Female | 2,056 | 55 | 33 | 4 | 45 | 35 | 3 |
| 70 and up: | | | | | | | |
| Male | 1,172 | 65 | 34 | 3 | 50 | 36 | 2 |
| Female | 1,876 | 55 | 29 | 3 | 45 | 31 | 3 |
| Sum | 115,563 | | | 264 | | | 212 |
| Kcal per capita per day | | | | 2,284 | | | 1,836 |

See footnote 1 on page 96.

TABLE 6.—*Caloric needs in 1965 of populations by age and sex*—Continued

BRAZIL—(1965) ESTIMATES OF CURRENT CALORIC NEEDS BASED ON FAO REFERENCE BODY WEIGHTS (UPPER ESTIMATE) AND ON BODY WEIGHTS AS DETERMINED IN LATIN AMERICA (LOWER ESTIMATE)

| Age (years) | Population (thousands) | Body weight (kilograms) | (Upper) caloric allowance Kcal per kilogram per day | Caloric need, Kcal per day (billions) | Body weight (kilograms) | (Lower) caloric allowance, Kcal per kilogram per day | Caloric need, Kcal per day (billions) |
|---|---|---|---|---|---|---|---|
| 0 to 1 | 3,037 | 9 | 128 | 3 | 7 | 128 | 3 |
| 1 to 4 | 10,660 | 13 | 105 | 15 | 12 | 105 | 13 |
| 5 to 9 | 11,636 | 24 | 82 | 23 | 20 | 82 | 19 |
| 10 to 14: | | | | | | | |
| Male | 4,915 | 40 | 68 | 13 | 32 | 68 | 11 |
| Female | 4,927 | 40 | 64 | 13 | 32 | 64 | 10 |
| 15 to 19: | | | | | | | |
| Male | 4,109 | 60 | 60 | 15 | 50 | 72 | 15 |
| Female | 4,165 | 50 | 48 | 10 | 48 | 50 | 10 |
| 20 to 29: | | | | | | | |
| Male | 6,351 | 65 | 49 | 20 | 62 | 49 | 15 |
| Female | 6,435 | 55 | 42 | 15 | 55 | 42 | 19 |
| 30 to 39: | | | | | | | |
| Male | 4,726 | 65 | 48 | 15 | 62 | 48 | 14 |
| Female | 4,783 | 55 | 41 | 11 | 55 | 41 | 11 |
| 40 to 49: | | | | | | | |
| Male | 3,434 | 65 | 46 | 10 | 62 | 46 | 10 |
| Female | 3,491 | 55 | 39 | 7 | 55 | 39 | 7 |
| 50 to 59: | | | | | | | |
| Male | 2,287 | 65 | 43 | 6 | 62 | 43 | 6 |
| Female | 2,344 | 55 | 36 | 5 | 55 | 36 | 5 |
| 60 to 69: | | | | | | | |
| Male | 1,315 | 65 | 39 | 3 | 62 | 39 | 3 |
| Female | 1,407 | 55 | 33 | 3 | 55 | 33 | 3 |
| 70 and up: | | | | | | | |
| Male | 583 | 65 | 34 | 1 | 62 | 34 | 1 |
| Female | 696 | 55 | 29 | 1 | 55 | 29 | 1 |
| Sum | 81,301 | | | 189 | | | 176 |
| Kcal per capita per day | | | | 2,330 | | | 2,164 |

See footnote 1 on page 96.

TABLE 7.—*Caloric needs in 1970 by age and sex*

WORLD (1970) PROJECTION OF CALORIC NEEDS FOR HIGH AND LOW ESTIMATES OF POPULATION GROWTH [1]

| Age (years) | Body weight (kilograms) | Caloric allowance (Kcal per kilogram per day) | Population (upper level) (millions) | Caloric need Kcal per day (billions) | Population (lower level) (millions) | Caloric need Kcal per day (billions) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 128 | 109 | 126 | 100 | 116 |
| 1 to 4 | 13 | 105 | 380 | 519 | 364 | 498 |
| 5 to 9 | 24 | 82 | 445 | 876 | 445 | 876 |
| 10 to 14: | | | | | | |
| Male | 40 | 68 | 207 | 564 | 207 | 564 |
| Female | 40 | 64 | 200 | 514 | 200 | 514 |
| 15 to 19: | | | | | | |
| Male | 60 | 60 | 183 | 661 | 183 | 661 |
| Female | 50 | 48 | 178 | 426 | 178 | 426 |
| 20 to 29: | | | | | | |
| Male | 65 | 49 | 283 | 902 | 283 | 902 |
| Female | 55 | 42 | 272 | 628 | 272 | 628 |
| 30 to 39: | | | | | | |
| Male | 65 | 48 | 230 | 718 | 230 | 718 |
| Female | 55 | 41 | 223 | 502 | 223 | 502 |
| 40 to 49: | | | | | | |
| Male | 65 | 46 | 180 | 537 | 180 | 537 |
| Female | 55 | 39 | 183 | 392 | 183 | 392 |
| 50 to 59: | | | | | | |
| Male | 65 | 43 | 125 | 349 | 125 | 349 |
| Female | 55 | 36 | 134 | 265 | 134 | 265 |
| 60 to 69: | | | | | | |
| Male | 65 | 39 | 85 | 215 | 85 | 215 |
| Female | 55 | 33 | 96 | 174 | 96 | 174 |
| 70 and up: | | | | | | |
| Male | 65 | 34 | 46 | 101 | 46 | 101 |
| Female | 55 | 29 | 65 | 103 | 65 | 103 |
| Sum | | | 3,624 | 8,572 | 3,599 | 8,541 |
| Kcal per capita per day | | | | 2,366 | | 2,373 |

[1] See Table 6 for sources of data and additional information.

TABLE 7.—*Caloric needs in 1970 by age and sex*—Continued

INDIA—(1970) PROJECTION OF CALORIC NEEDS FOR HIGH AND LOW ESTIMATES OF POPULATION GROWTH

| Age (years) | Body weight (kilograms) | Caloric allowance (Kcal per kilogram per day) | Population (upper level) (thousands) | Caloric need Kcal per day (billions) | Population (lower level) (thousands) | Caloric need Kcal per day (billions) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 128 | 20,990 | 24 | 17,190 | 20 |
| 1 to 4 | 13 | 105 | 71,258 | 97 | 64,773 | 88 |
| 5 to 9 | 24 | 82 | 75,345 | 148 | 75,345 | 148 |
| 10 to 14: | | | | | | |
| Male | 40 | 68 | 33,274 | 91 | 33,274 | 91 |
| Female | 40 | 64 | 32,093 | 82 | 32,093 | 82 |
| 15 to 19: | | | | | | |
| Male | 48 | 66 | 27,936 | 89 | 27,936 | 89 |
| Female | 42 | 49 | 26,758 | 55 | 26,758 | 55 |
| 20 to 29: | | | | | | |
| Male | 55 | 51 | 44,818 | 126 | 44,818 | 126 |
| Female | 45 | 44 | 42,178 | 84 | 42,178 | 84 |
| 30 to 39: | | | | | | |
| Male | 55 | 50 | 34,533 | 95 | 34,533 | 95 |
| Female | 45 | 43 | 32,233 | 62 | 32,233 | 62 |
| 40 to 49: | | | | | | |
| Male | 55 | 48 | 26,242 | 69 | 26,242 | 69 |
| Female | 45 | 42 | 23,419 | 44 | 23,419 | 44 |
| 50 to 59: | | | | | | |
| Male | 55 | 45 | 17,658 | 44 | 17,658 | 44 |
| Female | 45 | 38 | 15,432 | 26 | 15,432 | 26 |
| 60 to 69: | | | | | | |
| Male | 55 | 41 | 9,918 | 22 | 9,918 | 22 |
| Female | 45 | 35 | 9,015 | 14 | 9,015 | 14 |
| 70 and up: | | | | | | |
| Male | 55 | 36 | 4,525 | 9 | 4,525 | 9 |
| Female | 45 | 31 | 4,746 | 7 | 4,746 | 7 |
| Sum | | | 552,371 | 1,188 | 542,086 | 1,175 |
| Kcal per capita per day | | | | | | |

[1] See Table 6 for sources of data and other additional information.

TABLE 7.—*Caloric needs in 1970 by age and sex*—Continued

PAKISTAN—(1970) PROJECTION OF CALORIC NEEDS FOR HIGH AND LOW ESTIMATES OF POPULATION GROWTH

| Age (years) | Body weight (kilograms) | Caloric allowance (Kcal per kilogram per day) | Population (upper level) (thousands) | Caloric need Kcal per day (billions) | Population (lower level) (thousands) | Caloric need Kcal per day (billions) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 128 | 6,160 | 7 | 5,046 | 6 |
| 1 to 4 | 13 | 105 | 20,728 | 28 | 18,846 | 26 |
| 5 to 9 | 24 | 82 | 21,173 | 42 | 21,172 | 42 |
| 10 to 14: | | | | | | |
| Male | 40 | 68 | 8,595 | 23 | 8,595 | 23 |
| Female | 40 | 64 | 8,329 | 21 | 8,329 | 21 |
| 15 to 19: | | | | | | |
| Male | 46 | 65 | 7,332 | 22 | 7,332 | 22 |
| Female | 42 | 50 | 7,075 | 15 | 7,075 | 15 |
| 20 to 29: | | | | | | |
| Male | 50 | 53 | 9,352 | 25 | 9,352 | 25 |
| Female | 45 | 44 | 8,724 | 17 | 8,724 | 17 |
| 30 to 39: | | | | | | |
| Male | 50 | 51 | 7,384 | 19 | 7,384 | 19 |
| Female | 45 | 43 | 6,833 | 13 | 6,833 | 13 |
| 40 to 49: | | | | | | |
| Male | 50 | 50 | 5,476 | 14 | 5,476 | 14 |
| Female | 45 | 42 | 4,999 | 9 | 4,999 | 9 |
| 50 to 59: | | | | | | |
| Male | 50 | 46 | 3,753 | 9 | 3,753 | 9 |
| Female | 45 | 38 | 3,533 | 6 | 3,533 | 6 |
| 60 to 69: | | | | | | |
| Male | 50 | 42 | 2,182 | 5 | 2,182 | 5 |
| Female | 45 | 35 | 2,281 | 4 | 2,281 | 4 |
| 70 and up: | | | | | | |
| Male | 50 | 36 | 1,187 | 2 | 1,187 | 2 |
| Female | 45 | 31 | 1,799 | 2 | 1,799 | 2 |
| Sum | | | 136,895 | 283 | 133,898 | 279 |
| Kcal per capita per day | | | | 2,356 | | 2,388 |

[1] See Table 6 for sources of data and other additional information.

TABLE 7.—*Caloric needs in 1970 by age and sex*—Continued

BRAZIL—(1970) PROJECTION OF CALORIC NEEDS FOR HIGH AND LOW ESTIMATES OF POPULATION GROWTH

| Age (years) | Body weight (kilograms) | Caloric allowance (Kcal per kilogram per day) | Population (upper level) (thousands) | Caloric need Kcal per day (billions) | Population (lower level) (thousands) | Caloric need Kcal per day (billions) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 128 | 3,508 | 4 | 3,227 | 4 |
| 1 to 4 | 13 | 105 | 12,342 | 17 | 11,959 | 16 |
| 5 to 9 | 24 | 82 | 13,171 | 26 | 13,171 | 26 |
| 10 to 14: | | | | | | |
| Male | 40 | 68 | 5,799 | 16 | 5,799 | 16 |
| Female | 40 | 64 | 5,711 | 15 | 5,711 | 15 |
| 15 to 19: | | | | | | |
| Male | 50 | 72 | 4,856 | 17 | 4,856 | 17 |
| Female | 48 | 50 | 4,867 | 12 | 4,867 | 12 |
| 20 to 29: | | | | | | |
| Male | 62 | 49 | 7,394 | 22 | 7,394 | 22 |
| Female | 55 | 42 | 7,501 | 17 | 7,501 | 17 |
| 30 to 40: | | | | | | |
| Male | 62 | 48 | 5,317 | 16 | 5,317 | 16 |
| Female | 55 | 41 | 5,421 | 12 | 5,421 | 12 |
| 40 to 49: | | | | | | |
| Male | 62 | 46 | 3,907 | 11 | 3,907 | 11 |
| Female | 55 | 39 | 3,955 | 8 | 3,955 | 8 |
| 50 to 59: | | | | | | |
| Male | 62 | 43 | 2,655 | 7 | 2,655 | 7 |
| Female | 55 | 36 | 2,749 | 5 | 2,749 | 5 |
| 60 to 69: | | | | | | |
| Male | 62 | 39 | 1,544 | 4 | 1,544 | 4 |
| Female | 55 | 33 | 1,660 | 3 | 1,660 | 3 |
| 70 and up: | | | | | | |
| Male | 62 | 34 | 737 | 2 | 737 | 2 |
| Female | 55 | 29 | 876 | 1 | 876 | 1 |
| Sum | | | 93,970 | 215 | 93,306 | 214 |
| Kcal per capita per day | | | | 2,202 | | 2,241 |

[1] See Table 6 for sources of data and other additional information.

TABLE 8.—*Caloric needs in 1975 by age and sex*

WORLD—(1975) PROJECTION OF CALORIC NEEDS FOR HIGH AND LOW ESTIMATES OF POPULATION GROWTH [1]

| Age (years) | Body weight (kilograms) | Caloric allowance (Kcal per kilogram per day) | Population (upper level) (millions) | Caloric need Kcal per day (billions) | Population (lower level) (millions) | Caloric need Kcal per day (billions) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 128 | 123 | 142 | 106 | 122 |
| 1 to 4 | 13 | 105 | 437 | 597 | 384 | 525 |
| 5 to 9 | 24 | 82 | 468 | 921 | 445 | 875 |
| 10 to 14: | | | | | | |
| Male | 40 | 68 | 223 | 607 | 223 | 607 |
| Female | 40 | 64 | 215 | 549 | 215 | 549 |
| 15 to 19: | | | | | | |
| Male | 60 | 60 | 205 | 738 | 205 | 738 |
| Female | 50 | 48 | 198 | 475 | 198 | 475 |
| 20 to 29: | | | | | | |
| Male | 65 | 49 | 332 | 1,055 | 331 | 1,055 |
| Female | 55 | 42 | 319 | 738 | 319 | 738 |
| 30 to 39: | | | | | | |
| Male | 65 | 48 | 243 | 760 | 243 | 760 |
| Female | 55 | 41 | 235 | 529 | 235 | 529 |
| 40 to 49: | | | | | | |
| Male | 65 | 46 | 200 | 597 | 200 | 597 |
| Female | 55 | 39 | 197 | 423 | 197 | 423 |
| 50 to 59: | | | | | | |
| Male | 65 | 43 | 138 | 384 | 138 | 384 |
| Female | 55 | 36 | 147 | 292 | 147 | 292 |
| 60 to 69: | | | | | | |
| Male | 65 | 39 | 92 | 234 | 92 | 234 |
| Female | 55 | 33 | 106 | 192 | 106 | 192 |
| 70 and up: | | | | | | |
| Male | 65 | 34 | 53 | 117 | 53 | 117 |
| Female | 55 | 29 | 74 | 118 | 74 | 118 |
| Sum | | | 4,005 | 9,468 | 3,911 | 9,330 |
| Kcal per capita per day | | | | 2,364 | | 2,385 |

[1] See Table 6 for sources of data and other additional information.

TABLE 8.—*Caloric needs in 1975 by age and sex*—Continued

INDIA—(1975) PROJECTION OF CALORIC NEEDS FOR HIGH AND LOW ESTIMATES OF POPULATION GROWTH

| Age (years) | Body weight (kilograms) | Caloric allowance (Kcal per kilogram per day) | Population (upper level) (thousands) | Caloric need Kcal per day (billions) | Population (lower level) (thousands) | Caloric need Kcal per day (billions) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 128 | 24,179 | 28 | 18,521 | 21 |
| 1 to 4 | 13 | 105 | 82,505 | 113 | 63,364 | 86 |
| 5 to 9 | 24 | 82 | 88,702 | 175 | 78,945 | 155 |
| 10 to 14: | | | | | | |
| Male | 40 | 68 | 38,267 | 104 | 38,267 | 104 |
| Female | 40 | 64 | 36,170 | 93 | 36,170 | 93 |
| 15 to 19: | | | | | | |
| Male | 52 | 63 | 32,893 | 108 | 32,893 | 108 |
| Female | 45 | 48 | 31,636 | 68 | 31,636 | 68 |
| 20 to 29: | | | | | | |
| Male | 58 | 50 | 51,020 | 148 | 51,020 | 148 |
| Female | 48 | 44 | 48,368 | 102 | 48,368 | 102 |
| 30 to 39: | | | | | | |
| Male | 58 | 49 | 38,136 | 108 | 38,136 | 108 |
| Female | 48 | 43 | 35,566 | 73 | 35,566 | 73 |
| 40 to 49: | | | | | | |
| Male | 58 | 47 | 29,485 | 80 | 29,485 | 80 |
| Female | 48 | 41 | 27,050 | 53 | 27,050 | 53 |
| 50 to 59: | | | | | | |
| Male | 58 | 44 | 20,447 | 52 | 20,447 | 52 |
| Female | 48 | 38 | 18,010 | 33 | 18,010 | 33 |
| 60 to 69: | | | | | | |
| Male | 58 | 40 | 11,896 | 28 | 11,896 | 28 |
| Female | 48 | 35 | 10,714 | 18 | 10,714 | 18 |
| 70 and up: | | | | | | |
| Male | 58 | 35 | 5,604 | 11 | 5,604 | 11 |
| Female | 48 | 31 | 5,635 | 8 | 5,635 | 8 |
| Sum | | | 636,283 | 1,403 | 601,727 | 1,349 |
| Kcal per capita per day | | | | 2,206 | | 2,247 |

[1] See Table 6 for sources of data and other additional information.

TABLE 8.—*Caloric needs in 1975 by age and sex*—Continued

PAKISTAN—(1975) PROJECTION OF CALORIC NEEDS FOR HIGH AND LOW ESTIMATES OF POPULATION GROWTH

| Age (years) | Body weight (kilograms) | Caloric allowance (Kcal per kilogram per day) | Population (upper level) (thousands) | Caloric need Kcal per day (billions) | Population (lower level) (thousands) | Caloric need Kcal per day (billions) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 128 | 7,463 | 9 | 5,719 | 7 |
| 1 to 4 | 13 | 105 | 25,239 | 34 | 19,376 | 26 |
| 5 to 9 | 24 | 82 | 25,338 | 50 | 22,551 | 44 |
| 10 to 14: | | | | | | |
| Male | 40 | 68 | 10,623 | 29 | 10,623 | 29 |
| Female | 40 | 64 | 10,225 | 26 | 10,225 | 26 |
| 15 to 19: | | | | | | |
| Male | 50 | 63 | 8,498 | 27 | 8,498 | 27 |
| Female | 46 | 48 | 8,232 | 18 | 8,232 | 18 |
| 20 to 29: | | | | | | |
| Male | 53 | 52 | 12,540 | 35 | 12,540 | 35 |
| Female | 48 | 44 | 11,944 | 25 | 11,944 | 25 |
| 30 to 40: | | | | | | |
| Male | 53 | 51 | 7,588 | 21 | 7,588 | 21 |
| Female | 48 | 43 | 7,034 | 15 | 7,034 | 15 |
| 40 to 49: | | | | | | |
| Male | 53 | 49 | 6,380 | 17 | 6,380 | 17 |
| Female | 48 | 41 | 5,887 | 12 | 5,887 | 12 |
| 50 to 59: | | | | | | |
| Male | 53 | 46 | 4,344 | 11 | 4,344 | 11 |
| Female | 48 | 38 | 4,086 | 7 | 4,086 | 7 |
| 60 to 69: | | | | | | |
| Male | 53 | 42 | 2,524 | 6 | 2,524 | 6 |
| Female | 48 | 35 | 2,606 | 4 | 2,606 | 4 |
| 70 and up: | | | | | | |
| Male | 53 | 36 | 1,283 | 2 | 1,283 | 2 |
| Female | 48 | 31 | 1,832 | 2 | 1,832 | 2 |
| Sum | | | 163,665 | 351 | 153,272 | 335 |
| Kcal per capita per day | | | | 2,133 | | 2,177 |

[1] See Table 6 for sources of data and other additional information.

TABLE 8.—*Caloric needs in 1975 by age and sex*—Continued

BRAZIL—(1975) PROJECTION OF CALORIC NEEDS FOR HIGH AND LOW ESTIMATES OF POPULATION GROWTH

| Age (years) | Body weight (kilograms) | Caloric allowance (Kcal per kilogram per day) | Population (upper level) (thousands) | Caloric need Kcal per day (billions) | Population (lower level) (thousands) | Caloric need Kcal per day (billions) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 128 | 4,116 | 5 | 3,581 | 4 |
| 1 to 4 | 13 | 105 | 14,547 | 20 | 12,978 | 18 |
| 5 to 9 | 24 | 82 | 15,337 | 30 | 14,702 | 29 |
| 10 to 14: | | | | | | |
| Male | 40 | 68 | 6,601 | 18 | 6,601 | 18 |
| Female | 40 | 64 | 6,452 | 16 | 6,452 | 16 |
| 15 to 19: | | | | | | |
| Male | 57 | 63 | 5,739 | 21 | 5,739 | 21 |
| Female | 52 | 48 | 5,653 | 14 | 5,653 | 14 |
| 20 to 29: | | | | | | |
| Male | 65 | 49 | 8,723 | 28 | 8,723 | 28 |
| Female | 58 | 41 | 8,808 | 21 | 8,808 | 21 |
| 30 to 39: | | | | | | |
| Male | 65 | 48 | 6,069 | 19 | 6,069 | 19 |
| Female | 58 | 40 | 6,166 | 14 | 6,166 | 14 |
| 40 to 49: | | | | | | |
| Male | 65 | 46 | 4,449 | 13 | 4,449 | 13 |
| Female | 58 | 38 | 4,539 | 10 | 4,539 | 10 |
| 50 to 59: | | | | | | |
| Male | 65 | 43 | 3,075 | 9 | 3,075 | 9 |
| Female | 58 | 35 | 3,206 | 7 | 3,206 | 7 |
| 60 to 69: | | | | | | |
| Male | 65 | 39 | 1,816 | 5 | 1,816 | 5 |
| Female | 58 | 32 | 1,968 | 4 | 1,968 | 4 |
| 70 and up: | | | | | | |
| Male | 65 | 34 | 914 | 2 | 914 | 2 |
| Female | 58 | 28 | 1,088 | 2 | 1,088 | 2 |
| Sum | | | 109,267 | 259 | 106,527 | 255 |
| Kcal per capita per day | | | | 2,346 | | 2,369 |

[1] See Table 6 for sources of data and additional information.

TABLE 9.—*Caloric needs in 1980 by age and sex*

WORLD—(1980) PROJECTION OF CALORIC NEEDS FOR HIGH AND LOW ESTIMATES OF POPULATION GROWTH [1]

| Age (years) | Body weight (kilograms) | Caloric allowance (Kcal per kilogram per day) | Population (upper level) (millions) | Caloric need Kcal per day (billions) | Population (lower level) (millions) | Caloric need Kcal per day (billions) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 128 | 147 | 170 | 119 | 137 |
| 1 to 4 | 13 | 105 | 496 | 678 | 412 | 562 |
| 5 to 9 | 24 | 82 | 539 | 1,062 | 472 | 929 |
| 10 to 14: | | | | | | |
| Male | 40 | 68 | 237 | 644 | 225 | 612 |
| Female | 40 | 64 | 227 | 580 | 215 | 551 |
| 15 to 19: | | | | | | |
| Male | 60 | 60 | 221 | 797 | 221 | 797 |
| Female | 50 | 48 | 213 | 511 | 213 | 511 |
| 20 to 29: | | | | | | |
| Male | 65 | 49 | 379 | 1,207 | 379 | 1,207 |
| Female | 55 | 42 | 367 | 847 | 367 | 847 |
| 30 to 39: | | | | | | |
| Male | 65 | 48 | 271 | 847 | 271 | 847 |
| Female | 55 | 41 | 261 | 588 | 261 | 588 |
| 40 to 49: | | | | | | |
| Male | 65 | 46 | 216 | 646 | 216 | 646 |
| Female | 55 | 39 | 211 | 453 | 211 | 453 |
| 50 to 59: | | | | | | |
| Male | 65 | 43 | 160 | 447 | 160 | 447 |
| Female | 55 | 36 | 168 | 332 | 168 | 332 |
| 60 to 69: | | | | | | |
| Male | 65 | 39 | 97 | 246 | 97 | 246 |
| Female | 55 | 33 | 112 | 203 | 112 | 203 |
| 70 and up: | | | | | | |
| Male | 65 | 34 | 61 | 134 | 61 | 134 |
| Female | 55 | 29 | 84 | 133 | 84 | 133 |
| Sum | | | 4,467 | 10,525 | 4,264 | 10,182 |
| Kcal per capita per day | | | | 2,356 | | 2,388 |

[1] See Table 6 for sources of data and other additional information.

TABLE 9.—*Caloric needs in 1980 by age and sex*—Continued

INDIA—(1980) PROJECTION OF CALORIC NEEDS FOR HIGH AND LOW ESTIMATES OF POPULATION GROWTH

| Age (years) | Body weight (kilograms) | Caloric allowance (Kcal per kilogram per day) | Population (upper level) (thousands) | Caloric need Kcal per day (billions) | Population (lower level) (thousands) | Caloric need Kcal per day (billions) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 128 | 28,296 | 33 | 22,015 | 23 |
| 1 to 4 | 13 | 105 | 97,113 | 133 | 75,068 | 103 |
| 5 to 9 | 24 | 82 | 103,513 | 214 | 79,394 | 156 |
| 10 to 14: | | | | | | |
| Male | 40 | 68 | 45,273 | 123 | 40,293 | 110 |
| Female | 40 | 64 | 42,589 | 109 | 37,904 | 97 |
| 15 to 19: | | | | | | |
| Male | 52 | 63 | 37,911 | 124 | 37,911 | 124 |
| Female | 45 | 48 | 35,753 | 77 | 35,753 | 77 |
| 20 to 29: | | | | | | |
| Male | 58 | 50 | 59,436 | 172 | 59,436 | 172 |
| Female | 48 | 44 | 56,825 | 120 | 56,825 | 120 |
| 30 to 39: | | | | | | |
| Male | 58 | 49 | 43,084 | 122 | 43,084 | 122 |
| Female | 48 | 43 | 40,225 | 83 | 40,225 | 83 |
| 40 to 49: | | | | | | |
| Male | 58 | 47 | 32,684 | 89 | 32,684 | 89 |
| Female | 48 | 41 | 30,373 | 60 | 30,373 | 60 |
| 50 to 59: | | | | | | |
| Male | 58 | 44 | 23,653 | 60 | 23,653 | 60 |
| Female | 48 | 38 | 21,318 | 39 | 21,318 | 39 |
| 60 to 69: | | | | | | |
| Male | 58 | 40 | 14,146 | 33 | 14,146 | 33 |
| Female | 48 | 35 | 12,760 | 21 | 12,760 | 21 |
| 70 and up: | | | | | | |
| Male | 58 | 35 | 7,007 | 14 | 7,007 | 14 |
| Female | 48 | 31 | 6,852 | 10 | 6,852 | 10 |
| Sum | | | 738,811 | 1,633 | 676,701 | 1,515 |
| Kcal per capita per day | | | | 2,202 | | 2,241 |

[1] See Table 6 for sources of data and other additional information.

TABLE 9.—*Caloric needs in 1980 by age and sex*—Continued

PAKISTAN—(1980) PROJECTION OF CALORIC NEEDS FOR HIGH AND LOW ESTIMATES OF POPULATION GROWTH

| Age (years) | Body weight (kilograms) | Caloric allowance (Kcal per kilogram per day) | Population (upper level) (thousands) | Caloric need Kcal per day (billions) | Population (lower level) (thousands) | Caloric need Kcal per day (billions) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 128 | 9,204 | 11 | 7,163 | 8 |
| 1 to 4 | 13 | 105 | 31,169 | 43 | 24,105 | 33 |
| 5 to 9 | 24 | 82 | 31,075 | 61 | 23,848 | 47 |
| 10 to 14: | | | | | | |
| Male | 40 | 68 | 12,744 | 35 | 11,344 | 31 |
| Female | 40 | 64 | 12,253 | 31 | 10,907 | 28 |
| 15 to 19: | | | | | | |
| Male | 50 | 63 | 10,507 | 33 | 10,507 | 33 |
| Female | 46 | 48 | 10,112 | 22 | 10,112 | 22 |
| 20 to 29: | | | | | | |
| Male | 53 | 52 | 15,509 | 43 | 15,509 | 43 |
| Female | 48 | 44 | 14,996 | 32 | 14,996 | 32 |
| 30 to 39: | | | | | | |
| Male | 53 | 51 | 9,046 | 24 | 9,046 | 24 |
| Female | 48 | 43 | 8,441 | 17 | 8,441 | 17 |
| 40 to 49: | | | | | | |
| Male | 53 | 49 | 7,030 | 18 | 7,030 | 18 |
| Female | 48 | 41 | 6,545 | 13 | 6,545 | 13 |
| 50 to 59: | | | | | | |
| Male | 53 | 46 | 4,937 | 12 | 4,937 | 12 |
| Female | 48 | 38 | 4,648 | 8 | 4,648 | 8 |
| 60 to 69: | | | | | | |
| Male | 53 | 42 | 2,925 | 7 | 2,925 | 7 |
| Female | 48 | 35 | 2,983 | 5 | 2,983 | 5 |
| 70 and up: | | | | | | |
| Male | 53 | 36 | 1,463 | 3 | 1,463 | 3 |
| Female | 48 | 31 | 1,968 | 3 | 1,968 | 3 |
| Sum | | | 197,555 | 421 | 178,477 | 387 |
| Kcal per capita per day | | | | 2,131 | | 2,171 |

[1] See Table 6 for sources of data and other additional information.

TABLE 9.—*Caloric needs in 1980 by age and sex*—Continued

BRAZIL—(1980) PROJECTION OF CALORIC NEEDS FOR HIGH AND LOW ESTIMATES OF POPULATION GROWTH

| Age (years) | Body weight (kilograms) | Caloric allowance (Kcal per kilogram per day) | Population (upper level) (thousands) | Caloric need Kcal per day (billions) | Population (lower level) (thousands) | Caloric need Kcal per day (billions) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 128 | 4,838 | 6 | 3,967 | 5 |
| 1 to 4 | 13 | 105 | 17,248 | 24 | 14,565 | 20 |
| 5 to 9 | 24 | 82 | 18,170 | 36 | 16,125 | 32 |
| 10 to 14: | | | | | | |
| Male | 40 | 68 | 7,756 | 21 | 7,434 | 20 |
| Female | 40 | 64 | 7,467 | 19 | 7,158 | 19 |
| 15 to 19: | | | | | | |
| Male | 57 | 63 | 6,541 | 24 | 6,541 | 24 |
| Female | 52 | 48 | 6,398 | 16 | 6,398 | 16 |
| 20 to 29: | | | | | | |
| Male | 65 | 49 | 10,348 | 33 | 10,348 | 33 |
| Female | 58 | 41 | 10,303 | 25 | 10,303 | 25 |
| 30 to 39: | | | | | | |
| Male | 65 | 48 | 7,110 | 22 | 7,110 | 22 |
| Female | 58 | 40 | 7,238 | 17 | 7,238 | 17 |
| 40 to 49: | | | | | | |
| Male | 65 | 46 | 5,043 | 15 | 5,043 | 15 |
| Female | 58 | 38 | 5,181 | 11 | 5,181 | 11 |
| 50 to 59: | | | | | | |
| Male | 65 | 43 | 3,533 | 10 | 3,533 | 10 |
| Female | 58 | 35 | 3,664 | 7 | 3,664 | 7 |
| 60 to 69: | | | | | | |
| Male | 65 | 39 | 2,139 | 5 | 2,139 | 5 |
| Female | 58 | 32 | 2,341 | 4 | 2,341 | 4 |
| 70 and up: | | | | | | |
| Male | 65 | 34 | 1,116 | 2 | 1,116 | 2 |
| Female | 58 | 28 | 1,336 | 2 | 1,336 | 2 |
| Sum | | | 127,770 | 299 | 121,540 | 289 |
| Kcal per capita per day | | | | 2,342 | | 2,376 |

[1] See Table 6 for source of data and additional information.

TABLE 10.—*Caloric needs in 1985 by age and sex*

WORLD—(1985) PROJECTION OF CALORIC NEEDS FOR HIGH AND LOW ESTIMATES OF POPULATION GROWTH[1]

| Age (years) | Body weight (kilograms) | Caloric allowance (Kcal per kilogram per day) | Population (upper level) (millions) | Caloric need Kcal per day (billions) | Population (lower level) (millions) | Caloric need Kcal per day (billions) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 128 | 162 | 186 | 116 | 134 |
| 1 to 4 | 13 | 105 | 580 | 792 | 440 | 601 |
| 5 to 9 | 24 | 82 | 624 | 1,227 | 514 | 1,013 |
| 10 to 14: | | | | | | |
| Male | 40 | 68 | 274 | 746 | 240 | 652 |
| Female | 40 | 64 | 263 | 672 | 230 | 588 |
| 15 to 19: | | | | | | |
| Male | 60 | 60 | 236 | 851 | 225 | 808 |
| Female | 50 | 48 | 226 | 542 | 215 | 515 |
| 20 to 29: | | | | | | |
| Male | 65 | 49 | 419 | 1,335 | 419 | 1,335 |
| Female | 55 | 42 | 404 | 933 | 404 | 933 |
| 30 to 39: | | | | | | |
| Male | 65 | 48 | 321 | 1,001 | 321 | 1,001 |
| Female | 55 | 41 | 309 | 698 | 309 | 698 |
| 40 to 49: | | | | | | |
| Male | 65 | 46 | 231 | 692 | 231 | 692 |
| Female | 55 | 39 | 225 | 481 | 225 | 482 |
| 50 to 59: | | | | | | |
| Male | 65 | 43 | 180 | 502 | 180 | 502 |
| Female | 55 | 36 | 183 | 362 | 183 | 362 |
| 60 to 69: | | | | | | |
| Male | 65 | 39 | 109 | 276 | 109 | 276 |
| Female | 55 | 33 | 124 | 226 | 124 | 226 |
| 70 and up: | | | | | | |
| Male | 65 | 34 | 68 | 151 | 68 | 151 |
| Female | 55 | 29 | 94 | 150 | 94 | 150 |
| Sum | | | 5,032 | 11,824 | 4,647 | 11,118 |
| Kcal per capita per day | | | | 2,350 | | 2,393 |

[1] See Table 6 for sources of data and other additional information.

TABLE 10.—*Caloric needs in 1985 by age and sex*—Continued

INDIA—(1985) PROJECTION OF CALORIC NEEDS FOR HIGH AND LOW ESTIMATES OF POPULATION GROWTH

| Age (years) | Body weight (kilograms) | Caloric allowance Kcal per kilogram per day | Population (upper level) (thousands) | Caloric need Kcal per day (billions) | Population (lower level) (thousands) | Caloric need Kcal per day (billions) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 128 | 33,253 | 38 | 25,305 | 29 |
| 1 to 4 | 13 | 105 | 114,889 | 157 | 88,924 | 121 |
| 5 to 9 | 24 | 82 | 122,573 | 241 | 94,871 | 187 |
| 10 to 14: | | | | | | |
| Male | 40 | 68 | 53,118 | 145 | 40,742 | 111 |
| Female | 40 | 64 | 49,618 | 127 | 38,057 | 97 |
| 15 to 19: | | | | | | |
| Male | 55 | 63 | 44,935 | 156 | 39,992 | 139 |
| Female | 47 | 48 | 42,194 | 95 | 37,553 | 85 |
| 20 to 29: | | | | | | |
| Male | 61 | 50 | 69,492 | 212 | 69,492 | 212 |
| Female | 51 | 43 | 65,901 | 145 | 65,901 | 145 |
| 30 to 39: | | | | | | |
| Male | 61 | 49 | 49,416 | 148 | 49,416 | 148 |
| Female | 51 | 42 | 46,545 | 100 | 46,545 | 100 |
| 40 to 49: | | | | | | |
| Male | 61 | 47 | 36,443 | 104 | 36,443 | 104 |
| Female | 51 | 40 | 33,879 | 69 | 33,879 | 69 |
| 50 to 59: | | | | | | |
| Male | 51 | 44 | 26,916 | 72 | 26,916 | 72 |
| Female | 51 | 37 | 24,942 | 47 | 24,942 | 47 |
| 60 to 69: | | | | | | |
| Male | 61 | 40 | 16,685 | 41 | 16,685 | 41 |
| Female | 51 | 34 | 15,192 | 26 | 15,192 | 26 |
| 70 and up: | | | | | | |
| Male | 61 | 35 | 8,992 | 19 | 8,992 | 19 |
| Female | 51 | 30 | 8,739 | 13 | 8,739 | 13 |
| Sum | | | 863,722 | 1,955 | 768,586 | 1,765 |
| Kcal per capita per day | | | | 2,263 | | 2,295 |

[1] See Table 6 for sources of data and other additional information.

TABLE 10.—*Caloric needs in 1985 by age and sex*—Continued

PAKISTAN—(1985) PROJECTION OF CALORIC NEEDS FOR HIGH AND LOW ESTIMATES OF POPULATION GROWTH

| Age (years) | Body weight (kilograms) | Caloric allowance Kcal per kilogram per day | Population (upper level) (thousands) | Caloric need Kcal per day (billions) | Population (lower level) (thousands) | Caloric need Kcal per day (billions) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 128 | 11,409 | 13 | 8,686 | 10 |
| 1 to 4 | 13 | 105 | 38,923 | 53 | 30,134 | 41 |
| 5 to 9 | 24 | 82 | 38,683 | 76 | 29,957 | 59 |
| 10 to 14: | | | | | | |
| Male | 40 | 68 | 15,667 | 43 | 12,023 | 33 |
| Female | 40 | 64 | 15,054 | 39 | 11,553 | 30 |
| 15 to 19: | | | | | | |
| Male | 52 | 63 | 12,611 | 41 | 11,226 | 37 |
| Female | 48 | 48 | 12,128 | 28 | 10,794 | 25 |
| 20 to 29: | | | | | | |
| Male | 56 | 51 | 18,601 | 53 | 18,601 | 53 |
| Female | 51 | 43 | 17,973 | 39 | 17,973 | 39 |
| 30 to 39: | | | | | | |
| Male | 56 | 50 | 12,111 | 34 | 12,111 | 34 |
| Female | 51 | 42 | 11,550 | 25 | 11,550 | 25 |
| 40 to 49: | | | | | | |
| Male | 56 | 48 | 7,216 | 19 | 7,216 | 19 |
| Female | 51 | 40 | 6,735 | 14 | 6,735 | 14 |
| 50 to 59: | | | | | | |
| Male | 56 | 45 | 5,764 | 15 | 5,764 | 15 |
| Female | 51 | 37 | 5,470 | 10 | 5,470 | 10 |
| 60 to 69: | | | | | | |
| Male | 56 | 41 | 3,428 | 8 | 3,428 | 8 |
| Female | 51 | 34 | 3,464 | 6 | 3,464 | 6 |
| 70 and up: | | | | | | |
| Male | 56 | 36 | 1,730 | 4 | 1,730 | 4 |
| Female | 51 | 30 | 2,200 | 3 | 2,200 | 3 |
| Sum | | | 240,717 | 523 | 210,615 | 465 |
| Kcal per capita per day | | | | 2,171 | | 2,203 |

[1] See Table 6 for sources of data and other additional information.

TABLE 10.—*Caloric needs in 1985 by age and sex*—Continued

BRAZIL—(1985). PROJECTION OF COLORIC NEEDS FOR HIGH AND LOW ESTIMATES OF POPULATION GROWTH

| Age (years) | Body weight (kilograms) | Caloric allowance Kcal per kilogram per day | Population (upper level) (thousands) | Caloric need Kcal per day (billions) | Population (lower level) (thousands) | Caloric need Kcal per day (billions) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 128 | 5,691 | 7 | 4,325 | 5 |
| 1 to 4 | 13 | 105 | 20,447 | 28 | 16,298 | 22 |
| 5 to 9 | 24 | 82 | 21,626 | 43 | 18,151 | 36 |
| 10 to 14: | | | | | | |
| Male | 40 | 68 | 9,210 | 25 | 8,174 | 22 |
| Female | 40 | 64 | 8,849 | 23 | 7,853 | 20 |
| 15 to 19: | | | | | | |
| Male | 59 | 65 | 7,696 | 30 | 7,377 | 28 |
| Female | 54 | 48 | 7,417 | 19 | 7,110 | 18 |
| 20 to 29: | | | | | | |
| Male | 68 | 48 | 12,037 | 39 | 12,037 | 39 |
| Female | 61 | 41 | 11,848 | 30 | 11,848 | 30 |
| 30 to 39: | | | | | | |
| Male | 68 | 47 | 8,437 | 27 | 8,437 | 27 |
| Female | 61 | 40 | 8,552 | 21 | 8,552 | 21 |
| 40 to 49: | | | | | | |
| Male | 68 | 45 | 5,796 | 18 | 5,796 | 18 |
| Female | 61 | 38 | 5,931 | 14 | 5,931 | 14 |
| 50 to 59: | | | | | | |
| Male | 68 | 42 | 4,060 | 12 | 4,060 | 12 |
| Female | 61 | 35 | 4,239 | 9 | 4,239 | 9 |
| 60 to 69: | | | | | | |
| Male | 68 | 38 | 2,510 | 6 | 2,510 | 6 |
| Female | 61 | 32 | 2,764 | 5 | 2,764 | 5 |
| 70 and up: | | | | | | |
| Male | 68 | 33 | 1,356 | 3 | 1,356 | 3 |
| Female | 61 | 28 | 1,638 | 3 | 1,638 | 3 |
| Sum | | | 150,104 | 362 | 138,456 | 338 |
| Kcal per capita per day | | | | 2,399 | | 2,446 |

[1] See Table 6 for sources of data and other additional information.

TABLE 11.—*Estimates of protein needs based on FAO Reference body weights* [1]

WORLD—1965

| Age | Population (millions) | Protein required (grams per kilogram per day) | Body weight FAO Reference (kilograms) | Protein needs (metric tons per day) |
|---|---|---|---|---|
| 0 to 1 | 98 | 2 | 9 | 1,769 |
| 1 to 4 | 369 | 1.06 | 13 | 5,082 |
| 5 to 9 | 416 | .94 | 24 | 9,387 |
| 10 to 14: | | | | |
| Male | 187 | .86 | 40 | 6,419 |
| Female | 180 | .86 | 40 | 6,219 |
| 15 to 19: | | | | |
| Male | 158 | .77 | 60 | 7,290 |
| Female | 151 | .77 | 50 | 5,821 |
| 20 to 29: | | | | |
| Male | 256 | .71 | 65 | 11,809 |
| Female | 247 | .71 | 55 | 9,614 |
| 30 to 39: | | | | |
| Male | 215 | .71 | 65 | 9,899 |
| Female | 210 | .71 | 55 | 8,208 |
| 40 to 49: | | | | |
| Male | 157 | .71 | 65 | 7,204 |
| Female | 161 | .71 | 55 | 6,318 |
| 50 to 59: | | | | |
| Male | 119 | .71 | 65 | 5,514 |
| Female | 128 | .71 | 55 | 4,967 |
| 60 to 69: | | | | |
| Male | 74 | .71 | 65 | 3,442 |
| Female | 87 | .71 | 55 | 3,358 |
| 70+: | | | | |
| Male | 39 | .71 | 65 | 1,841 |
| Female | 56 | .71 | 55 | 2,202 |
| Total | 3,308 | | | 116,369 |
| Total: | | | | |
| FAO Reference Protein (metric tons per day) | | | | 116,369 |
| FAO Reference Protein (grams per capita per day) | | | | 35.2 |
| Protein of NPU of 62 (metric tons per day) | | | | 187,692 |
| Protein of NPU of 62 (grams per capita per day) | | | | 56.7 |

See footnotes at end of table.

TABLE 11.—*Estimates of protein needs based on FAO Reference body weights* [1]—Continued

WORLD (1970) PROJECTION OF PROTEIN NEEDS

| Age | Body weight (kilograms) | Protein required (grams per kilogram per day) | High [3] population estimate (millions) | High-level protein needs (metric tons per day) | Low [3] population estimate (millions) | Low-level protein needs (metric tons per day) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 2 | 109 | 1,965 | 100 | 1,809 |
| 1 to 4 | 13 | 1.06 | 380 | 5,239 | 364 | 5,022 |
| 5 to 9 | 24 | .94 | 445 | 10,036 | 445 | 10,036 |
| 10 to 14: | | | | | | |
| Male | 40 | .86 | 207 | 7,138 | 207 | 7,138 |
| Female | 40 | .86 | 200 | 6,907 | 200 | 6,907 |
| 15 to 19: | | | | | | |
| Male | 60 | .77 | 183 | 8,477 | 183 | 8,477 |
| Female | 50 | .77 | 178 | 6,837 | 178 | 6,837 |
| 20 to 29: | | | | | | |
| Male | 65 | .71 | 283 | 13,065 | 283 | 13,065 |
| Female | 55 | .71 | 272 | 10,609 | 272 | 10,609 |
| 30 to 39: | | | | | | |
| Male | 65 | .71 | 230 | 10,619 | 230 | 10,619 |
| Female | 55 | .71 | 223 | 8,696 | 223 | 8,696 |
| 40 to 49: | | | | | | |
| Male | 65 | .71 | 180 | 8,293 | 180 | 8,293 |
| Female | 55 | .71 | 183 | 7,138 | 183 | 7,138 |
| 50 to 59: | | | | | | |
| Male | 65 | .71 | 125 | 5,759 | 125 | 5,759 |
| Female | 55 | .71 | 134 | 5,224 | 134 | 5,224 |
| 60 to 69: | | | | | | |
| Male | 65 | .71 | 85 | 3,908 | 85 | 3,908 |
| Female | 55 | .71 | 96 | 3,740 | 96 | 3,740 |
| 70 and up: | | | | | | |
| Male | 65 | .71 | 46 | 2,113 | 46 | 2,113 |
| Female | 55 | .71 | 65 | 2,522 | 65 | 2,522 |
| Total | | | 3,624 | 128,295 | 3,599 | 127,912 |
| Total: | | | | | | |
| FAO Reference Protein (metric tons per day) | | | | 128,295 | | 127,912 |
| FAO Reference Protein (grams per capita per day) | | | | 35.4 | | 35.5 |
| Protein of NPU of 62 (metric tons per day) | | | | 206,927 | | 206,326 |
| Protein of NPU of 62 (grams per capita per day) | | | | 57.1 | | 57.3 |

See footnotes at end of table.

TABLE 11.—*Estimates of protein needs based on FAO Reference body weights* [1]—Continued

WORLD (1975) PROJECTION OF PROTEIN NEEDS

| Age | Body weight (kilograms) | Protein required (grams per kilogram per day) | High [3] population estimate (millions) | High-level protein needs (metric tons per day) | Low [3] population estimate (millions) | Low-level protein needs (metric tons per day) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 2 | 123 | 2,215 | 106 | 1,906 |
| 1 to 4 | 13 | 1.06 | 437 | 6,023 | 384 | 5,295 |
| 5 to 9 | 24 | .94 | 468 | 10,558 | 445 | 10,030 |
| 10 to 14: | | | | | | |
| Male | 40 | .86 | 223 | 7,674 | 223 | 7,674 |
| Female | 40 | .86 | 215 | 7,382 | 215 | 7,382 |
| 15 to 19: | | | | | | |
| Male | 60 | .77 | 205 | 9,471 | 205 | 9,471 |
| Female | 50 | .77 | 198 | 7,626 | 198 | 7,626 |
| 20 to 29: | | | | | | |
| Male | 65 | .71 | 332 | 15,284 | 331 | 15,284 |
| Female | 55 | .71 | 319 | 12,472 | 319 | 12,472 |
| 30 to 39: | | | | | | |
| Male | 65 | .71 | 243 | 11,232 | 243 | 11,232 |
| Female | 55 | .71 | 235 | 9,153 | 235 | 9,153 |
| 40 to 49: | | | | | | |
| Male | 65 | .71 | 200 | 9,216 | 200 | 9,216 |
| Female | 55 | .71 | 197 | 7,708 | 197 | 7,078 |
| 50 to 59: | | | | | | |
| Male | 65 | .71 | 138 | 6,345 | 138 | 6,345 |
| Female | 55 | .71 | 147 | 5,748 | 147 | 5,748 |
| 60 to 69: | | | | | | |
| Male | 65 | .71 | 92 | 4,259 | 92 | 4,259 |
| Female | 55 | .71 | 106 | 4,139 | 106 | 4,139 |
| 70 and up: | | | | | | |
| Male | 65 | .71 | 53 | 2,450 | 53 | 2,450 |
| Female | 55 | .71 | 74 | 2,889 | 74 | 2,889 |
| Total | | | 4,005 | 141,853 | 3,911 | 140,288 |
| Total: | | | | | | |
| FAO Reference Protein (metric tons per day) | | | | 141,853.1 | | 140,288 |
| FAO Reference Protein (grams per capita per day) | | | | 35.4 | | 35.9 |
| Protein of NPU of 62 (metric tons per day) | | | | 228,795 | | 226,271 |
| Protein of NPU of 62 (grams per capita per day) | | | | 57.1 | | 57.9 |

See footnotes at end of table.

TABLE 11.—*Estimates of protein needs based on FAO Reference body weights* [1]—Continued

WORLD (1980) PROJECTION OF PROTEIN NEEDS

| Age | Body weight (kilograms) | Protein required (grams per kilogram per day) | High [3] population estimate (millions) | High-level protein needs (metric tons per day) | Low [3] population estimate (millions) | Low-level protein needs (metric tons per day) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 2 | 147 | 2,651 | 119 | 2,147 |
| 1 to 4 | 13 | 1.06 | 496 | 6,840 | 412 | 5,673 |
| 5 to 9 | 24 | .94 | 539 | 12,168 | 472 | 10,648 |
| 10 to 14: | | | | | | |
| Male | 40 | .86 | 237 | 8,145 | 225 | 7,736 |
| Female | 40 | .86 | 227 | 7,795 | 215 | 7,406 |
| 15 to 19: | | | | | | |
| Male | 60 | .77 | 221 | 10,233 | 221 | 10,233 |
| Female | 50 | .77 | 213 | 8,192 | 213 | 8,192 |
| 20 to 29: | | | | | | |
| Male | 65 | .71 | 379 | 17,486 | 379 | 17,486 |
| Female | 55 | .71 | 367 | 14,215 | 367 | 14,315 |
| 30 to 39: | | | | | | |
| Male | 65 | .71 | 271 | 12,529 | 271 | 12,529 |
| Female | 55 | .71 | 261 | 10,175 | 261 | 10,176 |
| 40 to 49: | | | | | | |
| Male | 65 | .71 | 216 | 9,977 | 216 | 9,977 |
| Female | 55 | .71 | 211 | 8,239 | 211 | 8,239 |
| 50 to 59: | | | | | | |
| Male | 65 | .71 | 160 | 7,388 | 160 | 7,388 |
| Female | 55 | .71 | 168 | 6,548 | 168 | 6,548 |
| 60 to 69: | | | | | | |
| Male | 65 | .71 | 97 | 4,485 | 97 | 4,485 |
| Female | 55 | .71 | 112 | 4,377 | 112 | 4,377 |
| 70 and up: | | | | | | |
| Male | 65 | .71 | 61 | 2,805 | 61 | 2,805 |
| Female | 55 | .71 | 84 | 3,268 | 84 | 3,268 |
| Total | | | 4,467 | 157,628 | 4,264 | 154,348 |
| Total: | | | | | | |
| FAO Reference Protein (metric tons per day) | | | | 157,628 | | 154,348 |
| FAO Reference Protein (grams per capita per day) | | | | 35.3 | | 36.0 |
| Protein of NPU of 62 (metric tons per day) | | | | 254,238 | | 247,803 |
| Protein of NPU of 62 (grams per capita per day) | | | | 56.9 | | 58.1 |

See footnotes at end of table.

TABLE 11.—*Estimates of protein needs based on FAO Reference body weights*[1]—Continued

WORLD (1985) PROJECTION OF PROTEIN NEEDS

| Age | Body weight (kilograms) | Protein required (grams per kilogram per day) | High[3] population estimate (millions) | High-level protein needs (metric tons per day) | Low[3] population estimate (millions) | Low-level protein needs (metric tons per day) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 2 | 162 | 2,910 | 116 | 2,095 |
| 1 to 4 | 13 | 1.06 | 580 | 7,996 | 440 | 6,064 |
| 5 to 9 | 24 | .94 | 624 | 14,070 | 514 | 11,607 |
| 10 to 14: | | | | | | |
| Male | 40 | .86 | 274 | 9,429 | 240 | 8,249 |
| Female | 40 | .86 | 263 | 9,030 | 230 | 7,901 |
| 15 to 19: | | | | | | |
| Male | 60 | .77 | 236 | 10,921 | 225 | 10,371 |
| Female | 50 | .77 | 226 | 8,693 | 215 | 8,262 |
| 20 to 29: | | | | | | |
| Male | 65 | .71 | 419 | 19,350 | 419 | 19,350 |
| Female | 55 | .71 | 404 | 14,780 | 404 | 15,780 |
| 30 to 39: | | | | | | |
| Male | 65 | .71 | 321 | 14,804 | 321 | 14,804 |
| Female | 55 | .71 | 309 | 12,082 | 309 | 12,082 |
| 40 to 49: | | | | | | |
| Male | 65 | .71 | 231 | 10,674 | 231 | 10,674 |
| Female | 55 | .71 | 225 | 8,766 | 225 | 8,766 |
| 50 to 59: | | | | | | |
| Male | 65 | .71 | 180 | 8,293 | 180 | 8,293 |
| Female | 55 | .71 | 183 | 7,130 | 183 | 7,130 |
| 60 to 69: | | | | | | |
| Male | 65 | .71 | 109 | 5,016 | 109 | 5,016 |
| Female | 55 | .71 | 124 | 4,857 | 124 | 4,857 |
| 70 and up: | | | | | | |
| Male | 65 | .71 | 68 | 3,156 | 68 | 3,156 |
| Female | 55 | .71 | 94 | 3,674 | 94 | 3,674 |
| Total | | | 5,032 | 176,640 | 4,647 | 168,139 |
| Total: | | | | | | |
| FAO Reference Protein (metric tons per day) | | | | 176,640 | | 168,139 |
| FAO Reference Protein (grams per capita per day) | | | | 35.1 | | 36.2 |
| Protein of NPU of 62 (metric tons per day) | | | | 284,903 | | 272,000 |
| Protein of NPU of 62 (grams per capita per day) | | | | 56.6 | | 58.5 |

[1] WHO Tech. Report Series No. 301, Protein Requirements.

[2] Includes 1.7 grams and kilograms for infant protein requirement plus an allowance for increased requirements during pregnancy using FAO procedures.

[3] See population projection tables and footnotes.

TABLE 12.—*Estimates of protein needs based on FAO Reference body weight and body weight as determined in India*—Continued

INDIA—1965

| Age | Population (thousands) | Protein [1] required (grams per kilogram per day) | Body weight,[1] FAO Reference (kilograms) | Protein needs (metric tons per day) | Body weight,[2] Indian data (kilograms) | Protein needs (metric tons per day) |
|---|---|---|---|---|---|---|
| 0 to 1 | 17,757 | [3] 2 | 9 | 319 | 7 | 248 |
| 1 to 4 | 61,410 | 1.06 | 13 | 846 | 10 | 650 |
| 5 to 9 | 66,381 | .94 | 24 | 1,497 | 17 | 1,060 |
| 10 to 14: | | | | | | |
| Male | 28,333 | .86 | 40 | 974 | 28 | 682 |
| Female | 27,204 | .86 | 40 | 935 | 28 | 655 |
| 15 to 19: | | | | | | |
| Male | 24,533 | .77 | 60 | 1,133 | 48 | 906 |
| Female | 23,204 | .77 | 50 | 893 | 42 | 750 |
| 20 to 29: | | | | | | |
| Male | 40,001 | .71 | 65 | 1,846 | 55 | 1,562 |
| Female | 37,739 | .71 | 55 | 1,473 | 45 | 1,205 |
| 30 to 39: | | | | | | |
| Male | 31,653 | .71 | 65 | 1,460 | 55 | 1,236 |
| Female | 29,298 | .71 | 55 | 1,144 | 45 | 936 |
| 40 to 49: | | | | | | |
| Male | 23,240 | .71 | 65 | 1,072 | 55 | 907 |
| Female | 20,314 | .71 | 55 | 793 | 45 | 649 |
| 50 to 59: | | | | | | |
| Male | 15,397 | .71 | 65 | 710 | 55 | 601 |
| Female | 13,459 | .71 | 55 | 525 | 45 | 430 |
| 60 to 69: | | | | | | |
| Male | 8,327 | .71 | 65 | 384 | 55 | 325 |
| Female | 7,740 | .71 | 55 | 302 | 45 | 247 |
| 70 and up: | | | | | | |
| Male | 3,752 | .71 | 65 | 173 | 55 | 146 |
| Female | 4,110 | .71 | 55 | 160 | 45 | 131 |
| Total | 483,852 | | | 16,647 | | 13,326 |
| Total: | | | | | | |
| FAO Reference Protein (metric tons per day) | | | | 16,647 | | 13,326 |
| FAO Reference Protein (grams per capita per day) | | | | 34.4 | | 27.6 |
| Protein of NPU of 57 (metric tons per day) | | | | 29,206 | | 23,290 |
| Protein of NPU of 57 (grams per capita per day) | | | | 60.4 | | 48.3 |

See footnotes at end of table.

TABLE 12.—*Estimates of protein needs based on FAO Reference body weight and body weight as determined in India*—Continued

INDIA (1970) PROJECTION OF PROTEIN NEEDS [4]

| Age | Body weight (kilograms) | Protein required (grams per kilogram per day) | High population estimate (thousands) | High-level protein needs (metric tons per day) | Low population estimate (thousands) | Low-level protein needs (metric tons per day) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 2 | 20,990 | 377 | 17,190 | 309 |
| 1 to 4 | 13 | 1.06 | 71,258 | 981 | 64,773 | 892 |
| 5 to 9 | 24 | .94 | 75,345 | 1,699 | 75,345 | 1,699 |
| 10 to 14: | | | | | | |
| Male | 40 | .86 | 33,274 | 1,144 | 33,274 | 1,144 |
| Female | 40 | .86 | 32,093 | 1,103 | 32,093 | 1,103 |
| 15 to 19: | | | | | | |
| Male | 48 | .77 | 27,936 | 1,032 | 27,936 | 1,032 |
| Female | 42 | .77 | 26,758 | 865 | 26,758 | 865 |
| 20 to 29: | | | | | | |
| Male | 55 | .71 | 44,818 | 1,750 | 44,818 | 1,750 |
| Female | 45 | .71 | 42,178 | 1,347 | 42,178 | 1,347 |
| 30 to 39: | | | | | | |
| Male | 55 | .71 | 34,533 | 1,348 | 34,533 | 1,348 |
| Female | 45 | .71 | 32,233 | 1,029 | 32,233 | 1,029 |
| 40 to 49: | | | | | | |
| Male | 55 | .71 | 26,242 | 1,024 | 26,242 | 1,024 |
| Female | 45 | .71 | 23,419 | 748 | 23,419 | 748 |
| 50 to 59: | | | | | | |
| Male | 55 | .71 | 17,658 | 589 | 17,658 | 689 |
| Female | 45 | .71 | 15,432 | 493 | 15,432 | 493 |
| 60 to 69: | | | | | | |
| Male | 55 | .71 | 9,918 | 387 | 9,918 | 387 |
| Female | 45 | .71 | 9,015 | 288 | 9,015 | 288 |
| 70 and up: | | | | | | |
| Male | 55 | .71 | 4,525 | 176 | 4,525 | 176 |
| Female | 45 | .71 | 4,746 | 151 | 4,746 | 151 |
| Total | | | 552,371 | 16,641 | 542,086 | 16,484 |
| Total: | | | | | | |
| FAO Reference Protein (metric tons per day) | | | | 16,641 | | 16,484 |
| FAO Reference Protein (grams per capita per day) | | | | 30.1 | | 30.4 |
| Protein of NPU of 57 (metric tons per day) | | | | 29,195 | | 28,919 |
| Protein of NPU of 57 (grams per capita per day) | | | | 52.9 | | 53.3 |

See footnotes at end of table.

TABLE 12.—*Estimates of protein needs based on FAO Reference body weight and body weight as determined in India*—Continued

INDIA (1975) PROJECTION OF PROTEIN NEEDS

| Age | Body weight (kilograms) | Protein required (grams per kilogram per day) | High population estimate (thousands) | High-level protein needs (metric tons per day) | Low population estimate (thousands) | Low-level protein needs (metric tons per day) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 2 | 24,179 | 435 | 18,521 | 333 |
| 1 to 4 | 13 | 1.06 | 82,505 | 1,136 | 63,364 | 873 |
| 5 to 9 | 24 | .94 | 88,702 | 2,001 | 78,945 | 1,780 |
| 10 to 14: | | | | | | |
| Male | 40 | .86 | 38,267 | 1,316 | 38,267 | 1,316 |
| Female | 40 | .86 | 36,170 | 1,244 | 36,170 | 1,244 |
| 15 to 19: | | | | | | |
| Male | 52 | .77 | 32,893 | 1,317 | 32,893 | 1,317 |
| Female | 45 | .77 | 31,636 | 1,096 | 31,636 | 1,096 |
| 20 to 29: | | | | | | |
| Male | 58 | .71 | 51,020 | 2,101 | 51,020 | 2,101 |
| Female | 48 | .71 | 48,368 | 1,648 | 48,368 | 1,648 |
| 30 to 39: | | | | | | |
| Male | 58 | .71 | 38,136 | 1,570 | 38,136 | 1,570 |
| Female | 48 | .71 | 35,566 | 1,212 | 35,566 | 1,212 |
| 40 to 49: | | | | | | |
| Male | 58 | .71 | 29,485 | 1,214 | 29,485 | 1,214 |
| Female | 48 | .71 | 27,050 | 921 | 27,050 | 921 |
| 50 to 59: | | | | | | |
| Male | 58 | .71 | 20,447 | 842 | 20,447 | 842 |
| Female | 48 | .71 | 18,010 | 613 | 18,010 | 613 |
| 60 to 69: | | | | | | |
| Male | 58 | .71 | 11,896 | 489 | 11,896 | 489 |
| Female | 48 | .71 | 10,714 | 365 | 10,714 | 365 |
| 70 and up: | | | | | | |
| Male | 58 | .71 | 5,604 | 230 | 5,604 | 230 |
| Female | 48 | .71 | 5,635 | 192 | 5,635 | 192 |
| Total | | | 636,283 | 19,967 | 601,727 | 19,363 |
| Total: | | | | | | |
| FAO Reference Protein (metric tons per day) | | | | 19,967 | | 19,363 |
| FAO Reference Protein (grams per capita per day) | | | | 31.4 | | 31.2 |
| Protein of NPU of 57 (metric tons per day) | | | | 35,029 | | 33,970 |
| Protein of NPU of 57 (grams per capita per day) | | | | 55.0 | | 56.5 |

See footnotes at end of table.

263-888 O—67——10

TABLE 12.—*Estimates of protein needs based on FAO Reference body weight and body weight as determined in India*—Continued

INDIA (1980) PROJECTION OF PROTEIN NEEDS

| Age | Body weight (kilograms) | Protein required (grams per kilogram per day) | High population estimate (thousands) | High-level protein needs (metric tons per day) | Low population estimate (thousands) | Low-level protein needs (metric tons per day) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 2 | 28,296 | 509 | 22,015 | 396 |
| 1 to 4 | 13 | 1.06 | 97,113 | 1,338 | 75,068 | 1,034 |
| 5 to 9 | 24 | .94 | 103,513 | 2,335 | 79,394 | 1,791 |
| 10 to 14: | | | | | | |
| Male | 40 | .86 | 45,273 | 1,557 | 40,293 | 1,386 |
| Female | 40 | .86 | 42,589 | 1,465 | 37,904 | 1,303 |
| 15 to 19: | | | | | | |
| Male | 52 | .77 | 37,911 | 1,517 | 37,911 | 1,517 |
| Female | 45 | .77 | 35,753 | 1,238 | 35,753 | 1,238 |
| 20 to 29: | | | | | | |
| Male | 58 | .71 | 59,436 | 2,447 | 59,436 | 2,447 |
| Female | 48 | .71 | 56,825 | 1,936 | 56,825 | 1,936 |
| 30 to 39: | | | | | | |
| Male | 58 | .71 | 43,084 | 1,774 | 43,084 | 1,774 |
| Female | 48 | .71 | 40,225 | 1,370 | 40,225 | 1,370 |
| 40 to 49: | | | | | | |
| Male | 58 | .71 | 32,684 | 1,345 | 32,684 | 1,345 |
| Female | 48 | .71 | 30,373 | 1,035 | 30,373 | 1,035 |
| 50 to 59: | | | | | | |
| Male | 58 | .71 | 23,653 | 974 | 23,653 | 974 |
| Female | 48 | .71 | 21,318 | 726 | 21,318 | 726 |
| 60 to 69: | | | | | | |
| Male | 58 | .71 | 14,146 | 582 | 14,146 | 582 |
| Female | 48 | .71 | 12,760 | 434 | 12,760 | 434 |
| 70 and up: | | | | | | |
| Male | 58 | .71 | 7,007 | 288 | 7,007 | 288 |
| Female | 48 | .71 | 6,852 | 233 | 6,852 | 233 |
| Total | | | 738,811 | 23,112 | 676,701 | 21,819 |
| Total: | | | | | | |
| FAO Reference Protein (metric tons per day) | | | | 23,112 | | 21,819 |
| FAO Reference Protein (grams per capita per day) | | | | 31.3 | | 32.2 |
| Protein of NPU of 57 (metric tons per day) | | | | 40,548 | | 38,279 |
| Protein of NPU of 57 (grams per capita per day) | | | | 54.9 | | 56.6 |

See footnotes at end of table.

TABLE 12.—*Estimates of protein needs based on FAO Reference body weight and body weight as determined in India*—Continued

INDIA (1985) PROJECTION OF PROTEIN NEEDS

| Age | Body weight (kilograms) | Protein required (grams per kilogram per day) | High population estimate (thousadds) | High-level protein needs (metric tons per day) | Low population estimate (thousands) | Low-level protein needs (metric tons per day) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 2 | 33,253 | 598 | 25,305 | 455 |
| 1 to 4 | 13 | 1.06 | 114,889 | 1,583 | 88,924 | 1,225 |
| 5 to 9 | 24 | .94 | 122,573 | 2,765 | 94,871 | 2,140 |
| 10 to 14: | | | | | | |
| Male | 40 | .86 | 53,118 | 1,827 | 40,742 | 1,401 |
| Female | 40 | .86 | 49,618 | 1,706 | 38,057 | 1,309 |
| 15 to 19: | | | | | | |
| Male | 55 | .77 | 44,935 | 1,902 | 39,992 | 1,693 |
| Female | 47 | .77 | 42,194 | 1,527 | 37,533 | 1,359 |
| 20 to 29: | | | | | | |
| Male | 61 | .71 | 69,492 | 3,009 | 69,492 | 3,009 |
| Female | 51 | .71 | 65,901 | 2,386 | 65,901 | 2,386 |
| 30 to 39: | | | | | | |
| Male | 61 | .71 | 49,416 | 2,140 | 49,416 | 2,140 |
| Female | 51 | .71 | 46,545 | 1,685 | 46,545 | 1,685 |
| 40 to 49: | | | | | | |
| Male | 61 | .71 | 36,443 | 1,578 | 36,443 | 1,578 |
| Female | 51 | .71 | 33,879 | 1,226 | 33,879 | 1,226 |
| 50 to 59: | | | | | | |
| Male | 61 | .71 | 26,916 | 1,165 | 26,916 | 1,165 |
| Female | 51 | .71 | 24,942 | 903 | 24,942 | 903 |
| 60 to 69: | | | | | | |
| Male | 61 | .71 | 16,685 | 722 | 16,685 | 722 |
| Female | 51 | .71 | 15,192 | 550 | 15,192 | 550 |
| 70 and up: | | | | | | |
| Male | 61 | .71 | 8,992 | 389 | 8,992 | 389 |
| Female | 51 | .71 | 8,739 | 316 | 8,739 | 316 |
| Total | | | 863,722 | 27,985 | 768,586 | 25,659 |
| Total: | | | | | | |
| FAO Reference Protein (metric tons per day) | | | | 27,985 | | 25,659 |
| FAO Reference Protein (grams per capita per day) | | | | 32.4 | | 33.4 |
| Protein of NPU of 57 (metric tons per day) | | | | 49,097 | | 45,015 |
| Protein of NPU of 57 (grams per capita per day) | | | | 56.8 | | 58.6 |

[1] WHO Tech. Report Series No. 301, Protein Requirements.

[2] Heights and weights as determined in India by the Nutrition Research Laboratories.

[3] Includes 1.7 grams per kilogram for infant protein requirement plus an allowance for increased requirements during pregnancy using FAO procedure.

[4] See population projection tables and footnotes.

TABLE 13.—*Estimates of protein needs based on FAO reference body weight and body weight as determined in Pakistan*

PAKISTAN—1965

| Age | Population (thousands) | Protein [1] required grams per (kilogram per day) | Body weight, [1] FAO reference (kilograms) | Protein needs (metric tons per day) | Body weight, [2] Pakistan data (kilograms) | Protein needs (metric tons per day) |
|---|---|---|---|---|---|---|
| 0 to 1 | 5,147 | [3] 2 | 9 | 93 | 7 | 72 |
| 1 to 4 | 17,504 | 1.06 | 13 | 241 | 10 | 185 |
| 5 to 9 | 17,224 | .94 | 24 | 388 | 17 | 275 |
| 10 to 14: | | | | | | |
| Male | 7,419 | .86 | 40 | 255 | 30 | 191 |
| Female | 7,163 | .86 | 40 | 246 | 30 | 184 |
| 15 to 19: | | | | | | |
| Male | 5,445 | .77 | 60 | 251 | 46 | 192 |
| Female | 5,103 | .77 | 50 | 196 | 42 | 165 |
| 20 to 29: | | | | | | |
| Male | 7,835 | .71 | 65 | 361 | 50 | 278 |
| Female | 7,267 | .71 | 55 | 283 | 45 | 232 |
| 30 to 39: | | | | | | |
| Male | 6,689 | .71 | 65 | 308 | 50 | 237 |
| Female | 6,141 | .71 | 55 | 239 | 45 | 196 |
| 40 to 49: | | | | | | |
| Male | 4,823 | .71 | 65 | 222 | 50 | 171 |
| Female | 4,391 | .71 | 55 | 171 | 45 | 140 |
| 50 to 59: | | | | | | |
| Male | 3,274 | .71 | 65 | 151 | 50 | 116 |
| Female | 3,092 | .71 | 55 | 120 | 45 | 99 |
| 60 to 69: | | | | | | |
| Male | 1,942 | .71 | 65 | 90 | 50 | 69 |
| Female | 2,056 | .71 | 55 | 80 | 45 | 66 |
| 70 and up: | | | | | | |
| Male | 1,172 | .71 | 65 | 54 | 50 | 42 |
| Female | 1,876 | .71 | 55 | 73 | 45 | 60 |
| Total | 115,563 | ---------- | ---------- | 3,829 | ---------- | 2,973 |
| Total: | | | | | | |
| FAO reference protein (metric tons per day) | | | | 3,829 | ---------- | 2,973 |
| FAO reference protein (grams per capita per day) | | | | 33.1 | ---------- | 25.7 |
| Protein of NPU of 60 (metric tons per day) | | | | 6,381 | ---------- | 4,956 |
| Protein of NPU of 60 (grams per capita per day) | | | | 55.2 | ---------- | 42.9 |

See footnotes at end of table.

TABLE 13.—*Estimates of protein needs based on FAO reference body weight and body weight as determined in Pakistan*—Continued

PAKISTAN (1970) PROJECTION OF PROTEIN NEEDS [4]

| Age | Body weight (kilograms) | Protein required (grams per kilogram per day) | High population estimate (thousands) | High-level protein needs (metric tons per day) | Low population estimate (thousands) | Low-level protein needs (metric tons per day) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 2 | 6,160 | 110 | 5,046 | 91 |
| 1 to 4 | 13 | 1.06 | 20,727 | 285 | 18,846 | 259 |
| 5 to 9 | 24 | .94 | 21,172 | 477 | 21,172 | 477 |
| 10 to 14: | | | | | | |
| Male | 40 | .86 | 8,595 | 295 | 8,595 | 295 |
| Female | 40 | .86 | 8,329 | 286 | 8,329 | 286 |
| 15 to 19: | | | | | | |
| Male | 46 | .77 | 7,332 | 259 | 7,332 | 259 |
| Female | 42 | .77 | 7,075 | 228 | 7,075 | 228 |
| 20 to 29: | | | | | | |
| Male | 50 | .71 | 9,352 | 331 | 9,352 | 331 |
| Female | 45 | .71 | 8,724 | 278 | 8,724 | 278 |
| 30 to 39: | | | | | | |
| Male | 50 | .71 | 7,384 | 262 | 7,384 | 262 |
| Female | 45 | .71 | 6,833 | 218 | 6,833 | 218 |
| 40 to 49: | | | | | | |
| Male | 50 | .71 | 5,476 | 194 | 5,476 | 194 |
| Female | 45 | .71 | 4,999 | 159 | 4,999 | 159 |
| 50 to 59: | | | | | | |
| Male | 50 | .71 | 3,753 | 129 | 3,753 | 129 |
| Female | 45 | .71 | 3,533 | 112 | 3,533 | 112 |
| 60 to 69: | | | | | | |
| Male | 50 | .71 | 2,182 | 78 | 2,182 | 78 |
| Female | 45 | .71 | 2,281 | 73 | 2,281 | 73 |
| 70 and up: | | | | | | |
| Male | 50 | .71 | 1,187 | 42 | 1,187 | 42 |
| Female | 45 | .71 | 1,799 | 57 | 1,799 | 57 |
| Total | | | 136,893 | 3,882 | 133,898 | 3,828 |
| Total: | | | | | | |
| FAO reference protein (metric tons per day) | | | | 3,882 | | 3,828 |
| FAO reference protein (grams per capita per day) | | | | 28.3 | | 28.7 |
| Protein of NPU of 60 (metric tons per day) | | | | 6,471 | | 6,394 |
| Protein of NPU of 60 (grams per capita per day) | | | | 47.3 | | 47.7 |

See footnotes at end of table.

TABLE 13.—*Estimates of protein needs based on FAO reference body weight and body weight as determined in Pakistan*—Continued

PAKISTAN (1975) PROJECTION OF PROTEIN NEEDS

| Age | Body weight (kilograms) | Protein required (grams per kilogram per day) | High population estimate (thousands) | High-level protein needs (metric tons per day) | Low population estimate (thousands) | Low-level protein needs (metric tons per day) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 2 | 7,462 | 134 | 5,716 | 102 |
| 1 to 4 | 13 | 1.06 | 25,239 | 347 | 19,376 | 266 |
| 5 to 9 | 24 | .94 | 25,338 | 571 | 22,551 | 508 |
| 10 to 14: | | | | | | |
| Male | 40 | .86 | 10,623 | 365 | 10,623 | 365 |
| Female | 40 | .86 | 10,225 | 351 | 10,225 | 351 |
| 15 to 19: | | | | | | |
| Male | 50 | .77 | 8,498 | 327 | 8,498 | 327 |
| Female | 46 | .77 | 8,232 | 291 | 8,232 | 291 |
| 20 to 29: | | | | | | |
| Male | 53 | .71 | 12,540 | 471 | 12,540 | 471 |
| Female | 48 | .71 | 11,944 | 407 | 11,944 | 407 |
| 30 to 39: | | | | | | |
| Male | 53 | .71 | 7,588 | 285 | 7,588 | 285 |
| Female | 48 | .71 | 7,034 | 239 | 7,034 | 239 |
| 40 to 49: | | | | | | |
| Male | 53 | .71 | 6,380 | 240 | 6,380 | 240 |
| Female | 48 | .71 | 5,887 | 200 | 5,887 | 200 |
| 50 to 59: | | | | | | |
| Male | 53 | .71 | 4,344 | 163 | 4,344 | 163 |
| Female | 48 | .71 | 4,086 | 139 | 4,086 | 139 |
| 60 to 69: | | | | | | |
| Male | 53 | .71 | 2,524 | 95 | 2,524 | 95 |
| Female | 48 | .71 | 2,606 | 89 | 2,606 | 89 |
| 70 and up: | | | | | | |
| Male | 53 | .71 | 1,283 | 48 | 1,283 | 48 |
| Female | 48 | .71 | 1,832 | 62 | 1,832 | 62 |
| Total | | | 163,665 | 4,831 | 153,272 | 4,648 |
| Total: | | | | | | |
| FAO reference protein (metric tons per day) | | | | 4,831 | | 4,648 |
| FAO reference protein (grams per capita per day) | | | | 29.5 | | 30.4 |
| Protein of NPU of 60 (metric tons per day) | | | | 8,053 | | 7,761 |
| Protein of NPU of 60 (grams per capita per day) | | | | 49.2 | | 50.6 |

See footnotes at end of table.

TABLE 13.—*Estimates of protein needs based on FAO reference body weight and body weight as determined in Pakistan*—Continued

PAKISTAN (1980) PROJECTION OF PROTEIN NEEDS

| Age | Body weight (kilograms) | Protein required (grams per kilogram per day) | High population estimate (thousands) | High-level protein needs (metric tons per day) | Low population estimate (thousands) | Low-level protein needs (metric tons per day) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 2 | 9,204 | 165 | 7,164 | 128 |
| 1 to 4 | 13 | 1.06 | 31,169 | 427 | 24,105 | 332 |
| 5 to 9 | 24 | .94 | 31,075 | 701 | 23,847 | 538 |
| 10 to 14: | | | | | | |
| Male | 40 | .86 | 12,744 | 438 | 11,344 | 390 |
| Female | 40 | .86 | 12,253 | 421 | 10,907 | 375 |
| 15 to 19: | | | | | | |
| Male | 50 | .77 | 10,507 | 404 | 10,507 | 404 |
| Female | 46 | .77 | 10,112 | 358 | 10,112 | 358 |
| 20 to 29: | | | | | | |
| Male | 53 | .71 | 15,509 | 583 | 15,509 | 583 |
| Female | 48 | .71 | 14,996 | 511 | 14,996 | 511 |
| 30 to 39: | | | | | | |
| Male | 53 | .71 | 9,046 | 340 | 9,046 | 340 |
| Female | 48 | .71 | 8,441 | 287 | 8,441 | 287 |
| 40 to 49: | | | | | | |
| Male | 53 | .71 | 7,030 | 264 | 7,030 | 264 |
| Female | 48 | .71 | 6,545 | 223 | 6,545 | 223 |
| 50 to 59: | | | | | | |
| Male | 53 | .71 | 4,937 | 185 | 4,937 | 185 |
| Female | 48 | .71 | 4,648 | 158 | 4,648 | 158 |
| 60 to 69: | | | | | | |
| Male | 53 | .71 | 2,925 | 110 | 2,925 | 110 |
| Female | 48 | .71 | 2,983 | 101 | 2,893 | 101 |
| 70 and up: | | | | | | |
| Male | 53 | .71 | 1,463 | 55 | 1,463 | 55 |
| Female | 48 | .71 | 1,968 | 67 | 1,968 | 67 |
| Total | | | 197,555 | 5,807 | 178,477 | 5,477 |
| Total: | | | | | | |
| FAO reference protein (metric tons per day) | | | | 5,807 | | 5,416 |
| FAO reference protein (grams per capita per day) | | | | 29.4 | | 30.3 |
| Protein of NPU of 60 (metric tons per day) | | | | 9,679 | | 9,026 |
| Protein of NPU of 60 (grams per capita per day) | | | | 49.0 | | 50.6 |

See footnotes at end of table.

TABLE 13.—*Estimates of protein needs based on FAO reference body weight and body weight as determined in Pakistan*—Continued

PAKISTAN (1985) PROJECTION OF PROTEIN NEEDS

| Age | Body weight (kilograms) | Protein required (grams per kilogram per day) | High population estimate (thousands) | High-level protein needs (metric tons per day) | Low population estimate (thousands) | Low-level protein needs (metric tons per day) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 2 | 11,409 | 205 | 8,687 | 156 |
| 1 to 4 | 13 | 1.06 | 38,922 | 536 | 30,134 | 415 |
| 5 to 9 | 24 | .94 | 38,684 | 872 | 29,956 | 675 |
| 10 to 14: | | | | | | |
| Male | 40 | .86 | 15,667 | 538 | 12,023 | 413 |
| Female | 40 | .86 | 15,054 | 517 | 11,553 | 397 |
| 15 to 19: | | | | | | |
| Male | 52 | .77 | 12,611 | 504 | 11,226 | 449 |
| Female | 48 | .77 | 12,128 | 448 | 10,794 | 398 |
| 20 to 29: | | | | | | |
| Male | 56 | .71 | 18,601 | 739 | 18,601 | 739 |
| Female | 51 | .71 | 17,973 | 650 | 17,973 | 650 |
| 30 to 39: | | | | | | |
| Male | 56 | .71 | 12,111 | 481 | 12,111 | 481 |
| Female | 51 | .71 | 11,550 | 418 | 11,550 | 418 |
| 40 to 49: | | | | | | |
| Male | 56 | .71 | 7,216 | 286 | 7,216 | 286 |
| Female | 51 | .71 | 6,735 | 243 | 6,735 | 243 |
| 50 to 59: | | | | | | |
| Male | 56 | .71 | 5,764 | 229 | 5,764 | 229 |
| Female | 51 | .71 | 5,470 | 198 | 5,470 | 198 |
| 60 to 69: | | | | | | |
| Male | 56 | .71 | 3,428 | 136 | 3,428 | 136 |
| Female | 51 | .71 | 3,464 | 125 | 3,464 | 125 |
| 70 and up: | | | | | | |
| Male | 56 | .71 | 1,730 | 69 | 1,730 | 69 |
| Female | 51 | .71 | 2,200 | 80 | 2,200 | 80 |
| Total | | | 240,717 | 7,282 | 210,615 | 6,565 |
| Total: | | | | | | |
| FAO reference protein (metric tons per day) | | | | 7,282 | | 6,565 |
| FAO reference protein (grams per capita per day) | | | | 30.3 | | 31.2 |
| Protein of NPU of 60 (metric tons per day) | | | | 12,137 | | 10,942 |
| Protein of NPU of 60 (grams per capita per day) | | | | 50.4 | | 52.0 |

[1] WHO Tech. Report Series No. 301, Protein Requirements.

[2] ICNND Nutrition Survey of East Pakistan and personal data of Dr. Barbara Underwood.

[3] Includes 1.7 grams per kilogram for infant protein requirement plus an allowance for pregnancy using FAO procedure.

[4] See population projection tables and footnotes.

TABLE 14.—*Estimates of protein needs based on FAO reference body weight and body weight as determined in Brazil*

BRAZIL—1965

| Age | Population (thousands) | Protein [1] required grams per kilogram per day | Body weight [1] FAO reference (kilograms) | Protein needs (metric tons per day) | Body weight [2] Brazil data (kilograms) | Protein needs (metric tons per day) |
|---|---|---|---|---|---|---|
| 0 to 1 | 3,037 | [3] 2.0 | 9 | 55 | 7 | 43 |
| 1 to 4 | 10,660 | 1.06 | 13 | 146 | 12 | 135 |
| 5 to 9 | 11,636 | .94 | 24 | 262 | 20 | 218 |
| 10 to 14: | | | | | | |
| Male | 4,915 | .86 | 40 | 169 | 32 | 135 |
| Female | 4,927 | .86 | 40 | 169 | 32 | 135 |
| 15 to 19: | | | | | | |
| Male | 4,109 | .77 | 60 | 189 | 50 | 158 |
| Female | 4,165 | .77 | 50 | 153 | 48 | 153 |
| 20 to 29: | | | | | | |
| Male | 6,351 | .71 | 65 | 293 | 62 | 279 |
| Female | 6,435 | .71 | 55 | 251 | 55 | 251 |
| 39 to 39: | | | | | | |
| Male | 4,726 | .71 | 65 | 218 | 62 | 208 |
| Female | 4,783 | .71 | 55 | 186 | 55 | 186 |
| 40 to 49: | | | | | | |
| Male | 3,434 | .71 | 65 | 158 | 62 | 151 |
| Female | 3,491 | .71 | 55 | 136 | 55 | 136 |
| 50 to 59: | | | | | | |
| Male | 2,287 | .71 | 65 | 105 | 62 | 100 |
| Female | 2,344 | .71 | 55 | 91 | 55 | 91 |
| 60 to 69: | | | | | | |
| Male | 1,315 | .71 | 65 | 61 | 62 | 58 |
| Female | 1,407 | .71 | 55 | 55 | 55 | 55 |
| 70 and up: | | | | | | |
| Male | 583 | .71 | 65 | 27 | 62 | 26 |
| Female | 696 | .71 | 55 | 28 | 55 | 27 |
| Total | 81,301 | | | 2,757 | | 2,550 |
| Total: | | | | | | |
| FAO Reference Protein (metric tons per day) | | | | 2,757 | | 2,550 |
| FAO Reference Protein (grams per capita per day) | | | | 33.9 | | 31.4 |
| Protein of NPU of 65 (metric tons per day) | | | | 4,245 | | 3,924 |
| Protein of NPU of 65 (grams per capita per day) | | | | 52.2 | | 48.3 |

See footnotes at end of table.

TABLE 14.—*Estimates of protein needs based on FAO reference body weight and body weight as determined in Brazil*—Continued

BRAZIL (1970) PROJECTION OF PROTEIN NEEDS [4]

| Age | Body weight (kilograms) | Protein required (grams per kilogram per day) | High population estimate (thousands) | High level protein needs (metric tons per day) | Low population estimate (thousands) | Low level protein needs (metric tons per day) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 2.0 | 3,508 | 63 | 3,227 | 58 |
| 1 to 4 | 13 | 1.06 | 12,342 | 170 | 11,959 | 164 |
| 5 to 9 | 24 | .94 | 13,171 | 297 | 13,171 | 297 |
| 10 to 14: | | | | | | |
| Male | 40 | .86 | 5,799 | 199 | 5,799 | 199 |
| Female | 40 | .86 | 5,711 | 196 | 5,711 | 196 |
| 15 to 19: | | | | | | |
| Male | 50 | .77 | 4,856 | 186 | 4,856 | 186 |
| Female | 48 | .77 | 4,867 | 179 | 4,867 | 179 |
| 20 to 29: | | | | | | |
| Male | 62 | .71 | 7,394 | 325 | 7,394 | 325 |
| Female | 55 | .71 | 7,501 | 292 | 7,501 | 292 |
| 30 to 39: | | | | | | |
| Male | 62 | .71 | 5,317 | 234 | 5,317 | 234 |
| Female | 55 | .71 | 5,421 | 211 | 5,421 | 211 |
| 40 to 49: | | | | | | |
| Male | 62 | .71 | 3,907 | 171 | 3,907 | 171 |
| Female | 55 | .71 | 3,955 | 154 | 3,955 | 154 |
| 50 to 59: | | | | | | |
| Male | 62 | .71 | 2,655 | 116 | 2,655 | 116 |
| Female | 55 | .71 | 2,749 | 107 | 2,749 | 107 |
| 60 to 69: | | | | | | |
| Male | 62 | .71 | 1,544 | 68 | 1,544 | 68 |
| Female | 55 | .71 | 1,660 | 65 | 1,660 | 65 |
| 70 and up: | | | | | | |
| Male | 62 | .71 | 737 | 32 | 737 | 32 |
| Female | 55 | .71 | 876 | 34 | 876 | 34 |
| Total | | | 93,970 | 3,107 | 93,306 | 3,097 |
| Total: | | | | | | |
| FAO Reference Protein (metric tons per day) | | | | 3,107 | | 3,097 |
| FAO Reference Protein (grams per capita per day) | | | | 33.1 | | 33.2 |
| Protein of NPU of 65 (metric tons per day) | | | | 4,780 | | 4,764 |
| Protein of NPU of 65 (grams per capita per day) | | | | 50.8 | | 51.1 |

See footnotes at end of table.

TABLE 14.—*Estimates of protein needs based on FAO reference body weight and body weight as determined in Brazil*—Continued

BRAZIL (1975) PROJECTION OF PROTEIN NEEDS

| Age | Body weight (kilograms) | Protein required (grams per kilogram per day) | High population estimate (thousands) | High-level protein needs (metric tons per day) | Low population estimate (thousands) | Low-level protein needs (metric tons per day) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 2.0 | 4,116 | 74 | 3,581 | 64 |
| 1 to 4 | 13 | 1.06 | 14,548 | 200 | 12,978 | 178 |
| 5 to 9 | 24 | .94 | 15,337 | 346 | 14,702 | 331 |
| 10 to 14: | | | | | | |
| Male | 40 | .86 | 6,601 | 227 | 6,601 | 227 |
| Female | 40 | .86 | 6,452 | 221 | 6,452 | 221 |
| 15 to 19: | | | | | | |
| Male | 57 | .77 | 5,739 | 251 | 5,739 | 251 |
| Female | 52 | .77 | 5,653 | 226 | 5,653 | 226 |
| 20 to 29: | | | | | | |
| Male | 65 | .71 | 8,723 | 402 | 8,723 | 402 |
| Female | 58 | .71 | 8,808 | 362 | 8,808 | 362 |
| 30 to 39: | | | | | | |
| Male | 65 | .71 | 6,069 | 280 | 6,069 | 280 |
| Female | 58 | .71 | 6,166 | 253 | 6,166 | 253 |
| 40 to 49: | | | | | | |
| Male | 65 | .71 | 4,449 | 205 | 4,449 | 205 |
| Female | 58 | .71 | 4,539 | 186 | 4,539 | 186 |
| 50 to 59: | | | | | | |
| Male | 65 | .71 | 3,075 | 141 | 3,075 | 141 |
| Female | 58 | .71 | 3,206 | 132 | 3,206 | 132 |
| 60 to 69: | | | | | | |
| Male | 65 | .71 | 1,816 | 84 | 1,816 | 84 |
| Female | 58 | .71 | 1,968 | 81 | 1,968 | 81 |
| 70 and up: | | | | | | |
| Male | 65 | .71 | 914 | 42 | 914 | 42 |
| Female | 58 | .71 | 1,088 | 45 | 1,088 | 45 |
| Total | | | 109,267 | 3,765 | 106,527 | 3,719 |
| Total: | | | | | | |
| FAO Reference Protein (metric tons per day) | | | | 3,765 | | 3,719 |
| FAO Reference Protein (grams per capita per day) | | | | 34.4 | | 34.9 |
| Protein of NPU of 65 (metric tons per day) | | | | 5,792 | | 5,722 |
| Protein of NPU of 65 (grams per capita per day) | | | | 53.0 | | 53.7 |

See footnotes at end of table.

TABLE 14.—*Estimates of protein needs based on FAO reference body weight and body weight as determined in Brazil*—Continued

BRAZIL (1980) PROJECTION OF PROTEIN NEEDS

| Age | Body weight (kilograms) | Protein required (grams per kilogram per day) | High population estimate (thousands) | High-level protein needs (metric tons per day) | Low population estimate (thousands) | Low-level protein needs (metric tons per day) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 2 | 4,838 | 87 | 3,967 | 71 |
| 1 to 4 | 13 | 1.06 | 17,248 | 237 | 14,565 | 200 |
| 5 to 9 | 24 | .94 | 18,170 | 409 | 16,125 | 363 |
| 10 to 14: | | | | | | |
| Male | 40 | .86 | 7,756 | 266 | 7,434 | 255 |
| Female | 40 | .86 | 7,467 | 256 | 7,158 | 246 |
| 15 to 19: | | | | | | |
| Male | 57 | .77 | 6,541 | 287 | 6,541 | 287 |
| Female | 52 | .77 | 6,398 | 256 | 6,398 | 256 |
| 20 to 29: | | | | | | |
| Male | 65 | .71 | 10,348 | 477 | 10,348 | 477 |
| Female | 58 | .71 | 10,303 | 424 | 10,303 | 424 |
| 30 to 39: | | | | | | |
| Male | 65 | .71 | 7,110 | 328 | 7,110 | 328 |
| Female | 58 | .71 | 7,238 | 298 | 7,238 | 298 |
| 40 to 49: | | | | | | |
| Male | 65 | .71 | 5,043 | 232 | 5,043 | 232 |
| Female | 58 | .71 | 5,181 | 213 | 5,181 | 213 |
| 50 to 59: | | | | | | |
| Male | 65 | .71 | 3,533 | 163 | 3,533 | 163 |
| Female | 58 | .71 | 3,664 | 150 | 3,664 | 150 |
| 60 to 69: | | | | | | |
| Male | 65 | .71 | 2,139 | 99 | 2,139 | 99 |
| Female | 58 | .71 | 2,341 | 96 | 2,341 | 96 |
| 70 and up: | | | | | | |
| Male | 65 | .71 | 1,116 | 52 | 1,116 | 52 |
| Female | 58 | .71 | 1,336 | 55 | 1,336 | 55 |
| Total | | | 127,770 | 4,391 | 121,540 | 4,270 |
| Total: | | | | | | |
| FAO Reference Protein (metric tons per day) | | | | 4,391 | | 4,270 |
| FAO Reference Protein (grams per capita per day) | | | | 34.4 | | 35.2 |
| Protein of NPU of 65 (metric tons per day) | | | | 6,755 | | 6,570 |
| Protein of NPU of 65 (grams per capita per day) | | | | 52 | | 54.1 |

See footnotes at end of table.

TABLE 14.—*Estimates of protein needs based on FAO reference body weight and body weight as determined in Brazil*—Continued

BRAZIL (1985) PROJECTION OF PROTEIN NEEDS

| Age | Body weight (kilograms) | Protein required (grams per kilogram per day) | High population estimate (thousands) | High-level protein needs (metric tons per day) | Low population estimate (thousands) | Low-level protein needs (metric tons per day) |
|---|---|---|---|---|---|---|
| 0 to 1 | 9 | 2 | 5,691 | 102 | 4,325 | 78 |
| 1 to 4 | 13 | 1.06 | 20,447 | 281 | 16,298 | 224 |
| 5 to 9 | 24 | .94 | 21,626 | 487 | 18,151 | 409 |
| 10 to 14: | | | | | | |
| Male | 40 | .86 | 9,210 | 316 | 8,174 | 281 |
| Female | 40 | .86 | 8,849 | 304 | 7,853 | 270 |
| 15 to 19: | | | | | | |
| Male | 59 | .77 | 7,696 | 249 | 7,377 | 335 |
| Female | 54 | .77 | 7,417 | 308 | 7,110 | 295 |
| 20 to 29: | | | | | | |
| Male | 68 | .71 | 12,037 | 581 | 12,037 | 581 |
| Female | 61 | .71 | 11,848 | 513 | 11,848 | 513 |
| 30 to 39: | | | | | | |
| Male | 68 | .71 | 8,437 | 407 | 8,437 | 407 |
| Female | 61 | .71 | 8,552 | 370 | 8,552 | 370 |
| 40 to 49: | | | | | | |
| Male | 68 | .71 | 5,796 | 279 | 5,796 | 279 |
| Female | 61 | .71 | 5,931 | 256 | 5,931 | 256 |
| 50 to 59: | | | | | | |
| Male | 68 | .71 | 4,060 | 196 | 4,060 | 196 |
| Female | 61 | .71 | 4,239 | 183 | 4,239 | 183 |
| 60 to 69: | | | | | | |
| Male | 68 | .71 | 2,510 | 121 | 2,510 | 121 |
| Female | 61 | .71 | 2,764 | 119 | 2,764 | 119 |
| 70 and up: | | | | | | |
| Male | 68 | .71 | 1,356 | 65 | 1,356 | 65 |
| Female | 61 | .71 | 1,638 | 71 | 1,638 | 71 |
| Total | | | 150,104 | 5,208 | 138,456 | 5,053 |
| Total: | | | | | | |
| FAO Reference Protein (metric tons per day) | | | | 5,208 | | 5,053 |
| FAO Reference Protein (grams per capita per day) | | | | 35.4 | | 36.5 |
| Protein of NPU of 65 (metric tons per day) | | | | 8,180 | | 7,783 |
| Protein of NPU of 65 (grams per capita per day) | | | | 54.5 | | 56.2 |

[1] WHO Tech. Report Series No. 301, Protein Requirements.
[2] ICNND Nutrition Survey Data for North East Brazil and other Latin American countries.
[3] Includes 1.7 gm/kg for infant protein requirement plus an allowance for pregnancy using FAO procedure.
[4] See population projection tables and footnotes.

# CHAPTER 2

# PROJECTED TRENDS OF TRADE IN AGRICULTURAL PRODUCTS

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## Contents

| | | Page |
|---|---|---|
| 2.1.0 | Summary | 139 |
| 2.2.0 | Introduction | 142 |
| 2.3.0 | Current World Trade and Agricultural Policies | 142 |
| 2.3.1 | The United States | 142 |
| 2.3.1.1 | Lower Market Prices | 143 |
| 2.3.1.2 | P.L. 480 Exports | 143 |
| 2.3.1.3 | East-West Trade | 144 |
| 2.3.1.4 | Prices and Quantities | 145 |
| 2.3.1.5 | United States Import Programs | 146 |
| 2.3.2 | Other Developed Countries | 148 |
| 2.3.2.1 | European Economic Community | 148 |
| 2.3.2.2 | Other Countries | 149 |
| 2.3.3 | Developing Countries | 150 |
| 2.3.4 | International Commodity Trade Institutions | 156 |
| 2.4.0 | World Trade in Agricultural Products | 158 |
| 2.4.1 | Projection to 1970 | 158 |
| 2.4.1.1 | Developed Countries | 160 |
| 2.4.1.2 | Developing Countries | 160 |
| 2.4.1.3 | Wheat Outlook for 1970 | 161 |
| 2.4.1.4 | Rice Outlook for 1970 | 163 |
| 2.4.1.5 | Coarse Grain Outlook for 1970 | 163 |
| 2.4.1.6 | Soybean Outlook for 1970 | 165 |
| 2.4.2 | Projections to 1980 | 165 |
| 2.4.2.1 | Recent Trends | 172 |
| 2.4.2.2 | Improved Disappearance Levels | 174 |
| 2.4.2.3 | Accelerated Agricultural Development | 174 |
| 2.4.2.4 | "Adjusted Trends" Projection | 175 |
| 2.4.2.5 | Wheat | 175 |
| 2.4.2.6 | Rice | 176 |
| 2.4.2.7 | Coarse Grains | 176 |
| 2.4.2.8 | Total Grains | 177 |



Previous Page Blank

Page

2.5.0 Point Directions for Agricultural and Trade Policy ---- 177
2.5.1 Implications for the Developing Countries ------ 177
2.5.1.1 Alternatives ---------- 179
2.5.1.2 Production Increase, Better Distribution Favored ---------- 180
2.5.1.3 Could Improve Income Distribution ---- 182
2.5.1.4 United States Role ---------- 183
2.5.1.5 Process a Long One ---------- 183
2.5.1.6 Food Aid Impact on Recipients -------- 183
2.5.1.7 World-Wide Exchange Necessary ------ 184
2.5.2 Implications for the Industrialized Nations ----- 184
2.5.2.1 The Reduction of Barriers to Markets for Primary Products ---------- 186
2.5.2.2 The Organization of Concessional Sales -- 187
2.5.3 Implications for the United States ---------- 188

# 2.0 PROJECTED TRENDS OF TRADE IN AGRICULTURAL PRODUCTS

## *2.1.0 Summary*

While most developing countries have increased their agricultural output, increases in production have not kept pace with rising consumption. This has been made possible by rising net imports from developed countries, largely on the basis of concessional sales from the United States.

Increasing world food production is, in part, dependent upon having markets available to producers. It is through trade that world prices and market opportunities are reflected to food producers, thus providing incentives and means for expanding output. Many trade and agricultural policies tend to emphasize national self-sufficiency and to employ protective mechanisms which inhibit freer trade.

If per capita food consumption and the quality of human nutrition in the developing free world are to rise at a more rapid rate than in recent years, a combination of the following, all of which appear to be possible, will need to occur in the developing countries:

1. Decrease population growth rates.
2. Increase agricultural production and productivity more rapidly than at present.
3. Increase per capita income more rapidly than current rates of advance.
4. Accelerate commercial trade in food with some interim expansion of food aid through increased participation of other developed countries.

The fundamental problem is how to achieve total economic growth—to raise productivity and increase the purchasing power of the people. To accelerate development, the agricultural complex of farms, industries, services and public policies is of critical concern because:

1. Improved productivity in agriculture is essential to self-sustained growth.
2. Most developing countries have the potential for increasing both agricultural production and the ability of their people to acquire food.
3. This sector employs more than 50 percent of the labor force.

4. A substantial portion of the low income people are rural residents.

Analysis of trade and agricultural policies of developed and developing countries suggests that:

1. Economic and technical assistance from developed countries to support more rapid economic development is an essential pre-condition to improvement in human nutrition and living standards in developing nations.

2. To increase the rate of economic development and to improve world efficiency in agricultural production, countries and areas should concentrate on products in which they have or can develop a comparative advantage. This calls for freer trade, not for narrow national self-sufficiency or tightly protected regional trading blocs. Specifically, the United States should further liberalize its own tariff and quota policies on agricultural products and should continue to press for freer access to the European Economic Community (EEC) and other regional trading blocs by non-members. To the extent that common markets are a step toward freer trade to the world as well as to their members, they should be encouraged.

3. Because food exports to developing countries on concessional terms will be required for some years to come to accelerate overall economic growth:

*a.* Food aid and storage of reserve stocks of key foods should be the joint responsibility of the several developed nations. Most actual food aid will be bilateral but discussions and planning with respect to cooperation in the organization and financing of concessional sales should take place in a multi-lateral framework.

*b.* Food aid should be administered to provide maximum incentives to the developing countries to increase production by investing in their own agriculture. (This may mean higher, not lower food prices in recipient countries. Food aid should not be used to depress prices received by producers.)

4. United States concessional trade (food aid) should:

*a.* Be conditioned on implementation of self-help requirements.

*b.* Encourage reduction or removal of export taxes on agricultural products and taxes on imports of agricultural inputs in recipient countries.

c. Be motivated by objectives other than that of disposing of surpluses.

5. In connection with United States aid and self-help policies, the developing countries should be encouraged to expand their food trade with one another as well as with the developed world. Reductions in

barriers to the movement of food and agricultural production inputs will encourage production, lower costs, and stimulate expansion in line with comparative advantage.

6. Expansion of concessional sales over an indefinite period is not in the best interest of either donor or recipient nations nor is it physically possible. Long-term, hard bases of trade are not established. Production capability of donor nations is expanded at the donor nations' expense, not on the basis of comparative advantage or viable markets. Recipient nations may use such imports as a crutch to avoid the consequences of unchecked population growth, an unproductive agriculture, and irresponsibility in accelerating domestic economic growth.

7. The United States and other developed countries should carefully review their import policies with respect to potential export commodities of developing countries to reduce impediments to increased consumption and imports.

8. The world capacity to produce wheat may again in the future be larger than the economic demand for the crop. Thus, it is important that world price policies on wheat be set so that they can be competitive with feed grains. Further, if Canada, Australia, and Argentina are to continue to expand their wheat exports, these exports will probably have to move in part on a concessional basis. The United States should not withdraw from the commercial markets and leave them to competitors while it provides most of the food aid.

9. United States producers of major commodities have an important stake in the viable commercial world markets for products which can be used to meet international competition. Among these products are the coarse grains, wheat, cotton, and plant proteins, especially soybeans. Our trade and agricultural policies must be such that the United States remains aggressive in the expanding commercial markets of the world: (a) to assure continued growth in efficiency and productivity in the United States and (b) to obtain the foreign exchange with which to buy commodities for which foreign producers have greater comparative advantage.

10. East-West trade appears to be increasing; the ability of the developed to help the developing will be conditioned by the Eastern world. If the Eastern world is an active buyer in the commercial market, its purchases will likely take priority over concessional sales. Therefore, improved international intelligence concerning crop conditions and plans to buy and sell is needed to make complex international marketing more predictable.

11. International commodity organizations should maintain and intensify their efforts to forecast supply and demand conditions for their commodities and they should provide technical help to shift production to items presently or prospectively in short supply.

### *2.2.0 Introduction*

World food production could rise to levels adequate to feed all people while malnutrition remained the unfortunate lot for many. Distribution within countries and among countries and people is not automatic. Trade is one means by which stocks abundant in one country are exchanged directly or multilaterally for goods and services of other nations. All of the trading partners stand to benefit from international trade, excuted in accord with the principle of comparative advantage.

In this analysis we:

—Describe the current food situation in the United States and the developed as well as the developing world with respect to trade, agricultural policy, and commodity trade agreements.

—Present projections of world trade in agricultural products under differing assumptions with respect to growth. In essence, this is an attempt to forecast the magnitudes of trade potential, primarily in terms of cereal grain equivalents, on both concessional and commercial bases.

—Suggest directions in which trade and agricultural policy should move if a primary objective is to accelerate growth and productivity in agriculture as a part of balanced development.

### *2.3.0 Current World Trade and Agricultural Policies*

#### *2.3.1 The United States*

Important current United States agricultural policies and programs from the standpoint of international trade include:

*a.* Aggressive efforts to expand commercial exports and develop foreign markets.

*b.* Sustained initiative for multilateral action through the reduction of tariffs and non-tariff barriers to trade.

*c.* Programs and policies associated with reductions in domestic stocks of major surplus commodities.

*d.* The closer alignment of United States prices of some farm products to prices in international markets.

*e.* Changes in P.L. 480 and food aid programs.

*f.* Import protection policies on certain agricultural products.

Export expansion activities have been a significant factor in the doubling of United States exports over the past decade. Federal Government programs of acreage diversion, concessional sales, and expansion of exports have been instrumental in reducing stocks of wheat, feed grains and dairy products. However, cotton, tobacco, and peanut stocks continue at relatively high levels. In 1965, approxi-

mately 57 million acres were diverted from production under various programs. Several features of the programs are discretionary, thereby permitting a certain degree of flexibility of response to meet changing supply and demand conditions.

*2.3.1.1 Lower Market Prices.* United States market prices for some farm products have been aligned more closely with prices in international markets in recent years. Adjustments were first made on feed grains with subsequent changes for wheat and cotton.

When direct subsidies of feed grain exports were stopped, the legislation was changed to provide "cooperators" with a combination of price support loans, price support payments, and diversion payments for voluntarily diverting acreage from production. These program provisions attempt to protect the income of cooperators, while at the same time making possible the reduction of support prices and lower market prices.

Wheat legislation has been modified to bring United States market prices closer to prices in world markets. At the same time, the mechanism for payment of export subsidies has been continued. Export payments averaged about 30 percent of the export value in 1966 (Table 2–1).

TABLE 2–1.—*Average per unit export value and estimated export payment for selected agricultural commodities, July–June 1965–66*

| Commodity | Unit | Average export value [1] | Average export payment (preliminary) |
|---|---|---|---|
| Wheat (grain) | Bushel | 1.62 | 20.48 |
| Cotton, upland | Pound | 0.25 | 2.06 |
| Rice, milled | Hundredweight | 7.26 | 21.84 |
| Peanuts | Pound | 0.11 | 2.07 |

[1] Derived from quantities and values reported by the Bureau of the Census.
[2] Payment-in-kind.
[3] Estimated differential between domestic market price and CCC export sales price.

Comparable adjustments in support prices and, in market prices in turn, have not been instituted for dairy products, rice, peanuts, or tobacco. During the past year, rice export subsidies have been substantially reduced because of the sharp rise in international market prices. Export payments on dairy have been discontinued as domestic markets absorbed all output at market prices.

*2.3.1.2 P.L. 480 Exports.* Legislation recently passed by Congress makes several significant changes in the program. For example, the legislation:

1. Authorizes sale and delivery of commodities not in surplus.

2. Emphasizes self-help by recipient countries in increasing food production.

3. Directs that a transition be made from sales for foreign currencies to sales for dollars.

The value of food shipments under P.L. 480 has been relatively stable, ranging from $1.53 billion to $1.67 billion over the past 5 years. More of the P.L. 480 shipments are now going to low income countries. In 1965, about 85 percent of the P.L. 480 shipments went to countries with 1960 per capita incomes under $200. Shipments under long-term credits have increased rapidly. In the past year, about two-thirds of P.L. 480 shipments were in the form of wheat, wheat flour, and grain sorghuns. Over 70 percent of wheat exports were made under P.L. 480 (Table 2–2).

TABLE 2–2.—*United States agricultural exports of selected commodities, 1965*

| Commodity | Total U.S. exports (million dollars) | Percent of production exported [1] | Percentage of exports under major Government programs [2] |
|---|---|---|---|
| Wheat and wheat flour | 1,184 | 55 | 70 |
| Feed grains | 1,134 | 16 | 7 |
| Soybeans | ------ | [3] 48 | ------ |
| Oilseeds and products | 1,156 | ------ | 12 |
| Tobacco | 383 | 25 | 16 |
| Cotton | 486 | 30 | 23 |
| Dry milk | 126 | 43 | 49 |

[1] Based on 1965–66 data.
[2] Based on value data, Public Law 480 and AID.
[3] Including bean equivalent of soybean oil for export.

Source: U.S. Department of Agriculture Economic Research Service. Foreign agricultural trade of the United States. July and September 1966.

Most of the P.L. 480 shipments have continued to be under Title I (sales for local currencies). In several countries the local currencies held by the Federal Government far exceed the anticipated levels of United States local currency needs.

*2.3.1.3 East-West Trade.* In 1963–64 imports of wheat by Communist China and the USSR reached a peak of 20.6 million metric tons and were at a similar level in 1965–66. The United States has been largely excluded from direct participation in these sales. A significant factor that limited United States wheat exports to the USSR was the requirement that one-half of the sales of wheat sold to these areas be shipped on United States flagships. This implies a freight cost about $4 per metric ton higher than for purchases from Canada. There have, however, been indirect effects of the Sino-Soviet Bloc purchases of wheat on United States wheat exports.

The expanded volume of East-West trade in industrial as well as agricultural products raises substantial trade policy questions for the Western world.

*2.3.1.4 Prices and Quantities.* World export prices of agricultural products declined about 20 percent from the early 1950's to 1962. Price changes since 1962 have been mixed. Export prices of grains except for rice have remained near the 1962 levels (Table 2–3).

TABLE 2–3.[1]—*Average unit value of specified United States export commodities, fiscal years, average 1950–54, annually 1960–66; and July 1965 and 1966* [2]

[Dollars per metric ton]

| Fiscal year | Corn | Wheat [3] | Rice | Cotton |
|---|---|---|---|---|
| 1950–54 average | 68.92 | 78.05 | 195.17 | 823.62 |
| 1960 | 51.07 | 62.79 | 150.22 | 532.80 |
| 1961 | 49.29 | 64.04 | 139.89 | 570.68 |
| 1962 | 49.00 | 65.76 | 143.93 | 596.62 |
| 1963 | 50.47 | 66.82 | 148.40 | 582.62 |
| 1964 | 53.65 | 65.81 | 151.49 | 563.53 |
| 1965 | 54.94 | 63.72 | 157.11 | 555.41 |
| 1966 | 54.69 | 60.04 | 160.51 | 507.89 |
| July: | | | | |
| 1965 | 55.31 | 60.26 | 164.24 | 586.43 |
| 1966 | 56.30 | 62.42 | 167.11 | 571.00 |

[1] Compiled from official records, Bureau of the Census.
[2] Calculated by dividing value by quantity.
[3] Includes grain equivalent of flour.

This has contributed to an important continuing deficit in the United States balance of payments. Commercial agricultural exports expanded by $1.3 billion from 1960 to 1965 (Table 2–4) while concessional sales of agricultural products have made possible substantial

TABLE 2–4.—*Agriculture's contribution to the balance-of-payments, calendar years 1960–65*

[Millions of dollars]

| Item | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 |
|---|---|---|---|---|---|---|
| Commercial agricultural exports | 3,361 | 3,423 | 3,483 | 3,972 | 4,595 | 4,699 |
| Plus: imputed dollar export earnings from exports of agricultural products under specified Government programs [1] | 128 | 163 | 163 | 217 | 328 | 363 |
| Total agricultural dollar earnings: actual plus imputed | 3,489 | 3,586 | 3,646 | 4,189 | 4,923 | 5,062 |
| Less: agricultural imports for consumption | 3,824 | 3,691 | 3,868 | 4,011 | 4,082 | 4,088 |
| Net contribution to the balance-of-payments attributable to agricultural merchandise trade | −335 | −105 | −222 | 178 | 841 | 974 |

[1] Foreign currencies and commodities utilized in lieu of dollars by U.S. Government agencies abroad may be considered for balance-of-payments accounting purposes as a dollar expenditure financed by an equivalent commercial export of farm products.

Source: Kruer, G. R. Agricultural exports continue to help balance of payments. U.S. Dep. Agr. Econ. Res. Serv. Foreign Agr. Trade of the U.S.: 47–52. September 1966.

United States procurement of foreign supplies and services with foreign currencies. Returns from concessional sales in some rapidly growing countries such as Israel, Spain, Taiwan, and Greece have been largely converted from P.L. 480 to commercial imports.

*2.3.1.5 United States Import Programs.* The United States has a relatively liberal policy with regard to imports of tropical agricultural products. About one-half of their agricultural imports are free of duty. These are largely the complementary imports, such as coffee and bananas (Table 2–5). The ad valorem equivalent of the other half of the commodities averages close to 10 percent. Some import quotas are imposed. The major ones are applicable to sugar and, under Section 22 of the Agricultural Adjustment Act of 1933 as amended, to wheat and wheat flour, cotton, peanuts, and certain dairy products. (Table 2–6).

TABLE 2–5.—*U.S. import duties on selected products*

| *Product* | *Tariff rate* |
|---|---|
| Cattle, fresh chilled or frozen | $0.03 per lb. |
| Goats and sheep (except lambs), fresh chilled or frozen | $0.025 per lb. |
| Rice: | |
| Paddy | $0.0125 per lb. |
| Milled | $0.025 per lb. |
| Broken | $0.003125 per lb. |
| Wheat: | |
| For milling | $0.21 per bu. |
| Flour | $0.52 per cwt. |
| Corn for feed | $0.25 per bu. |
| Vegetable oils: | |
| Peanut | $0.04 per lb. |
| Olive | $0.0325–$0.0475 per lb. |
| Soybean | $0.035 per lb. |
| Cottonseed | $0.03 per lb. |
| Cotton (staple 1⅛ inches +) (linters and staple under 1⅛ inches enter tariff free). | $0.035–$0.0175 per lb. |
| Coffee | Free. |
| Cocoa: | |
| Unsweetened | $0.0075 per lb. |
| Sweetened (in bars or blocks weighing 10 lbs. or more) | $0.01 per lb. |
| Bananas | Free. |
| Tomatoes: | |
| Natural | $0.015 per lb. |
| Prepared or preserved | 21 percent. |

Source: Corder, L., and Parisi, A. A. U.S. import duties on agricultural products 1959. U.S. Dep. Agr. Handbook 143, 148 p. September 1959.

TABLE 2–6.—*U.S. import quotas, selected agricultural products*

| | |
|---|---|
| Wheat | 800,000 bu. |
| Wheat products | 4,000,000 lbs. |
| Cotton: | |
| Long staple | 45,656,420 lbs. |
| Short staple | 14,516,882 lbs. |
| Cotton waste | 5,482,509 lbs. |
| Cotton products | 1,000 lbs. |
| Peanuts | 1,709,000 lbs. |
| Butter | 707,000 lbs. |
| Dried skimmed milk | 1,807,000 lbs. |
| Dried whole milk | 7,000 lbs. |
| Cheddar cheese | 2,780,100 lbs. |
| Edam and Gouda cheese | 9,200,400 lbs. |
| Blue-mold cheese | 5,016,999 lbs. |
| Italian-type cheese | 11,500,100 lbs. |

Source: Corder, L., and Parisi, A. A. United States import duties on agricultural products 1959. U.S. Dep. Agr. Handbook 143, 148 p., September 1959.

One of the recent changes in United States agricultural import policy for agricultural products was the beef import legislation of 1964. This legislation applies only to fresh, chilled, and frozen beef; veal; mutton; and goat meat. Although the duties on these products were not changed, contingency quotas on imports were established. These quotas are to be applied if imports are forecast to exceed base quotas by at least 10 percent. To date, meat imports have not been high enough for the quotas to become operative.

Another important aspect of United States programs affecting imports has been the lowering of domestic support prices while protecting producer incomes with direct payments. Such programs are of special importance to cotton. In the past, when United States domestic prices were well above world levels, informal arrangements were made to restrain textile imports. The lower, current domestic market prices should discourage textile imports. Producer payments are also made to wool growers, but domestic prices of wool are maintained at levels higher than world prices by means of substantial import duties.

Only a small part of the world supply of sugar is sold at world prices. Most sugar is consumed in the countries where it is produced, and generally growers and processors are paid much higher prices than the world levels. Only about 30 percent of world sugar production moves in international trade, mostly under negotiated or controlled price systems. During recent years, the world price of sugar has fluctuated from over 10 cents to less than 2 cents per pound.

The United States sugar system involves limitations on total supplies available to local consumers and the control of supplies by quotas allocated to foreign countries and domestic producers. Domestic growers receive payments at a basic rate of approximately $\frac{9}{10}$ cent per

pound of recoverable sugar. Domestic prices are maintained at relatively stable levels, which in most years are considerably higher than world prices. In August 1966 the New York spot, duty paid, price was 7 cents per pound, while the world market price dropped to 1.6 cents per pound, f.o.b. Carribean. Sugar purchases from foreign countries are made at United States prices less the duty of ⅝ cent per pound.

*2.3.2 Other Developed Countries*

Agricultural protectionism in many of the developed countries other than the United States has increased during the past five years. The EEC has adopted policies designed to give their producers relatively high prices and to insulate them from competition from imports. The United Kingdom continues to pursue self-sufficiency objectives, and if European Free Trade Area (EFTA) countries should accede to the EEC the scope of increased protection may be considerably enlarged. Japan, Canada, Australia, and New Zealand retain highly protective policies.

*2.3.2.1 European Economic Community.* Coverage of the Common Agricultural Policy of EEC now applies to approximately 90 percent of the agricultural production in the Community. In addition, agreement has been reached on provisions for financing the costs of agricultural programs and the level of common prices in the single market stage. These common prices are to become effective during the period November 1966 to July 1, 1968.

The EEC system holds a price umbrella over domestic production, permitting it to move into marketing channels at approximately the support price level without facing competition from imported products. Imports are assessed a levy, which is sufficient to raise the price of the imported products to the Community level. Subsidies approximately equal to the levy facilitate exports, and thus bridge the gap between the Community and world prices on exports as the levy does on imports. Foreign supplies are permitted to fill residual requirements. With the implementation of EEC regulations, EEC prices of wheat, corn, cattle, and poultry would be from 40 to 70 percent above world prices of these products. Sugar would be supported at about $0.09 per pound (Table 2–7). In contrast to the United States policy, sugar imports are purchased at world prices.

The EEC has closely integrated agricultural price support and trade policy. Consequently, there is an almost complete absence of flexibility for policy makers to make adjustments in one without directly affecting the other. This is one of the stated reasons that the Community has found it difficult to make offers in the Kennedy Round that would result in significant trade liberalization.

TABLE 2–7.—*Estimated 1966 prices for selected products in countries participating in the European Economic Community if CAP policies were not implemented compared with world prices*

[Prices in U.S. dollars]

| Product | World price [1] | EEC import | Estimated levy | Ad valorem (equivalent percent) |
|---|---|---|---|---|
| Wheat ..... metric tons | $60.00 | $103.95 | $43.95 | 73 |
| Barley ..... do | 63.30 | 88.55 | 25.25 | 40 |
| Corn ..... do | 62.15 | 88.00 | 25.85 | 42 |
| Poultry meat ..... pounds | .27 | (2) | .11 | 41 |
| Pork carcasses ..... hundredweight | 25.10 | (2) | 6.08 | 24 |
| Live cattle ..... do | 21.00 | 30.05 | 8.95 | 43 |

[1] Assumed approximately equal to July–August 1966 levels, prices in terms of EEC standard quality.
[2] Considered as grain-derived products with no announced price objective. Levies are calculated on the basis of feed price differentials between the Community and world markets plus an element for protection.

Source: ERS: FDTD: IMTB.

The border treatment accorded agricultural imports into the Community is generally non-discriminatory for temperate zone products among third country suppliers. Preferences, however, are granted to States associated with the Community. Among these are Greece, Turkey, and 18 Associated Overseas Countries and Territories, largely former French Colonies in Africa. Association agreements with other European and African States are in various stages of negotiation.

These preferences have substantial implications for tropical products. Discrimination has developed in the case of bananas, for example. Previous to the establishment of the EEC, Germany had a zero duty as does the United States; France had 20 percent; and Italy a 50 percent duty, giving preference to their associated territories. The common external tariff on bananas is presently planned to be 20 percent.

*2.3.2.2 Other Countries.* Other developed countries have continued to push for increased self-sufficiency. For example, since the first part of the 1950's, the United Kingdom agricultural policies have employed deficiency payments to protect farm income with internal market prices permitted to reflect prices in international markets. Grants and subsidies are also made for such activities as fertilizer use. Deficiency payments and production grants and subsidies have been tremendously important to net farm income. Together they were equivalent to over 60 percent of net farm income in 1963–64 and 1964–65.

The United Kingdom degree of self-sufficiency for major products has increased. For meat, it has gone from 60 percent in the 1952–53/1954–55 period to 68 percent in the 1963–64/1965–66 period. For grains, it has gone from 54 percent to 60 percent between the same periods.

Bilateral arrangements have been emphasized extensively by the United Kingdom to give protection to internal markets and to restrain

any substantial increases in Exchequer expenditures for domestic agricultural programs. Further, increases in the protection offered to producers of grains and meats would be expected if the United Kingdom acceded to the EEC.

Japan has had a very tightly controlled import system in terms of volume of commodities imported, as well as on the sources of the imports and monopolistic units handling imports. There has been substantial liberalization in restrictions on imports of agricultural products, but important restrictions remain. In addition, price support programs to promote maximum self-sufficiency and to support farm income have been continued. Producer prices are generally well above prices in international markets. For example, producer prices for wheat are over $4.00 per bushel, while producer prices for rice have been over $12.00 per cwt.

Generally, Canada and Australia have lower levels of producer prices than the United States. The general economic conditions in those countries, the dependence on international markets, and more limited national funds have dictated alignment of internal producer prices to prices in international markets. Even so, supplies and prices of international markets are not generally allowed to be fully operative in domestic markets. While Canada, for example, has only a modest duty on wheat, all wheat imports must be licensed and licenses are not issued, resulting in feed grains entering Canada without a license. However, a program of feed grain subsidies is designed to prevent displacement of Canadian grain with imports from the United States.

The Canadian Wheat Board is illustrative of the monopoly type boards utilized by other exporting countries. All marketings of wheat in the Prairie Provinces are made to the Board which determines if a schedule of deliveries from individual producers is required and establishes the initial and subsequent payments to be made to producers. In turn, the Board handles all sales for domestic use and for exportation, engaging in commodity transactions with Communist Bloc countries as well as with private traders of other countries.

*2.3.3 Developing Countries.*

Trade regulations relating to food in the developing countries include a maze of exchange controls, tariffs duties, and surcharges, export taxes, quotas, bilateral arrangements, marketing board and State trading agencies, and import and export licensing requirements.

Export earnings from the major tropical zone agricultural products are little higher now than during the early 1950's. A slow growth in volume has been offset by a decline in prices. In contrast, export earnings of temperate zone agricultural products are now substantially above the early 1950's, reflecting a much more rapid growth in the

volume of exports which has more than offset the decline in export prices.

Both tropical and temperate zone agricultural export prices have shown a downward trend, although in the last year or so price averages of temperate zone products have strengthened (Table 2–8).

TABLE 2–8.—*Change in agricultural export prices for selected items during recent years* [1]

| Commodity | Annual change as a percent of average unit value [2] | | Average deviation from trend line as a percent of average unit value | |
|---|---|---|---|---|
| | 10-year trend (1954–63) | 17-year trend (1947–63) | 10-year trend (1954–63) | 17-year trend (1947–63) |
| Wheat | −0.3 | −2.7 | 2.6 | 7.8 |
| Corn | −2.6 | −3.6 | 4.5 | 9.1 |
| Soybeans | −1.1 | −2.2 | 6.8 | 9.0 |
| Rice (milled) | −1.7 | −2.4 | 7.1 | 10.2 |
| Coffee | −8.5 | −.2 | 7.2 | 25.7 |
| Cocoa | −7.8 | −.6 | 14.9 | 20.0 |
| Sugar (raw) | 3.9 | 1.0 | 13.2 | 10.7 |

[1] Unit values per metric ton.

[2] Annual change is measured by trend coefficient in $Y=a+bX$.

Source: Goolsby, O. H., Agricultural exports from temperate and tropical zones, changes in prices and foreign exchange earnings, 1947–63. U.S. Dep. Agr. Foreign Agr. Econ. Rep. No. 29 Mar. 1966.

The year to year fluctuations in prices of most of the major tropical products have been much greater than those of wheat, feed grains, and other temperate zone products (Table 2–9). Most of the exports of the tropical zone products go to developed countries, where price and income elasticities are low. Also, storage and export policies of the developed countries have tended to minimize the price fluctuations of the temperate zone export products.

Internal food prices in relation to other consumer prices were approximately at about the level of the mid-1950's during the early 1960's in most of the developing countries (Table 2–10). In the last two years, however, there has been a discernible increase in the relative prices of food in most of the developing countries of the Far East and Near East. Trends in Latin America and Africa apparently have been mixed. Increases in internal prices provide incentives for producers in several of these countries.

Needs to maximize foreign exchange earnings and to minimize foreign exchange expenditures are the prime considerations dictating trade policies of the developing countries. Related considerations include: (1) the separation in production, marketing, and consumption of the principal export products—such as coffee, jute, or bananas—from the food products—such as beans and grains—and, (2) the lack of financial resources to meet investment needs or to finance price support programs.

TABLE 2-9.—*Index of export prices of major agricultural commodities* [1]

[1957-59=100]

| Year | Tropical zone commodities [2] | Temperate zone commodities [3] | All agricultural exports |
|---|---|---|---|
| 1947-51 average | 97 | 125 | 110 |
| 1952 | 113 | 123 | 116 |
| 1953 | 107 | 123 | 110 |
| 1954 | 119 | 114 | 112 |
| 1955 | 110 | 108 | 106 |
| 1956 | 104 | 107 | 103 |
| 1957 | 105 | 108 | 106 |
| 1958 | 99 | 95 | 99 |
| 1959 | 95 | 97 | 96 |
| 1960 | 94 | 98 | 97 |
| 1961 | 89 | 96 | 93 |
| 1962 | 87 | 98 | 92 |
| 1963 | 96 | 103 | 99 |
| 1964 | 96 | 108 | 102 |
| 1965 | 90 | 104 | 100 |

[1] Unit values per metric ton.

[2] Includes rice (milled), bananas, copra, peanuts (shelled), palm oil, coffee, tea, cocoa, sugar (raw), rubber (natural), jute.

[3] Includes wheat, wheat flour, barley, corn, bacon, ham, salted pork, powdered milk, butter, cheese, eggs (in the shell), soybeans, wool (greasy).

Source: For major tropical and temperate zone commodities, data developed to construct chart in: Goolsby, O. H., Agricultural exports from temperate and tropical zones, changes in prices and foreign exchange earnings, 1947-63. U.S. Dep. Agr. Foreign Agr. Econ. Rep. No. 29. Mar. 1966. For all agricultural exports: Food and Agriculture Organization of the United Nations. State of food and agriculture. 1964-66 issues.

TABLE 2-10.—*Food prices relative to all prices in the Consumer Price Index in selected countries*

[1954-56=100]

| Country [1] | Year 1960 | Year 1963 | Year 1964 | Year 1965 |
|---|---|---|---|---|
| Costa Rica (San Jose) | 98 | 95 | 97 | 96 |
| Sudan | 95 | 98 | 101 | [2] 102 |
| Israel | 97 | 94 | 91 | 93 |
| Thailand (Bangkok) | 101 | 105 | 106 | [2] 107 |
| Brazil (Sao Paulo) | 104 | 101 | 105 | 98 |
| Venezuela (Caracas) | 93 | 96 | 98 | 99 |
| Colombia (Bogota) | 101 | 103 | 110 | 106 |
| Mexico (Mexico City) | 100 | 99 | 98 | 99 |
| Taiwan | 108 | 100 | 103 | 105 |
| Iran | 95 | 99 | 101 | 103 |
| Philippines (Manila) | 104 | 112 | 117 | 112 |
| Turkey (Istanbul) | 102 | 107 | 105 | 107 |
| India | 99 | 101 | 101 | 104 |
| Argentina | 118 | 113 | 117 | 117 |
| Pakistan (Karachi) | 106 | 108 | 111 | 113 |
| United Arab Republic | 103 | 107 | 110 | 120 |
| Nigeria (Lagos) | 96 | 93 | 93 | 92 |
| Chile | 97 | 107 | 108 | 110 |

[1] Arranged by rate of change in total crop output, 1955-63.

[2] Sudan, 11 months; Thailand, 10 months.

Source: United Nations. Monthly Bulletin of Statistics XV(12), Dec. 1963; XIX(1), Jan. 1965; and XX (5), May, 1966.

These considerations have led to: (1) agricultural product import substitution policies involving quotas, licenses, and relatively high duties on deficit agricultural products, thus enabling higher domestic prices for these agricultural commodities, (2) regulations that increase the internal prices of consumption and industrial goods generally and agricultural inputs in particular, and (3) export taxes (or equivalent pricing devices) that reduce the internal product prices of basic domestic and export products to levels below prevailing world prices.

In a number of cases, export subsidies are used, but in most cases these relate to minor export commodities. In recent years, some countries have also instituted subsidies on fertilizer and some other agricultural inputs, particularly in countries where food supply conditions have been critical.

Marketing boards—such as the Wheat Marketing Board of Argentina—or State trading agencies—such as employed in Taiwan—administer export and domestic pricing and trade policies for the principal export products. This form of trading reflects in part the emphasis in developing countries on national planning and initiative. Their activities are generally directed toward increased and stabilized foreign exchange earnings. The degree and extent of control varies widely. In some cases, it is largely assistance to exporters. In many cases, however, it involves complete control of procurement, pricing, and internal distribution.

Export taxes and retentions are used in many countries on the principal export products to generate revenue and foreign exchange. Examples include wheat, wool, beef, and mutton in Argentina; coffee in Brazil and Colombia; oil palm, peanuts, and other major agricultural exports in Nigeria; rice in Thailand; and jute, rice, peanut oil, and other commodities in India.

Many of the developing countries also use bilateral arrangements as incentives to stimulate agricultural exports. Some—Turkey, Pakistan, and the Philippines—have used barter arrangements. In other cases, bilateral arrangements with developed countries provide for the export of products at stabilized prices, often above world market prices. The United States, for example, provides an assured and profitable market to certain countries for specified quantities of sugar. The United Kingdom employs similar arrangements. France has over the years offered certain preferences in their markets to products from their associated territories.

Generally, tariffs are higher on processed products than on raw materials. The developing countries have increased their capacity to process both export and import products. This capacity is likely to increase, heightening the conflict with the needs of the developing countries.

For subsistence products, trade policies reflect a combined consideration of consumer prices, producer's incomes, needs for foreign exchange, and the availability of regional supplies.

Import licensing is prevalent, thereby making it possible for the Government to control the allocations of scarce foreign exchange. A combination of import quotas, exchange conversion rates, and duties on grains are found in many countries—such as Colombia, Brazil, Ecuador, and Chile—where domestic supplies are not adequate. These restrictions result in higher domestic producer prices.

With some exceptions, however, the level of price supports for grains is lower in the developing importing countries of Asia, Latin America, and Africa than in the developed importing countries of Western Europe (Table 2–11). Generally, this is because the higher level of economic activity in the developed countries makes them better able to bear the costs of high price support programs. Also, the developing countries are under greater pressure to maintain low consumer food prices because of low per capita income and unemployment.

In those developing countries where domestic supplies of grain and other food crops are adequate, export taxes and retentions commonly result in domestic producer prices below the world level. In the case of grains and related food crops, problems of assembling and grading also have reduced export opportunities.

As a result of the trade and domestic policies, the price of fertilizer and other production inputs in many of the developing countries has been high relative to the product prices for most food crops. For example, the ratio of fertilizer prices to rice prices in India in 1964 was about 4 times that in Japan and about 2½ times that in the United States. (Table 2–12).

Economic integration in the developing regions has made greatest progress in Latin America. A General Treaty of Central American Economic Integration was signed in December, 1960. The Treaty provided for the immediate establishment of a free trade area, to be followed within five years by a Common Market and Customs Union with a single external tariff. The latter has been accomplished for substantially all intra-regional trade, with the exception of the major agricultural products of the area. Most agricultural products are either exempt from free-trade treatment or subject to transitional restrictions of varying nature and duration.

A Latin American Free Trade Area was established in 1960. Progress to date has been slower than in the Central American Free Trade Area. Under the terms of the Treaty, a free trade area is to be established over a transitional period of twelve years, while the ultimate goal implicit in the Treaty is the eventual establishment of the Latin American Common Market and the economic integration of all of Latin America. Special provisions are made for agricultural products,

TABLE 2-11.—*Support prices for wheat in selected Title I and developed importing countries and exporting countries, crop years 1954-64*

[Dollars per metric ton]

| Country | 1954-58 average | 1959-63 average | 1963 | 1964 |
|---|---|---|---|---|
| IMPORTING COUNTRIES | | | | |
| Title I countries: | | | | |
| Egypt* | 78.3 | 70.4 | 61.4 | 61.4 |
| Yugoslavia | [1] 48.1 | 55.8 | 64.0 | 82.6 |
| Chile* | 64.5 | 62.6 | 58.8 | 74.2 |
| Pakistan | 63.9 | 75.8 | 76.1 | 76.1 |
| Tunisia | NA | 99.9 | 99.9 | *80.1 |
| Brazil* | 85.1 | 89.4 | 115.4 | 80.8 |
| Turkey* | 91.0 | 67.5 | 81.2 | 81.2 |
| Morocco | NA | 77.9 | 79.0 | 81.3 |
| Colombia* | NA | 111.3 | 110.2 | 87.4 |
| Greece | 103.5 | 84.7 | 90.0 | 99.9 |
| India | [2] 56.0 | 78.4 | 78.4 | 103.7 |
| Spain* | 96.6 | 91.5 | 102.5 | 111.0 |
| Developed countries: | | | | |
| Denmark | 68.0 | 70.5 | 70.9 | 70.9 |
| United Kingdom | 80.9 | 74.4 | 73.1 | 73.1 |
| Republic of South Africa | 82.3 | 82.0 | 81.2 | 85.5 |
| Belgium | 93.0 | 95.1 | 97.4 | 97.4 |
| Netherlands | 71.1 | 86.0 | 93.0 | 99.6 |
| Italy | 107.3 | 99.0 | 98.4 | 98.7 |
| Sweden | 83.8 | 92.8 | 102.5 | 106.6 |
| West Germany | 97.9 | 104.6 | 110.6 | 110.6 |
| Japan | 99.5 | 110.7 | 119.8 | 124.9 |
| Switzerland | 153.6 | 157.3 | 160.2 | 160.2 |
| Finland | [3] 156.5 | 160.9 | 168.6 | 187.4 |
| EXPORTING COUNTRIES | | | | |
| Argentina | 26.6 | 46.3 | 53.3 | 52.2 |
| Canada [4] | 60.8 | 64.5 | 66.9 | 63.9 |
| Australia | 69.8 | 62.1 | 59.2 | 60.0 |
| United States | 74.6 | 69.1 | 73.5 | [5] 63.2 |
| France [6] | 88.2 | 80.1 | 87.0 | 87.6 |

*Comparability of prices limited because of fluctuations in exchange rates. Local currencies converted to dollars at the official exchange rate. The free or import rate was used for Brazil, Chile, Colombia, and Argentina; Spain until 1959; and Turkey until 1958.

[1] 1957-58 average.

[2] 1954-55 average.

[3] 1956-58 average.

[4] Final payment to farmers.

[5] To the basic price of $1.30 per bushel is added $0.70 per bushel for 45 percent of the crop consumed domestically and $0.25 per bushel for 45 percent of the crop exported.

[6] Until 1962 prices after deduction of taxes; since then intervention prices.

Source: International Wheat Council. World Wheat Statistics; International Wheat Council. Review of the World Wheat Situation, 1963/1964; Food and Agriculture Organization of the United Nations; and U.S. Department of Agriculture, Foreign Agricultural Service.

263-888 O—67——12

TABLE 2-12.—*Ratio of fertilizer prices to wheat and rice prices for selected countries and 1963, 1964 crop years* [1]

| Commodity and country | Ratio of fertilizer prices to commodity price [2] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | N [3] | | $P_2O_5$ [3] | | $K_2O$ [3] | | Average [4] | |
| | 1963 | 1964 | 1963 | 1964 | 1963 | 1964 | 1963 | 1964 |
| Wheat: | | | | | | | | |
| United Arab Republic | 5.41 | 5.14 | 2.92 | (5) | 1.97 | 1.87 | 4.88 | (5) |
| India | 3.77 | 2.99 | 3.17 | 2.51 | 1.34 | 1.06 | 3.62 | 2.79 |
| Japan | 2.32 | 2.11 | 1.97 | 1.82 | .81 | .78 | 1.76 | 1.62 |
| Pakistan | 2.04 | 1.75 | 1.48 | 1.26 | .71 | .61 | 1.81 | 1.56 |
| Spain | 2.71 | 2.72 | 2.02 | 1.90 | .66 | .68 | 2.16 | 2.12 |
| United States | 3.76 | 3.38 | 2.77 | 2.55 | 1.38 | 1.28 | 2.63 | 2.40 |
| Rice (paddy): [6] | | | | | | | | |
| United Arab Republic | 7.16 | 7.16 | 3.86 | (5) | 2.61 | 2.61 | 6.46 | (5) |
| India | 4.25 | 4.66 | 3.57 | 3.91 | 1.51 | 1.65 | 3.97 | 4.35 |
| Japan | 1.59 | 1.51 | 1.35 | 1.30 | .56 | .56 | 1.20 | 1.16 |
| Pakistan | 1.65 | 1.76 | 1.20 | 1.27 | .57 | .61 | 1.47 | 1.56 |
| Philippines | (5) | 3.20 | (5) | 2.56 | (5) | 1.42 | (5) | 2.50 |
| Thailand | 4.10 | 5.25 | 3.31 | 4.32 | 1.85 | 2.22 | 3.56 | 4.55 |
| United States | 2.38 | 2.42 | 1.76 | 1.83 | .88 | .92 | 1.67 | 1.72 |

[1] Crop year is the year the crop was grown. Fertilizer, wheat, and rice prices used were for period fertilizer normally bought, and crops marketed.

[2] Ratios represent kilograms of increased production required to equal cost of a kilogram of fertilizer nutrient.

[3] Fertilizer prices used were prices to producers for principal kind of fertilizer used in the particular country.

[4] Average based on N, $P_2O_5$, and $K_2O$ in ratios used per hectare of arable land as shown in table 35, U.S. Dep. Agr. Foreign Agr. Econ. Rep. No. 27.

[5] Not available.

[6] Milled rice prices converted to paddy, using coefficient of 0.66.

Source: FDTD/EDB. Computed from data in Food and Agriculture Organization of the United Nations Production Yearbook, except U.S. Wheat price 1964–65 from U.S. Department of Agriculture, Economic Research Service.

imports of which may be limited in order to regulate domestic production and supplies. For such agricultural imports as are required to meet domestic deficits, priority is given to LAFTA members over third-country suppliers. In the industrial sector, particular stress is placed on regional integration of agricultural inputs such as farm machinery, fertilizers, and pesticides.

### *2.3.4 International Commodity Trade Institutions*

A broad network of international commodity trade institutions has developed, largely since the end of World War II. In general, these organizations were established to cope with situations of excess supply and depressed prices; they are not now oriented to dealing with problems of food shortage. Obviously, however, they will be affected by any worldwide campaign to increase agricultural production, particularly if shifts in production emphasis are involved; and their cooperation will be needed.

The organization of international commodity trade programs ranges from formal commodity agreements, through less formal arrange-

ments, to the organized international commodity groups whose periodic consultations and confrontations aim to resolve issues and influence conditions to mutual benefit. Among the food commodities, international agreements of varying scope and effectiveness currently cover wheat, sugar, olive oil, and coffee. Proposals for other commodity agreements have been advanced but so far none have proven acceptable. International commodity group consultations embracing the leading producing and importing countries take place regularly, mostly under the leadership of the Food and Agriculture Organization (FAO), on rice; oilseeds, oils and fats; bananas; citrus fruit; and tea. There are also groups dealing with the various fibers and with rubber. GATT commodity groups on grains, dairy products, and meat and meat products are also currently debating proposals, advanced under the Kennedy Round trade negotiations, for commodity trade arrangements.

International commodity agreements have not been notably successful either in stabilizing prices or in influencing production. In the latter sphere, perhaps the most hopeful device which has been agreed upon is the Coffee Agreement's Diversification Fund, controlled by the International Coffee Organization and the contributing exporter country. Although the Fund is of modest potential proportions, it is a hopeful sign which conceivably could point the way in other commodity sectors for an adjustment in cropping patterns.

In the short term, concern with price and with oversupply, actual or feared, will continue to dominate the commodity policy of exporting countries and of the international organizations to whom they look for remedial action.

In a situation where some commodities are in world oversupply while other are threatened with world shortage, a shift of production resources away from the overproduced items seems logical. Most of the commodities in oversupply, furthermore, do not qualify as "basic foods"; and some of these (e.g., jute and other soft fibers) face declining world demand. But any organized attempt on an international scale to adjust resource use must consider conditions of natural advantage and relative productive efficiency. Attempts to increase production for internal consumption at the expense of industrial crops for export will not always be in a country's best interests. The goal of international action, as well as of national agricultural policies, should be to encourage the production of those items for which natural conditions are favorable and for which there is market demand. This is the philosophy of the FAO's ambitious undertaking of an Indicative World Plan, now in preparation.

The international commodity organizations, despite their somewhat narrow interest and orientation, have a role to play in any organized efforts (as contrasted to reliance on the working of markets to bring about change) to increase food production. This role will be mainly

in the statistical, analytical, and technological fields—in providing data and specialized judgments on specific commodity situations and outlook to better enable governments to reach purposeful national decisions and, possibly, to act in concert on the international level. The food-deficit countries in particular are apt to be more and more concerned with whether they should encourage exchange-earning production or production for internal use.

In the immediate future, the international commodity bodies—commodity study groups as well as the governing bodies of formal international agreements—can assist by: (a) enlarging programs on the development of production and utilization statistics and projections; (b) preparing demand forecasts and relating these to the production outlook; (c) indicating the required levels of production needed; and (d) assisting member countries to improve their technology and balance between food and non-food crops, considering their comparative advantage.

## *2.4.0 World Trade In Agricultural Products*

### *2.4.1 Projection to 1970*

The value of United States agricultural exports increased to $6.2 billion in 1965 and to $6.7 billion in 1966—more than double their average value during 1952–54. They are expected to increase to more than $8 billion by 1970 (Table 2–13).

The export estimates for 1970 reflect primarily the import demand of the major market areas as indicated by projected production-consumption balances. It is assumed that within the next decade, sufficient flexibility will exist in the productive capacity of the United States to produce these quantities. *The level of agricultural exports within the next decade will be determined more by United States policy regarding levels of concessional exports than by the potential productive capacity of the United States.*

The projections distinguish between the commercial market and the concessional market. Most of the trade in the commercial market will continue to be between the developed nations (Tables 2–14 and 2–15). High levels of economic activity will foster trade despite the presence of trade barriers.

Two-thirds of the world's population live in the developing countries. As populations increase rapidly in the developing countries and there is some increase in real per capita income, demand for food probably will continue to outrun domestic production in the immediate future. Because of shortages of foreign exchange these needs are not likely to be filled except on concessional terms.

TABLE 2–13.—*Value of total United States agricultural exports, average 1959–61, annual 1965, and projected 1970, year ended December 31*[1]

[In millions of dollars]

| Commodity or group | Average 1959–61 | 1965 | Projected 1970[2] |
|---|---|---|---|
| Wheat and flour[3] | 1,033 | 1,184 | 1,500 |
| Rice, milled | 123 | 244 | 330 |
| Feed grains | 601 | 1,251 | 1,760 |
| Feed grains and products[4] | 571 | 1,168 | 1,630 |
| Prepared feeds[5] | 30 | 83 | 130 |
| Oilseeds and products | 578 | 1,167 | 1,590 |
| Oilseeds | 349 | 702 | 1,030 |
| Vegetable oils | 180 | 278 | 290 |
| Oilcake and meal | 49 | 187 | 270 |
| Animal products | 508 | 707 | 850 |
| Animal fats and oil | 178 | 232 | 260 |
| Hides and skins | 75 | 109 | 110 |
| Variety and other meats | 76 | 112 | 140 |
| Poultry meat | 51 | 58 | 60 |
| Dairy products | 128 | 196 | 280 |
| Cotton | 767 | 486 | 740 |
| Tobacco | 372 | 383 | 440 |
| Fruits | 254 | 313 | 320 |
| Vegetables | 137 | 155 | 170 |
| Other | 231 | 355 | 460 |
| Total | 4,604 | 6,245 | 8,160 |

[1] Includes food exported for relief or charity.
[2] Projected using 1964–65 prices.
[3] Excludes foreign wheat milled in bond for export.
[4] Includes rye grain.
[5] Includes some hay and fodder.

Source: Historical data based on information in U.S. Department of Agriculture Economic Research Service. Foreign agricultural trade of the United States (monthly reports and supplements).

TABLE 2–14.—*Value of export of United States farm products to major markets*

[In billions of dollars]

| Region | Average 1950–54 | Average 1960–64 | 1965 | Projected 1970 |
|---|---|---|---|---|
| Japan | 0.4 | 0.6 | 0.9 | 1.4 |
| Canada | .3 | .5 | .6 | .5 |
| European Economic Community | .9 | 1.2 | 1.5 | 1.8 |
| Other West Europe | .6 | .9 | .9 | 1.4 |
| Communist countries | .1 | .2 | .2 | .4 |
| Rest of world | 1.0 | 2.0 | 2.1 | 2.7 |
| Total | 3.3 | 5.4 | 6.2 | 8.2 |

Source: West, Quentin, "Foreign Supply and Demand Projections: Outlook for U.S. Agricultural Exports", Journal of Farm Economics, vol. 48, No. 5, December 1966.

TABLE 2–15.—*Value of total United States agricultural exports, calendar year 1965 and projected 1970* [1]

[In billions of dollars]

| Commodity or group | Calendar 1965 | | | Projected 1970 | | |
|---|---|---|---|---|---|---|
| | Total | Commercial | Government-financed programs | Total | Commercial | Government-financed programs |
| Wheat and flour [2] | 1.2 | 0.4 | 0.8 | 1.5 | 0.4 | 1.1 |
| Rice, milled | .2 | .2 | ---------- | .3 | .2 | .1 |
| Feed grains and feeds [3] | 1.3 | 1.2 | .1 | 1.8 | 1.6 | .2 |
| Oilseeds, oilcake, and products | 1.2 | 1.1 | .1 | 1.6 | 1.4 | .2 |
| Animal products | .5 | .5 | (4) | .6 | .6 | (4) |
| Dairy products | .2 | .1 | .1 | .3 | .2 | .1 |
| Cotton | .5 | .4 | .1 | .7 | .5 | .2 |
| Tobacco | .4 | .3 | .1 | .4 | .3 | .1 |
| Fruits and vegetables | .4 | .4 | (4) | .5 | .5 | (4) |
| Other | .3 | .2 | (4) | .5 | .4 | (4) |
| Total | 6.2 | 4.8 | 1.4 | 8.2 | 6.1 | 2.1 |

[1] Projected using 1964–65 prices.
[2] Excludes foreign wheat milled in bond for export.
[3] Includes rye, grain products, and some hay and fodder.
[4] Less than 0.05 billion.

*2.4.1.1 Developed Countries.* Population growth rates in the developed countries which are commercial markets for United States agricultural exports, have been a little in excess of one percent per year. However, these countries have been enjoying a very high rate of economic growth and rising incomes.

Rising incomes have promoted and will continue to promote an increased demand for livestock products. A shift to livestock production requires more land resources. Many of the developed nations, particularly Japan, do not have the land resources to meet growing demands for both livestock products and food crops. The policy of these nations has been to produce livestock using feed imports rather than to import livestock products. This policy has increased import requirements for feedgrains and oilcake and this growth is expected to continue for the rest of the decade.

An important factor in the commercial market is the trade between the Free World and the Communist countries. China became a net grain importer in 1960 and has imported 5 to 6 million tons annually since then. The USSR imported 12 million tons of wheat in 1963 and 9 million tons in 1965. Recently, the USSR entered into an agreement with Canada to purchase 9 million metric tons of wheat over the next three years. However, it is probable that the USSR will again be a net exporter by 1970.

*2.4.1.2 Developing Countries.* We assume that the high annual average growth rate of 2.5 percent in these countries will continue during

the next four years, as programs to modify population growth are not likely to be effective within that period.

Per capita income in these countries is increasing at a rate of almost 2 percent a year. With rising income, people consume more and better quality food. Most of the improvement in per capita consumption has come from imports, as domestic production has barely kept pace with population growth. These imports have been mostly grains to increase the caloric intake of the people. The developing countries (including mainland China but excluding Argentina) were net exporters of 3 million metric tons of grain prior to World War II but probably imported around 33 million metric tons in 1966.

Continued income growth and high population growth rates will tend to expand total food demand substantially and bring pressure for increased supplies. In some countries real food prices have risen, resulting in lower per capita consumption than would be indicated by the growth in income alone.

The extent to which imports will rise to meet increased demands will depend on export policies of the United States and other suppliers, as well as the import policies of the governments of the developing countries. Also, a strong commercial market in the developed nations, and in the Communist countries, may be a limiting factor in the amount of food that may be provided on concessional terms.

Food aid probably will continue to make an important contribution to diet improvement, as well as to economic development in the developing countries. However, considering the extent of nutritional needs, limitations on expanding food aid, and chronic balance of payments problems in these countries, the food gap eventually will have to be filled largely domestically and by improved trade among the developing countries themselves.

*2.4.1.3 Wheat Outlook for 1970.* The major area for expansion of United States commercial wheat trade will be in Japan—where it is expected that per capita consumption of food will increase along with feed use, while domestic production declines.

The importation of United States wheat by Western European countries is apt to decline as a result of their tendency toward self-sufficiency. Wheat imports by the developed regions will depend largely on price relationships between wheat and feed grain.

The level of wheat exports to the free-world, developing countries will likely increase. If recent trends continue—population increasing at an annual rate of 2.5 percent, total food production at 2.7 percent and per capita consumption about 0.5 percent—net imports of grains (mostly wheat) will increase to 27 million metric tons annually by 1970 (see Table 2–16). The United States would probably supply about 18 million metric tons.

TABLE 2-16.—*Wheat and flour (wheat equivalent): World production, net trade, United States exports, stock changes, and domestic disappearance by regions, average 1959–61, 1964–65, and 1970 projected.*

[1,000 metric tons]

| Region [1] | 1959–61 | | | | | 1964–65 | | | | | Projected 1970 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Production | Net trade [2] | U.S exports | Stock changes [3] | Domestic disappearance | Production [4] | Net trade [2] | U.S. exports | Stock changes [3] | Domestic disappearance | Production | Net trade [2] | U.S. exports | Domestic disappearance |
| Developed: | | | | | | | | | | | | | | |
| United States | 33,684 | −16,012 | ---------- | 1,470 | 16,202 | 35,126 | −19,510 | ---------- | 2,232 | 17,848 | 44,000 | −23,700 | ---------- | 20,300 |
| Canada | 10,764 | −8,970 | [5] 236 | −2,168 | 3,962 | 16,341 | −11,816 | 6 | 544 | 3,981 | 18,500 | −14,000 | 0 | 4,500 |
| Mexico | 1,286 | 4 | 11 | −88 | 1,378 | 1,800 | −380 | 25 | NA | 1,420 | 2,400 | −400 | 0 | 2,000 |
| River Plate | 5,853 | −1,947 | 81 | −184 | 4,090 | 11,941 | −4,232 | 1 | 2,422 | 5,287 | 8,400 | −3,100 | ---------- | 5,300 |
| Northern Europe | 22,442 | 7,748 | 1,680 | 346 | 29,844 | 27,948 | 2,548 | 988 | −8 | 30,504 | 27,600 | 6,400 | 900 | 34,000 |
| Southern Europe | 13,907 | 1,725 | 1,504 | −498 | 16,130 | 15,190 | 1,081 | 403 | −373 | 16,644 | 15,000 | 2,000 | 800 | 17,000 |
| Eastern Europe | 17,091 | 5,300 | 1,369 | 282 | 22,109 | 17,862 | 6,059 | 1,418 | NA | 23,921 | 19,000 | 6,500 | 1,800 | 25,500 |
| U.S.S.R. | 50,085 | −5,285 | 0 | −1,000 | 45,800 | 57,153 | 413 | 46 | 1,000 | 56,566 | 65,000 | −3,000 | 0 | 62,000 |
| South Africa | 719 | 226 | 24 | 9 | 936 | 1,072 | 1 | 1 | NA | 1,073 | 940 | 450 | 0 | 1,390 |
| Japan | 1,576 | 2,640 | 935 | 143 | 4,073 | 1,244 | 3,532 | 1,654 | 142 | 4,634 | 1,000 | 4,700 | 2,100 | 5,700 |
| Oceania | 6,447 | −3,940 | 0 | 72 | 2,435 | 10,282 | −6,270 | 0 | 1,251 | 2,761 | 11,000 | −8,100 | 0 | 2,900 |
| Developing: | | | | | | | | | | | | | | |
| Central America and Caribbean | 24 | 891 | 394 | 2 | 913 | 26 | 1,588 | 347 | NA | 1,614 | 30 | 1,500 | 410 | 1,530 |
| Other South America [6] | 1,951 | 3,250 | 1,960 | 93 | 5,108 | 1,746 | 3,872 | 2,055 | NA | 5,618 | 1,700 | 5,150 | 3,140 | 6,850 |
| North Africa | 4,144 | 2,328 | 1,936 | −26 | 6,498 | 4,168 | 3,433 | 2,194 | NA | 7,601 | 4,900 | 3,700 | 2,900 | 8,600 |
| West Central Africa | 22 | 435 | 138 | 0 | 457 | 16 | 747 | 191 | NA | 763 | 40 | 750 | 200 | 790 |
| East Africa | 151 | 208 | 16 | 0 | 359 | 145 | 205 | 4 | NA | 350 | 180 | 500 | 30 | 680 |
| West Asia | 12,660 | 1,903 | 1,521 | 341 | 14,222 | 13,795 | 2,212 | 957 | NA | 16,007 | 15,600 | 2,500 | 920 | 18,100 |
| South Asia | 16,515 | 5,007 | 4,027 | 1,636 | 19,886 | 16,369 | 8,973 | 7,724 | −680 | 26,022 | 21,800 | 9,500 | 8,850 | 31,300 |
| Other East Asia | 210 | 1,608 | 1,091 | −19 | 1,837 | 227 | 2,341 | 1,245 | NA | 2,568 | 290 | 2,650 | 1,650 | 2,940 |
| Communist Asia | 21,930 | 1,273 | 0 | −1,044 | 24,247 | 22,500 | 5,120 | 0 | 1,000 | 26,620 | 25,000 | 6,000 | 0 | 31,000 |
| World total | 221,461 | −1,608 | [7] 17,149 | −633 | 220,486 | 254,951 | −83 | [8] 19,572 | 3,066 | 251,802 | 282,380 | 0 | 23,700 | 282,380 |

[1] Countries included in regions are listed in World Food Budget, 1970 (2), p. 87.
[2] Plus indicates net imports; minus indicates net exports.
[3] Plus indicates addition to stocks; minus indicates withdrawal from stocks.
[4] Calendar 1964.
[5] Includes transshipped wheat.
[6] Includes Brazil.
[7] Total includes 226,000 metric tons whose destination is unidentified.
[8] Total includes 313,000 metric tons whose destination is unidentified.

If per capita real income should exceed the expected annual rate of increase of almost 2 percent in the developing countries, a rise in per capita consumption of food grains of about 1 percent per year could occur providing there is no rise in the real price of food grains. If this occurred, with production increasing only at about recent trends, imports of grain *could* increase to 30 millions tons by 1970. Depending upon our food and agricultural policy and import policies of the recipient countries, our wheat exports to those countries *could* reach 21 million tons by 1970.

There are indications that large imports of wheat into Communist China will continue. Recent contracts signed by Communist China reveal that the sizeable purchases of recent years will apparently be continued as a matter of government policy. Eastern European countries will maintain approximately their present imports, which are currently supplied by non-communist countries. If the USSR achieves its wheat production targets by 1970, Eastern European countries probably will acquire most of their import requirements from the USSR, their traditional supplier.

If the USSR again becomes a net wheat exporter and in 1970 there are no major droughts in the large exporting or importing countries, there is apt to be a more than adequate wheat supply to meet the effective world demand.

*2.4.1.4 Rice Outlook for 1970.* The current tight rice supply situation is expected to prevail in 1970, resulting in some shift in consumption from rice to other food grains. Production in the major Asian rice consuming countries in the remainder of this decade is projected to increase less rapidly than population.

Asian rice exporting countries are finding it difficult to maintain exports because of lagging production. Net exports from other countries in East Asia are expected to drop from 1.6 million tons in 1964/65 to 1.4 million tons in 1970.

United States rice exports by 1970 are projected to increase to 2.1 million metric tons, considerably above the 1964/65 level of 1.3 million metric tons (Table 2–17). This reflects a substantial expansion of our cash markets and an increase in the use of rice in food aid programs.

*2.4.1.5 Coarse Grain Outlook for 1970.* The expected continuation of the recent growth in the demand for meat in the principal markets—Western Europe and Japan—underlies the projected demand for coarse grains.

Rapidly changing feeding practices are apt to cause some further expansion in feed grain consumption per head of livestock and increased use of mixed feeds and protein supplements. There is evidence that grain is replacing potatoes in livestock rations in Northern European countries. Large scale broiler production in many West Euro-

TABLE 2-17.—*Rice (milled): World production, net trade, United States exports, stock changes, and domestic disappearance by regions, average 1959–61, 1964–65, and 1970 projected*

[1,000 metric tons]

| Region [1] | 1959–61 | | | | | 1964–65 | | | | | Projected 1970 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Production | Net trade [2] | U.S. exports | Stock changes [3] | Domestic disappearance | Production | Net trade [2] | U.S. exports | Stock changes [3] | Domestic disappearance | Production | Net trade [2] | U.S. exports | Domestic disappearance |
| Developed: | | | | | | | | | | | | | | |
| United States | 1,516 | −1,022 | 0 | 74 | 420 | 2,387 | −1,372 | 0 | 6 | 1,009 | 2,784 | −2,060 | 0 | 724 |
| Canada | 0 | 33 | 12 | 0 | 33 | 0 | 46 | 50 | 0 | 46 | 0 | 37 | 65 | 37 |
| Mexico | 182 | 2 | 7 | 17 | 167 | 178 | 2 | 4 | 0 | 180 | 250 | −13 | 2 | 237 |
| River Platte | 142 | −16 | 1 | −5 | 131 | 233 | −36 | 0 | 13 | 184 | 200 | −25 | 0 | 175 |
| Northern Europe | 82 | 464 | 111 | 12 | 534 | 78 | 447 | 122 | −2 | 527 | 109 | 499 | 190 | 608 |
| Southern Europe | 858 | −200 | 11 | −24 | 682 | 806 | −126 | 3 | 0 | 680 | 896 | −110 | 0 | 786 |
| Eastern Europe | 108 | 342 | 6 | 63 | 387 | 107 | 250 | 11 | 0 | 357 | 140 | 340 | 18 | 480 |
| U.S.S.R. | 144 | 447 | 0 | 0 | 591 | 331 | 250 | 0 | 0 | 581 | 800 | −50 | 0 | 750 |
| South Africa | 5 | 47 | 17 | 0 | 52 | 0 | 70 | 55 | 0 | 70 | 7 | 64 | 85 | 71 |
| Japan | 11,330 | 195 | 0 | 455 | 11,070 | 11,452 | 905 | 195 | 375 | 11,982 | 11,500 | 1,000 | 290 | 12,500 |
| Oceania | 99 | −55 | 3 | 0 | 44 | 117 | −66 | 11 | 0 | 51 | 140 | −109 | 10 | 31 |
| Developing: | | | | | | | | | | | | | | |
| Central America and Caribbean | 507 | 365 | 137 | 1 | 871 | 308 | 455 | 48 | 0 | 763 | 600 | 460 | 80 | 1,060 |
| Other South America [4] | 4,166 | −80 | 32 | 19 | 4,067 | 5,356 | −286 | 49 | −297 | 5,367 | 6,500 | −180 | 35 | 6,320 |
| North Africa | 924 | −234 | 19 | 6 | 684 | 1,323 | −305 | 0 | −1 | 1,019 | 1,800 | −407 | 0 | 1,393 |
| West Central Africa | 1,368 | 281 | 50 | 0 | 1,649 | 1,151 | 380 | 157 | 0 | 1,531 | 1,700 | 450 | 190 | 2,150 |
| East Africa | 935 | 108 | 1 | 0 | 1,043 | 936 | 190 | 6 | 0 | 1,126 | 1,225 | 125 | 10 | 1,350 |
| West Asia | 525 | 322 | 22 | −27 | 874 | 647 | 380 | 87 | 0 | 1,027 | 1,000 | 354 | 125 | 1,354 |
| South Asia | 44,144 | 1,116 | 251 | 1,204 | 44,056 | 53,555 | 1,341 | 325 | −332 | 55,228 | 58,500 | 1,775 | 460 | 60,275 |
| Other East Asia | 30,200 | −1,109 | 175 | 75 | 29,016 | 35,579 | −1,587 | 173 | 0 | 33,992 | 39,200 | −1,350 | 500 | 37,850 |
| Communist Aisa | 59,537 | −956 | 0 | −3,006 | 61,587 | 62,400 | −600 | 0 | 0 | 61,800 | 74,000 | −800 | 0 | 73,200 |
| World total | 156,772 | 50 | 855 | −1,136 | 157,958 | 176,944 | 338 | 1,296 | −238 | 177,520 | 201,351 | 0 | 2,060 | 201,351 |

[1] Countries included in regions are listed in World Food Budget 1970 (2), p. 87.

[2] Plus indicates net imports; minus indicates net exports. Where 1964–65 data were not available, data were approximated.

[3] Plus indicates addition to stocks; minus indicates withdrawal from stocks.

[4] Includes Brazil.

pean countries as well as Japan is expanding rapidly. Swine production in these areas also is moving into intensive feeding enterprises.

Beef production in Western Europe probably will continue to be tied in to the dairy enterprise with relatively little use of concentrates since consumer preference for "lean type" beef will persist during the next few years. High prices for beef as compared to pork and poultry will encourage consumers to shift to pork and poultry. Enterprises involving their production use more feed grains per pound of meat. If the price of wheat in relation to other feed grains is reduced when unified grain prices become effective in the EEC on July 1, 1967, increases in the use of wheat for feed would have a dampening effect on feed grain imports.

With domestic production of coarse grains lagging behind increased utilization, the United States can expect a substantial rise in net import requirements in our two major markets. For Western Europe, an increase is projected from 18 million tons in 1964/65 to 28 million tons in 1970. Japan's imports are projected at 10 million tons, more than double the 1964/65 level (Table 2–18). The United States will continue to be the dominant supplier of coarse grains with Argentina continuing a distant second. Projections for world trade in total grains are shown in Table 2–19.

*2.4.1.6 Soybean Outlook for 1970.* The world demand for soybeans will continue to be strong to 1970. Total United States exports in 1970 should reach 9.6 million tons of soybeans and 3.7 million tons of soybean oilcake and meal. The need for oil largely determines if a country imports soybeans or soybean meal.

A substantial increase in Japan's livestock production is expected, plus an increased use of soybean meal as a substitute for fishmeal in mixed feeds. Imports of soybeans are expected to increase to 3.4 million metric tons by 1970, about three times the level of 1959–61. About 3.0 million metric tons of this total is expected to come from the United States (Table 2–20).

In Western Europe, it is projected that by 1970, 5.4 million tons of soybeans and 2.8 million tons of soybean meal will be imported (Table 2–21). The United States should supply almost all of this amount.

*2.4.2 Projections to 1980*

The 1980 projections use the 1970 projections as a point of departure. To simplify these projections, we will use grain as an indicator of food output and disappearance. Grains occupy over two-thirds of the world's harvested cropland; they provide over one-half of man's food energy supply when consumed directly and a sizeable part of the remainder when consumed indirectly in the form of animal products. Gains constitute one-third of the value of world food trade. Also, data on grain production are more reliable than data on most other crops.

TABLE 2-18.—*Coarse grains: World production, net trade, United States exports, stock changes, and domestic disappearance by regions average 1959–61, 1964/65, and 1970 projected*

| Region [1] | 1959–61 | | | | | 1964–65 | | | | | Projected 1970 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Production | Net trade [2] | U.S exports [3] | Stock changes [4] | Domestic disappearance | Production | Net trade [2] | U.S. exports [3] | Stock changes [4] | Domestic disappearance | Production | Net trade [2] | U.S exports | Domestic disappearance |
| Developed: | | | | | | | | | | | | | | |
| United States | 135,551 | −10,536 | ---------- | 6,876 | 118,139 | 125,879 | −17,275 | ---------- | −13,936 | 122,540 | 170,300 | −29,000 | ---------- | 141,300 |
| Canada | 11,010 | −716 | [5] 971 | −832 | 11,126 | 11,677 | −633 | [4] 2,060 | −1,281 | 12,325 | 15,025 | −550 | 0 | 14,475 |
| Mexico | 5,427 | −111 | 112 | −131 | 5,447 | 8,231 | −811 | 157 | NA | 7,420 | 8,580 | −50 | 0 | 8,530 |
| River Plate | 8,935 | −3,145 | 54 | 36 | 5,754 | 8,965 | −5,134 | 4 | −1,055 | 4,886 | 12,500 | −5,500 | 0 | 7,000 |
| North Europe | 41,525 | 12,839 | 8,013 | 175 | 54,189 | 48,353 | 11,719 | 7,580 | NA | 60,072 | 55,100 | 19,000 | 13,900 | 74,100 |
| South Europe | 9,922 | 2,932 | 669 | 73 | 12,781 | 9,887 | 5,987 | 3,098 | NA | 15,874 | 10,570 | 8,500 | 4,500 | 19,070 |
| East Europe | 42,018 | 621 | 343 | 386 | 42,253 | 42,069 | [9] 2,000 | 204 | NA | 44,069 | 45,000 | 1,800 | 900 | 46,800 |
| U.S.S.R | 47,599 | −1,549 | 0 | 283 | 45,767 | 53,134 | [9] 1,483 | 0 | NA | 51,651 | 62,700 | −1,300 | 0 | 61,400 |
| South Africa | 4,824 | −929 | 1 | 116 | 3,779 | 4,854 | −734 | 1 | NA | 4,120 | 7,400 | −1,600 | 0 | 5,800 |
| Japan | 2,603 | 1,750 | 732 | −46 | 4,399 | 1,374 | 4,515 | 3,164 | NA | 5,889 | 1,400 | 9,500 | 8,000 | 10,900 |
| Oceania | 3,033 | −1,057 | 0 | 80 | 1,896 | 2,976 | −751 | 0 | −414 | 2,639 | 4,020 | −1,000 | 0 | 3,020 |
| Developing: | | | | | | | | | | | | | | |
| Central America and Caribbean [7] | 2,124 | 68 | 113 | −11 | 2,203 | 2,053 | 325 | 71 | NA | 2,378 | 2,800 | 300 | 75 | 3,100 |
| Other South America [9] | 11,509 | 181 | 167 | 60 | 11,630 | 15,702 | 437 | 81 | NA | 16,139 | 17,650 | 600 | 75 | 17,050 |
| North Africa | 9,430 | 73 | 436 | −318 | 9,675 | 9,391 | −4 | 238 | NA | 9,387 | 12,000 | 200 | 200 | 12,200 |
| West Central Africa | 10,189 | −7 | 47 | 0 | 10,118 | 7,126 | −70 | 39 | NA | 7,056 | 12,000 | 100 | 50 | 12,100 |
| East Africa | 8,181 | −54 | 43 | 0 | 8,127 | 6,206 | 22 | 44 | NA | 6,228 | 10,200 | −300 | 50 | 9,900 |
| West Asia | 9,212 | 384 | 500 | −332 | 9,928 | 7,767 | 236 | 403 | NA | 8,003 | 11,000 | 300 | 500 | 11,300 |
| South Asia | 23,920 | 122 | 136 | 100 | 23,942 | 26,945 | 122 | 190 | NA | 27,067 | 28,600 | 1,000 | 1,000 | 29,600 |
| Other East Asia | 5,802 | −384 | 232 | 16 | 5,402 | 8,131 | −634 | 236 | NA | 7,497 | 10,130 | −1,300 | 250 | 8,830 |
| Communist Asia | 37,603 | 398 | 0 | 0 | 38,001 | 46,000 | 412 | 0 | NA | 46,412 | 51,000 | 500 | 0 | 51,500 |
| World total | 430,417 | 670 | 12,569 | 6,531 | 424,556 | [8] 446,720 | [9] −754 | 17,600 | −16,686 | 461,652 | 547,975 | 0 | 29,500 | 547,975 |

[1] Countries included in regions are listed in World Food Budget 1970 (2), p. 87.
[2] Plus indicates net imports; minus indicates net exports.
[3] Fiscal year beginning July 1.
[4] Plus indicates addition to stocks; minus indicates withdrawal from stocks.
[5] Includes intransit shipments moving through Canada; about 90 percent of these shipments move to Western Europe.
[6] Calendar year 1964.
[7] Includes Brazil.
[8] Total includes 30,100 tons to countries unspecified.
[9] Includes imports of 1 million tons of corn to countries unspecified.

TABLE 2-19.—*Total grains: World production, net trade, United States exports, stock changes and domestic disappearance, by regions, average 1959-61, 1964/65 and 1970 projected*

[In thousands of metric tons]

| Region | 1959-61 | | | | | 1964-65 | | | | | Projected 1970 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Production | Net trade | U.S exports | Stock changes | Domestic disappearance | Production | Net trade | U.S. exports | Stock changes | Domestic disappearance | Production | Net trade | U.S. exports | Domestic disappearance |
| Developed: | | | | | | | | | | | | | | |
| United States | 170,751 | —27,570 | ---------- | 8,420 | 134,761 | 163,392 | —38,157 | ---------- | —16,162 | 141,397 | 217,084 | —54,760 | ---------- | 162,324 |
| Canada | 21,774 | —9,653 | 1,219 | —3,000 | 15,121 | 28,018 | —12,403 | 2,116 | —737 | 16,352 | 33,525 | —14,513 | 65 | 19,012 |
| Mexico | 6,895 | —105 | 130 | —202 | 6,992 | 10,209 | —1,189 | 186 | NA | 9,020 | 11,230 | —463 | 2 | 10,767 |
| River Plate | 14,930 | —5,108 | 136 | —153 | 9,975 | 21,139 | —9,402 | 5 | 1,380 | 10,357 | 21,100 | —8,625 | 0 | 12,475 |
| Northern Europe | 64,049 | 21,051 | 9,804 | 533 | 84,567 | 76,379 | 14,714 | 8,690 | —10 | 91,103 | 82,809 | 25,899 | 14,990 | 108,708 |
| Southern Europe | 24,687 | 4,457 | 2,184 | —449 | 29,593 | 25,883 | 6,942 | 3,504 | —373 | 33,198 | 26,466 | 10,390 | 5,300 | 36,856 |
| Eastern Europe | 59,217 | 6,263 | 1,718 | 731 | 64,749 | 60,038 | 8,309 | 1,633 | NA | 68,347 | 64,140 | 8,640 | 2,718 | 72,780 |
| U.S.S.R. | 97,828 | —6,387 | 0 | —717 | 92,158 | 110,618 | —820 | 46 | 1,000 | 108,798 | 128,500 | —4,350 | 0 | 124,150 |
| South Africa | 5,548 | —656 | 42 | 125 | 4,767 | 5,926 | —663 | 57 | NA | 5,263 | 8,347 | —1,086 | 85 | 7,261 |
| Japan | 15,509 | 4,585 | 1,667 | 552 | 19,542 | 14,070 | 8,952 | 5,013 | 517 | 22,505 | 13,900 | 15,200 | 10,390 | 29,100 |
| Oceania | 9,579 | —5,052 | 3 | 152 | 4,375 | 13,375 | —7,087 | 11 | 837 | 5,451 | 15,160 | —9,209 | 10 | 5,951 |
| Developing: | | | | | | | | | | | | | | |
| Central America and Caribbean | 2,655 | 1,324 | 644 | —8 | 3,987 | 2,387 | 2,368 | 466 | NA | 4,755 | 3,430 | 2,260 | 565 | 5,690 |
| Other South America | 17,626 | 3,351 | 2,159 | 172 | 20,805 | 22,804 | 4,023 | 2,185 | —297 | 27,124 | 25,850 | 4,370 | 3,250 | 30,220 |
| North Africa | 14,498 | 2,021 | 2,391 | —338 | 16,857 | 14,882 | 3,124 | 2,432 | —1 | 18,007 | 18,700 | 3,493 | 3,100 | 22,193 |
| West Central Africa | 11,579 | 645 | 235 | 0 | 12,224 | 8,293 | 1,057 | 387 | NA | 9,350 | 13,740 | 1,300 | 440 | 15,040 |
| East Africa | 9,267 | 262 | 60 | 0 | 9,529 | 7,287 | 417 | 54 | NA | 7,704 | 11,605 | 325 | 90 | 11,930 |
| West Asia | 22,397 | 2,609 | 2,043 | —18 | 25,024 | 22,209 | 2,828 | 1,447 | NA | 25,037 | 27,600 | 3,154 | 1,545 | 30,754 |
| South Asia | 84,579 | 6,245 | 4,414 | 2,940 | 87,884 | 96,869 | 10,436 | 8,239 | —1,012 | 108,317 | 108,900 | 12,275 | 10,310 | 121,175 |
| Other East Asia | 36,212 | 115 | 1,498 | 72 | 36,255 | 43,937 | 120 | 1,654 | NA | 44,057 | 49,620 | 0 | 2,400 | 49,620 |
| Communist Asia | 119,070 | 715 | 0 | —4,050 | 123,835 | 130,900 | 4,932 | 0 | 1,000 | 134,832 | 150,000 | 5,700 | 0 | 155,700 |
| World total | 808,650 | [1] —888 | 30,573 | 4,762 | 803,000 | [2] 878,615 | [3] —499 | 38,468 | —13,858 | 890,974 | 1,031,706 | 0 | 55,260 | 1,031,706 |

[1] Includes 226,000 metric tons of wheat for which destination is unidentified.

[2] Includes 1 million metric tons of coarse grains for which destination is unidentified.

[3] Includes 313,000 metric tons of wheat and 30,000 metric tons of coarse grains for which destination is unidentified.

TABLE 2-20.—*Soybeans: World production, net trade, United States exports, crushed, and availability, by regions average 1959–61, 1965 and 1970 projected*

[1,000 metric tons]

| Region | 1959–61 | | | | | 1965 | | | | | Projected 1970 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Production | Net trade [1] | U.S. exports | Crushed | Availability | Production | Net trade [1] | U.S. exports | Crushed | Availability | Production | Net trade [1] | U.S. exports | Crushed | Availability |
| Developed: | | | | | | | | | | | | | | | |
| United States [2] | 15,135 | —3,443 | -------- | 10,876 | [3] 11,834 | 19,103 | —5,775 | -------- | 13,036 | [4] 14,348 | 30,000 | —9,500 | -------- | 18,500 | 20,500 |
| Canada | 168 | 297 | 362 | 450 | 465 | 190 | 344 | 432 | 558 | 534 | 250 | 400 | 500 | 625 | 650 |
| Japan | 412 | 1,095 | 1,060 | 897 | 1,507 | 240 | 1,847 | 1,464 | 1,510 | 2,087 | 200 | 3,400 | 3,000 | 3,100 | 3,600 |
| Western Europe | (5) | 2,275 | 1,836 | 2,275 | 2,275 | (5) | 4,001 | 3,673 | 4,001 | 4,001 | (5) | 5,450 | 5,000 | 5,400 | 5,450 |
| Eastern Europe | 224 | 127 | 11 | 334 | 351 | 317 | 161 | 161 | 454 | 478 | 475 | 400 | 375 | 840 | 875 |
| Developing: | | | | | | | | | | | | | | | |
| Latin America | 166 | —8 | 22 | 141 | 158 | 405 | —32 | 39 | 333 | 373 | 720 | 50 | 100 | 650 | 770 |
| Africa | 10 | 13 | 22 | 22 | 23 | 26 | 12 | 12 | 12 | 14 | 30 | 0 | 25 | 25 | 30 |
| Asia (excluding Japan) | 10,405 | —715 | 353 | 3,900 | 9,690 | 7,593 | —192 | 415 | 3,100 | 7,401 | 9,375 | —100 | 600 | 4,400 | 9,275 |
| World total | 26,520 | —359 | 3,666 | 18,895 | [3] 26,303 | 27,874 | 342 | 6,196 | 23,004 | [4] 29,236 | 41,050 | 100 | 9,600 | 33,540 | 41,150 |

[1] Plus indicates net imports, minus indicates net exports.
[2] Data for crop year starting Sept. 1 of the previous year shown.
[3] Includes a decrease in stocks of 142,000 tons.
[4] Includes a decrease in stocks of 1,020,000 tons.
[5] Less than 500 tons.

TABLE 2–21.—*Soybean meal: World production, net trade, United States exports and availability, average 1959–61, 1965 and 1970 projected*

[1,000 metric tons]

| Region | 1959–61 | | | | 1965 | | | | Projected 1970 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Production | Net trade [1] | U.S. exports | Availability | Production | Net trade [1] | U.S. exports | Availability | Production | Net trade [1] | U.S. exports | Availability |
| Developed: | | | | | | | | | | | | |
| United States [2] | 8,496 | −530 | ---------- | [3] 7,957 | 10,238 | −1,868 | ---------- | [4] 8,385 | 14,540 | −3,600 | ---------- | 10,940 |
| Canada | 354 | 29 | 188 | 383 | 439 | 28 | 226 | 467 | 490 | 120 | 400 | 610 |
| Japan | 705 | 20 | 20 | 725 | 1,187 | 49 | 49 | 1,236 | 2.437 | 100 | 100 | 2,537 |
| Western Europe | 1,788 | 462 | 292 | 2,250 | 3,145 | 1,660 | 1,455 | 4,805 | 4,244 | 2,795 | 2,500 | 7,039 |
| Eastern Europe | 263 | 7 | 7 | 270 | 357 | 151 | 150 | 508 | 659 | 500 | 500 | 1,159 |
| Developing: | | | | | | | | | | | | |
| Latin America | 111 | 43 | 43 | 154 | 262 | 55 | 55 | 317 | 509 | 100 | 100 | 609 |
| Africa | 13 | 12 | ---------- | 1 | 9 | 6 | 2 | 3 | 20 | 35 | 50 | 55 |
| Asia (excluding Japan) | 3,065 | 18 | 18 | 3,083 | 2,437 | 32 | 32 | 2,469 | 3,458 | 50 | 50 | 3,508 |
| World total | 14,795 | 37 | 568 | [3] 14,823 | 18,074 | 101 | 1,969 | [4] 18,190 | 26,357 | 100 | 3,700 | 26,457 |

[1] Plus indicates net imports, minus indicates net exports.

[2] Data for the crop year beginning Oct. 1 of the previous year shown.

[3] Includes an increase in stocks of 9,000 metric tons.

[4] Includes a decrease in stocks of 15,000 metric tons.

For the world, two sets of projections are made: The first assumes continuation of our 1960–70 trends (Table 2–22) and the second an approximation of what might be called an "Adjusted Trends" projection for 1980 (Table 2–23). In both of these projections, the production and trade level of the United States for 1980 is the amount required to meet the net import needs of the rest of the world. In addition, for the developing, free-world regions projections are made under a static per capita disappearance situation, an improved consumption situation, and an accelerated agricultural production situation (Tables 2–24 and 2–25). The improved disappearance situation

TABLE 2–22.—*Grains: Production, disappearance and trade projections to 1980 assuming 1960–70 growth rates prevail in the 1970's* [1]

[1,000 metric tons]

| Region | Production | | | | Total grains | |
|---|---|---|---|---|---|---|
| | Wheat | Milled rice | Coarse grains | Total | Disappearance | Trade |
| Developed: | | | | | | |
| United States | ---------- | ---------- | ---------- | [2] 273,099 | 195,941 | [3] −77,158 |
| Canada | 31,901 | 0 | 20,588 | 52,489 | 23,866 | −28,623 |
| Mexico | 4,463 | 343 | 13,582 | 18,388 | 16,561 | −1,827 |
| River Plate | 12,080 | 282 | 17,463 | 29,825 | 15,660 | −14,165 |
| Northern Europe | 33,976 | 145 | 73,334 | 107,455 | 139,155 | 31,700 |
| Southern Europe | 16,244 | 932 | 11,222 | 28,398 | 45,816 | 17,418 |
| Eastern Europe | 21,197 | 181 | 48,251 | 69,629 | 82,001 | 12,372 |
| U.S.S.R. | 84,021 | 4,442 | 82,642 | 171,105 | 166,848 | −4,257 |
| South Africa | 1,227 | 10 | 11,382 | 12,619 | 11,062 | −1,557 |
| Japan | 631 | 11,616 | 754 | 13,001 | 43,491 | 30,490 |
| Oceania | 18,790 | 197 | 5,350 | 24,337 | 8,076 | −16,261 |
| Total developed regions | ---------- | ---------- | ---------- | 800,345 | 748,477 | −51,868 |
| Developing: | | | | | | |
| Central America and Caribbean | 38 | 710 | 3,691 | 4,439 | 8,104 | 3,665 |
| Other South America [4] | 1,476 | 10,094 | 27,149 | 38,719 | 43,880 | 5,161 |
| North Africa | 5,800 | 3,508 | 15,212 | 24,520 | 29,251 | 4,731 |
| West Central Africa | 73 | 2,113 | 14,064 | 16,250 | 18,514 | 2,264 |
| East Africa | 215 | 1,599 | 12,680 | 14,494 | 14,976 | 482 |
| West Asia | 19,204 | 1,913 | 13,148 | 34,265 | 37,858 | 3,593 |
| South Asia | 28,733 | 77,859 | 34,186 | 140,778 | 167,655 | 26,877 |
| Other East Asia | 401 | 50,671 | 17,634 | 68,706 | 67,991 | −715 |
| Communist Asia | 28,447 | 91,990 | 69,208 | 189,645 | 195,455 | 5,810 |
| Drilling, excluding Communist Asia | 55,940 | 148,467 | 137,764 | 342,171 | 388,229 | 46,058 |
| Total all developing regions | 84,387 | 240,457 | 206,972 | 531,816 | 583,684 | 51,868 |
| World total | ---------- | ---------- | ---------- | 1,332,161 | 1,332,161 | ---------- |

[1] Based on 1970 projections presented by Quentin M. West at the annual meetings of the American Farm Economics Association, College Park, Md., 1966.

[2] Indicates amount of production needed in the United States to satisfy domestic disappearance at recent trends (1960–70 rate) and net import requirements of the rest of the world under 1960–70 growth rates in production and disappearance.

[3] Net import requirements of rest of the world.

[4] Includes Brazil.

TABLE 2–23.—*Total grains: "Adjusted trends" projection of production, disappearance and net trade, to 1980 by regions*

[1,000 metric tons]

| Region | Wheat | | | Rice | | | Coarse grains | | | Total grains | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Production | Net trade | Disappearance | Production | Net trade | Disappearance | Production | Net trade | Disappearance | Production | Net trade | Disappearance |
| Developed: | | | | | | | | | | | | |
| United States | 51,500 | −29,500 | 22,000 | 3,070 | −2,020 | 1,050 | 234,400 | −52,000 | 182,400 | 288,970 | −83,520 | 205,450 |
| Canada | 21,800 | −16,500 | 5,300 | 0 | 50 | 50 | 20,000 | −2,000 | 18,000 | 41,800 | −18,450 | 23,350 |
| Mexico | 3,500 | −400 | 3,100 | 580 | −90 | 490 | 12,900 | −100 | 12,800 | 16,980 | −590 | 16,390 |
| River Plate | 11,000 | −4,700 | 6,300 | 200 | 30 | 230 | 14,200 | −5,900 | 8,300 | 25,400 | −10,570 | 14,830 |
| Northern Europe | 32,000 | 2,000 | 34,000 | 120 | 600 | 720 | 65,200 | 24,400 | 89,600 | 97,320 | 27,000 | 124,320 |
| Southern Europe | 17,000 | 900 | 17,900 | 1,000 | −50 | 950 | 11,300 | 16,500 | 27,800 | 29,300 | 17,350 | 46,650 |
| Eastern Europe | 14,000 | 6,000 | 20,000 | 200 | 350 | 550 | 50,000 | 3,500 | 53,500 | 64,200 | 9,850 | 74,050 |
| U.S.S.R. | 75,000 | −5,000 | 70,000 | 1,000 | 0 | 1,000 | 80,000 | −2,000 | 78,000 | 156,000 | −7,000 | 149,000 |
| South Africa | 1,300 | 500 | 1,800 | 20 | 80 | 100 | 11,000 | −3,500 | 7,500 | 12,320 | −2,920 | 9,400 |
| Japan | 800 | 7,200 | 8,000 | 14,500 | 1,300 | 15,800 | 1,200 | 16,000 | 17,200 | 16,500 | 24,500 | 41,000 |
| Oceania | 13,400 | −10,000 | 3,400 | 200 | −150 | 50 | 5,300 | −900 | 4,400 | 18,900 | −11,050 | 7,850 |
| Total developed regions | 241,300 | −49,500 | 191,800 | 20,890 | 100 | 20,990 | 505,500 | −6,000 | 499,500 | 767,690 | −55,400 | 712,290 |
| Developing: | | | | | | | | | | | | |
| Central America and Caribbean | 50 | 2,400 | 2,450 | 750 | 600 | 1,350 | 3,100 | 1,000 | 4,100 | 3,900 | 4,000 | 7,900 |
| Other South America | 2,700 | 6,800 | 9,500 | 8,200 | 100 | 8,300 | 25,000 | 1,300 | 26,300 | 35,900 | 8,200 | 44,100 |
| North Africa | 5,400 | 6,000 | 11,400 | 2,500 | −500 | 2,000 | 14,800 | 1,200 | 16,000 | 22,700 | 6,700 | 29,400 |
| West Central Africa | 50 | 1,200 | 1,250 | 2,250 | 750 | 3,000 | 16,000 | 750 | 16,750 | 18,300 | 2,700 | 21,000 |
| East Africa | 200 | 600 | 800 | 1,700 | 200 | 1,900 | 13,500 | −500 | 13,000 | 15,400 | 300 | 15,700 |
| West Asia | 19,000 | 5,600 | 24,600 | 1,500 | 500 | 2,000 | 12,500 | 2,750 | 15,250 | 33,000 | 8,850 | 41,850 |
| South Asia | 31,000 | 13,300 | 44,300 | 81,000 | 1,550 | 82,550 | 35,800 | 1,500 | 37,300 | 147,800 | 16,350 | 164,150 |
| Other East Asia | 400 | 3,600 | 4,000 | 53,500 | −1,800 | 51,700 | 18,100 | −2,500 | 15,600 | 72,000 | −700 | 71,300 |
| Communist Asia | 28,000 | 10,000 | 38,000 | 90,000 | −1,500 | 88,500 | 65,500 | 500 | 66,000 | 183,500 | 9,000 | 192,500 |
| Developing, excluding Communist Asia | 58,800 | 39,500 | 98,300 | 151,400 | 1,400 | 152,800 | 138,800 | 5,500 | 143,300 | 349,000 | 46,400 | 395,400 |
| Total all developing regions | 86,800 | 49,500 | 136,300 | 241,400 | −100 | 241,300 | 204,300 | 6,000 | 210,300 | 532,500 | 55,400 | 587,900 |
| World Total | 328,100 | ---------- | 328,100 | 262,290 | ---------- | 262,290 | 709,800 | ---------- | 709,800 | 1,300,190 | ---------- | 1,300,190 |

263–888 O—67——13

assumes that per capita grain disappearance will increase at an annual rate of 1 percent. The accelerated production situation assumes that the annual rate of growth in grain production would increase to 4 percent by 1975 and continue at that rate beyond 1975. In all of these projections there is the implicit assumption that although family planning will make some headway, it will not have much effect on population growth rates in the next 15 years.

*2.4.2.1 Recent Trends.* It is well to keep in mind the assumptions under which the projections to 1970 were made: normal weather, no worldwide conflict, continued economic growth, and a continuation of the current programs and policies affecting agriculture and trade—both in foreign countries and the United States.

If our 1960–70 trends continue in the developing, free-world regions, grain production would be expected to reach 342 million metric tons by 1980, an increase of about 2.7 percent annually (Table 2–22). This rate of growth is just slightly better than the population growth rate. Production has been increasing at a slower rate than disappearance in the developing countries and the growing gap has been made up by increased imports. Net grain imports would increase to 46 million metric tons by 1980.

In spite of increased imports, per capita consumption in the diet-deficit countries has been increasing at a rate of only one-half of 1 percent per year. Since the average per capita consumption is 10 percent below the recommended nutritional standard for calories, two

TABLE 2–24.—*Total grains: Production, disappearance and net trade, for developing, free world, 1959–61, 1964–65; projections to 1980 under alternative growth assumptions*

[Million metric tons]

| Estimates, alternative [1] assumptions | Production | Domestic disappearance | Net imports |
|---|---|---|---|
| 1959–61 | 199 | 212 | 17 |
| 1964–65 | 219 | 244 | 24 |
| 1970 | 259 | 287 | 28 |
| Alternative A—1980 | 342 | 362 | 20 |
| Alternative B—1980 | 342 | 388 | 46 |
| Alternative C—1980 | 349 | 395 | 46 |
| Alternative D—1980 | 342 | 409 | 67 |
| Alternative E—1980 | 382 | 409 | 27 |

[1] Alternatives:

*a.* Production increasing at 1960–70 growth rate, per capita disappearance static.

*b.* Production and disappearance increasing at 1960–70 growth rate.

*c.* Adjusted trends—it is assumed that strong pressures for more emphasis on agriculture, including greater attention to agriculture in the AID programs of the United States will have positive effects.

*d.* Production increasing at 1960–70 growth rate and per capita disappearance increasing at an annual rate of 1 percent. Should growth rates exceed projected levels, production and/or imports would have to be larger.

*e.* Rate of growth in product on increasing to 4 percent by 1975 and continuing at that rate to 1980; per capita disappearance increasing at an annual rate of 1 percent.

TABLE 2–25.—*Total grains: World production, disappearance, and net trade, by regions, average 1959–61, projections for 1970 and projections to 1980 under alternative assumptions*

[Million metric tons]

| Region | Production | Domestic disappearance | Net trade [1] |
|---|---|---|---|
| 1959–61: | | | |
| United States | 171 | 135 | —28 |
| Other developed, free world | 163 | 175 | 10 |
| Eastern Europe, and U.S.S.R. | 157 | 157 | 0 |
| Developing, free world | 199 | 212 | 17 |
| Communist Asia | 119 | 124 | 1 |
| Total | 809 | 803 | 0 |
| 1964–65: | | | |
| United States | 163 | 142 | [4]—38 |
| Other developed, free world | 195 | 193 | Neg. |
| Eastern Europe and U.S.S.R. | 171 | 177 | 7 |
| Developing, free world | 219 | 244 | 24 |
| Communist Asia | 131 | 135 | 5 |
| Total | 879 | 891 | —2 |
| 1970: | | | |
| United States | 217 | 162 | —55 |
| Other developed, free world | 213 | 230 | 17 |
| Eastern Europe and U.S.S.R. | 193 | 197 | 4 |
| Developing, free world | 259 | 287 | 28 |
| Communist Asia | 150 | 156 | 6 |
| Total | 1,032 | 1,032 | 0 |
| 1980—"Recent trends" alternative: [2] | | | |
| United States | 273 | 196 | —77 |
| Other developed, free world | 286 | 304 | 18 |
| Eastern Europe and U.S.S.R. | 241 | 249 | 8 |
| Developing, free world | 342 | 388 | 46 |
| Communist Asia | 190 | 195 | 5 |
| Total | 1,332 | 1,332 | 0 |
| 1980—"Adjusted trends" alternative: [3] | | | |
| United States | 289 | 205 | —84 |
| Other developed, free world | 259 | 284 | 25 |
| Eastern Europe and U.S.S.R. | 220 | 223 | 3 |
| Developing, free world | 349 | 395 | 46 |
| Communist Asia | 183 | 193 | 10 |
| Total | 1,300 | 1,300 | 0 |

[1] Minus indicates net exports; plus indicates net imports.

[2] Production and consumption increasing at 1960–70 growth rate.

[3] Assumes that the strong pressures for more emphasis on agriculture in less-developed countries, including greater attention to agriculture in the aid programs of the United States will have positive effects on agricultural production and consumption.

[4] Made possible by draining down U.S. stocks.

decades would be required at the present rate of annual improvement to bring the national average diet of these countries up to the standard, even with further expanded imports.

A continuation of present production and disappearance trends for a decade and a half into the future would be an undesirable alternative. Food consumption per capita would still be below nutritional standards. It would mean increasing dependency upon the United States for food. The cost of our aid would continue to spiral and recipient countries would not be motivated to develop the eventual ability to meet their own needs. Nevertheless, present per capita disappearance might be maintained. If the per capita disappearance remains static and recent trends in grain production continue, import needs in 1980 would be only 20 million metric tons, less than current net imports (Table 2–24).

*2.4.2.2 Improved Disappearance Levels.* A reasonable objective might be for consumption in developing countries to reach the minimum nutritional requirement for calories within the next decade. One way to achieve this goal would be to multiply the level of food aid to these countries.

If this objective were to be achieved with no improvement in food production trends in the developing countries, the net import gap would widen and reach a level of 67 million tons of grains by 1980. (Table 2–24). Also, no improvement in the agricultural sector would mean little, if any, acceleration in overall economic growth because a large share of the output of these economies comes from the agricultural sector. Thus, these countries could not afford to buy food and the increase in imports would have to be under a concessional program. This requirement would be over three times the recent levels of grain shipments under P.L. 480.

Beyond 1980 this import requirement would reach such a level that the needs of the diet-deficit countries would exceed the United States capacity to produce food, over and above the amounts needed for domestic use and commercial exports. Product prices would have to rise to occasion such production increases. The diet-deficit countries would become so dependent upon food aid that any interruption, even a dock strike, might have disasterous results.

*2.4.2.3 Accelerated Agricultural Development.* To reach the nutritional caloric standard within the next decade, and at the same time to begin to cut down the rate of increase in imports, grain production in the food-deficit countries would need to be accelerated from 2.7 percent annually to 4 percent per year by 1975; the gross domestic product would need to rise at an annual rate of 5 percent.

If this production goal were attained by 1975 and the increased disappearance situation were assumed, import requirements for grains could be reduced to 27 million tons by 1980.

Increasing the annual rate of agricultural growth to 4 percent is difficult but not impossible. A recent study of 26 of the developing countries shows that 12 have achieved an annual increase in agricultural production of more than 4 percent.[1]

Increased agricultural development on the part of the diet-deficit countries would provide them with an opportunity to expand their commercial export markets for agricultural products. Comparative advantage probably would lead many of the tropical countries to maintain or even increase their imports of many temperate zone agricultural products. As these countries progress, they will be able to buy more commecial imports. Increasing agricultural production in the diet-deficit countries would not only help meet the food needs of these countries but also improve their financial ability to import commodities on a commercial basis.

*2.4.2.4 "Adjusted Trends" Projection.* The actual supply and demand situation for grains in 1980 will probably be somewhat different from any of the above three assumptions. The long-range outlook staff of the Foreign Regional Analysis Division of the U.S. Department of Agriculture has put together a first approximation of what is called an "Adjusted Trend" projection for 1980 (Tables 2–23 and 2–25). It should be kept in mind that the projected United States exports include both commercial exports and food aid. This set of projections is generally somewhat less optimistic than those of the *Improved Consumption Level* and *Accerelated Agricultural Development.* However, we have *assumed that the strong pressures for more emphasis* on agriculture, including greater attention to agriculture in the aid programs of the United States will have positive effects. Some of the other assumptions and considerations in making these projections follow.

*2.4.2.5 Wheat.* In Western Europe, projections are generally in line with supply and demand studies which we have had made in France, Germany and Italy. These projections reflect continued increases in production coupled with a decrease in per capita consumption, thus resulting in smaller net imports. In Eastern Europe, production will increase slightly faster than consumption and the USSR is expected to supply most of the import requirements. The only substantial increases in commercial markets for wheat will be in Communist Asia and Japan. It is assumed that for some time the former will continue to be supplied by Canada and Australia. There will be a continued increase in import requirements of the developing countries to improve per capita consumption.

[1] U.S. Department of Agriculture Economic Research Service. Foreign Development and Trade Division. Changes in Agriculture in 26 developing nations, 1948–1963. U.S. Dep. Agr. Foreign Agr. Econ. Rep. No. 27, 134 p. 1965.

With the decrease in the commercial market in Europe and the Soviet Union, further expansion of exports by Australia, Canada and Argentina implies that these countries will likely be involved in the food aid picture. Argentina probably would be involved only if some sort of World Food Fund, such as that now being studied in the UN, is inaugurated.

The production and trade level shown for the United States for 1980 is the amount required to meet the net import needs of the rest of the world. If there are shortfalls in production or the other major wheat exporters do not produce for food aid, the level of United States production and trade would have to be much higher.

*2.4.2.6 Rice.* These projections imply a reversal of the tight rice supply situation which is projected for 1970. They assume adoption of the new rice varieties being developed in the Rice Research Institute in the Philippines with resulting increased yields in both the rice importing and exporting countries.

It is also assumed that the war in Viet Nam will be terminated successfully and that this country will resume its status as a net exporter. Further, Mainland China will continue to export rice as a matter of policy.

With abundant supplies, world prices for rice should be somewhat lower in relation to other grains so that Japan and other countries will continue to import rice.

The United States will be exporting over 2 million tons in the early 1970's. It is improbable that we will reduce rice acreage so there should be rice available for food aid to countries like India even though there may be a substantial increase in domestic production.

*2.4.2.7 Coarse Grains.* Commercial demand for feed grains should continue to expand rapidly in Western Europe and Japan. There should also be an expansion of the market in Eastern Europe. Relatively new markets should develop in Latin America and West Asia where demands of the livestock industry in the Caribbean, Venezuela, Israel and Turkey exceed domestic production.

Imports of coarse grains for food by developing countries should remain stable as increased production just about covers increased food requirements. However, some increase in grain imports for feed is expected to fill the needs of developing livestock industries, particularly poultry.

With the projected expanding commercial market for feed grains and the abundant wheat supply, Canada and Argentina would be expected to produce more feed grains for export. This is less likely for Australia which has a greater comparative advantage in wheat. The relative prices of wheat and feed grains will affect developments in these three countries and will also determine how much wheat goes into feed.

*2.4.2.8 Total Grains.* Under the "Adjusted Trends" assumption the import needs for grain in the developing free world countries would be 46 million metric tons, the same as the figure obtained using the 1960–70 growth rates. However, both production and disappearance levels would be greater reflecting a higher level of economic activity. The expected annual rate of growth in per capita disappearance under this assumption is around 0.7 percent compared to the 0.5 percent used in the 1960–70 trend assumption. Gross domestic product would rise an average of 4 to 5 percent per year. Because of the expected higher rate in overall economic growth, the purchasing power to buy needed food would be greater and the financial ability of the country to import commodities on a commercial basis would be improved. Thus, under this assumption, relatively more trade probably would be on a commercial basis than in the "1960–70 trend" projection thereby requiring fewer concessional sales from developed countries.

All import needs specified under each alternative need not be filled by concessional sales. A significant portion of exports to developing countries is already on a commercial basis. For example, considerable quantities of coarse grains are shipped to Latin America on a commercial basis. Some rice and food grains are also shipped on a commercial basis to other developing countries. Of the 24 million metric tons of net grain imports in the developing free world in 1964/65, it is estimated that only about two-thirds were concessional sales from the United States.

## *2.5.0 Pointing Directions for Agricultural and Trade Policy*

### *2.5.1. Implications for the Developing Countries*

Per capita food consumption in the developing world has been increasing only a fraction of a percent a year. Levels of nutrition are inadequate. Rates of growth in per capita consumption of food must be accelerated if a wide range of objectives to which both the United States and the developing countries are committed are to have any chance of success.

Recent rates of growth in the production of food in the developing countries have been slower than those of consumption. The difference is being made up by an accelerating flow of food imports, a substantial fraction of which has consisted of concessional food aid. While the last two years have been abnormal because of the crop failures in India where two-fifths of the people of the non-Communist developing world live, the lag in the rate of growth of production relative to consumption remains even when correction is made for these temporary setbacks.

If present trends continue, even the present inadequate growth rates in per capita consumption in the developing countries can be

maintained only by an expanding flow of food imports from the developed to the developing world. The growing gap between production and consumption could be met in three ways. Either (1) the developing countries would have to divert an increasing proportion of their limited foreign exchange earnings from capital goods and industrial raw materials to food purchases, or (2) foreign food aid would have to expand, or (3) indigenous food production would have to increase at a faster rate.

The problem of accelerating the rate of growth in per capita food consumption can be attacked in two broad ways. One is to attempt to reduce the rate of growth of population. The other is to increase the rate of growth of food availabilities in the developing world. The United States should use its influence and resources in technical assistance and funds to promote population control measures in every conceivable way. However, the most optimistic estimates suggest that, at best, the growth in food demand resulting from population expansion cannot be slowed for at least 10 to 15 years. The population control effort is an urgent one, but its impact in limiting food demands is probably two decades away, and in any case, can deal with only part of the problem. We must, therefore, devote vigorous efforts to accelerating the rate of growth of food availabilities.

Beyond a certain point, increases in per capita food consumption are likely to occur only as a consequence of increases in the rate of growth of effective money demand for food products. With few exceptions, subsistence agriculture has not provided adequate nutrition for its practitioners. The economic development to which the developing countries are committed requires a continuing expansion of the proportion of the population which is in non-agricultural pursuits. Improved productivity on farms will lead directly to some improvement in consumption by farmers of their own produce. But this improved productivity is very unlikely to take place without the commercialization of agriculture for which rising incomes are a necessary condition.

There is extensive statistical evidence to document the fact that, in low income countries, a large fraction of any increase in incomes goes into food consumption. Indeed, we can reasonably estimate that total food demand in the developing world will grow at a rate approximately equal to the rate of population growth plus one-half to three-fourths of the growth rate of per capita income. The main reason that per capita food consumption has been growing so slowly is that the general rate of economic development has been inadequate. An increase in the growth rate of food consumption requires a substantial increase in the growth rate of per capita incomes in the developing countries.

There is an important implication in this conclusion for the policies of the United States and the other developed countries. *These policies cannot be focused narrowly on the food problem alone.* Economic and technical assistance from the developed countries to support an expansion of balanced economic development is an essential precondition for dealing effectively with the world food problem.

This analysis is based on the premise that the overall rate of growth will be accelerated in a substantial portion of the developing world to levels which will permit an expansion in the growth of food demand to something in excess of 4 percent per year (versus the present rate of around 3 percent).[2] If a 2½ to 3 percent population growth rate is assumed, a growth rate for per capita incomes of 2 to 4 percent will be required as compared with an average current rate of between 1 and 2 percent. This rate has been achieved in a few developing countries and seems to be within the range of possibility for several others.

*2.5.1.1 Alternatives.* What are the alternative ways by which supplies can be provided to meet this growing demand? The impact of expanded world food consumption on world trade patterns depends upon which of three broad alternative strategies of the majority of the developing countries puruse. A first strategy would be to meet the expanded food needs primarily from sharply increased production and more efficient distribution in the developing countries themselves. This approach would include measures to increase yields, to reduce losses in storage and transit from pests and contamination, and to improve distribution. We do not necessarily imply that individual countries in the developing world should try to be self-sufficient in foodstuffs. Individual countries might concentrate on the production and export of food items in which they had a substantial comparative advantage. This could radically increase the volume of trade in foodstuffs among the various developing countries. Under this strategy the developing countries, taken as a group, would attempt to meet their own expanded food demand out of an expansion of their aggregate food production.

A second strategy would be for the developing countries to expand non-food exports to the developed world. The intent would be to meet expanded food needs by purchasing much larger quantities of food from the developed countries with the foreign exchange proceeds of their exports. There are many variants of this strategy. It might involve attempts to increase markedly the traditional raw material exports of the developing world, including such agricultural exports as coffee, cocoa, cotton, and tropical fruits. Or it could involve a major effort by the developing countries to penetrate developed country markets with new manufactured exports in which these countries could develop competence. This strategy would call for meeting the incre-

[2] In this portion of the analysis reference is to total food demand for which the income elasticity of demand is higher than for cereals or grains as a separate component of total food.

mental food needs of the bulk of the developing world from greatly expanded production of food in the presently developed countries and the sale of that food on essentially commercial terms.

A third strategy would be to accelerate the volume of food aid from developed to developing countries.

For any one developing country, and indeed for the developing world as a whole, the most likely strategy is, of course, a combination of these three. Nonetheless, in considering the directions in which United States policy should go, it is useful to distinguish these three strategies analytically to decide where major emphasis should be placed.

*2.5.1.2 Production increase, better distribution favored.* A satisfactory long-term solution to the world food problem requires that main reliance be placed on increases in the production of food and increases in the efficiency of its distribution within the group of developing countries.

The third alternative of an indefinite and growing reliance on food aid is unattractive to both donors and recipients. From the standpoint of donors, the domestic surpluses which resulted in the main from domestic policies intended to support the incomes of the agricultural population are dwindling. The production by the developed countries of large-scale agricultural surpluses to be used as food aid will require in the future the allocation of real resources to this purpose. While, for some years, the developed countries could produce enough extra food to meet the growing requirements of the developing world, the time is not too far distant when these requirements could not be supplied at reasonable cost. The developing countries, for their part, also do not want food aid to be permanent. They are deeply concerned about possible threats to their autonomy and independence of action. The recent interruption of food aid during the Kashmir dispute brought home vividly to Indians and Pakistanis their vulnerability in this kind of a situation.

Food aid has a vital role to play as a transitional measure over the next decade, but we must move as rapidly as possible to a situation in which the developing countries are not dependent on it as a regular feature of the landscape.

The strategy which calls for the developing countries, as a group, to attempt to meet their food demand by increasing their non-food exports to the developed world does not seem feasible over the next two decades. There may be individual countries, however, for which this strategy is both possible and desirable. Attention by both developed and developing countries to improving the efficiency of world production by increasing specialization and trade is desirable. The growing effective demand for food in the developing world as a whole,

however, cannot and should not be met primarily by a trade of non-food exports for food imports.

The traditional agricultural exports of the developing countries such as cotton, jute, and the tree crops (cocoa, tea, coffee), which are outside the basic food category, probably have limited possibilities for expansion. Some crops like cotton and jute are threatened by synthetic fibers and other substitutes. For others, such as coffee and tea, the income elasticity of demand in the developed countries is not promising. While we favor the maximum expansion possible in the marketing of these products to the developed world, this course alone is not likely to produce foreign exchange earnings of a magnitude that is in any way comparable to the food needs of the developing countries. As incomes in these countries rise, they may well have new opportunities to supply each other with larger quantities of commodities, but, again this will not earn them the exchange needed to buy food from the developed nations.

It is urgently important that the developing countries pay more vigorous attention to the expansion of their potential for manufactured exports. Here, however, they face a dilemma in the short and medium term. Expanded production of manufactured goods in the developing world will require heavy investments for imports from the developed world of both capital goods and equipment and of some key raw materials. To the extent that scarce foreign exchange resources are used to purchase food from the developed countries, the expansion of industrial capacity essential to the development of their long-run export potential will be inhibited. As they develop capital goods industries of their own, they may escape this paradox, but for the developing world, as a whole, this cannot be expected for at least two decades. Thus, there is serious danger that a policy of reliance upon trade with the developed countries for food will retard the whole process of economic development.

Beyond this is the question of whether, especially for some of the larger countries, reliance on imports for a large and growing fraction of food supplies might put intolerable burdens on their transport, port, and storage facilities. To pursue this alternative would necessitate much heavier investments in very costly social overhead than they would otherwise be required.

There are some powerful additional considerations which raise questions as to the desirability of non-food development in the less developing world as a way of paying for food imports. The overwhelming bulk of the population of the developing countries will, of necessity, continue to be rural for the next few decades no matter how rapidly industry grows. None of the larger developing countries engaged in major programs of industrialization has been able to provide non-rural employment opportunities rapidly enough to absorb

even the natural increase in the labor force, let alone, draw the partially employed surplus population out of rural communities. If development is to benefit the majority of the population which lives outside the cities, rural incomes must rise. This can happen on a sustained basis only if agricultural productivity rises.

*2.5.1.3 Could Improve Income Distribution.* The potential contribution which an all-out drive to improve agriculture can make to solving the problems of income distribution and providing employment opportunities to the marginal elements in the population may be even more important than its contribution to the growth of gross national product. Efforts to solve the problem of unemployment by a search for labor intensive industrial activities or by support of small scale "cottage" industries and handicrafts have in the main, failed. Rising agricultural incomes can bring dramatic improvements in the rural employment situation. Actually, direct employment in farming is unlikely to rise with improved productivity, though in some situations, such as where better irrigation makes multiple cropping possible, this may well occur. As has been demonstrated in Pakistan and elsewhere, however, many kinds of public works activities which are important to the improvement of agriculture and which have very substantial employment potential can be organized in the rural setting. These include bunding, terracing, water control, and construction and maintenance of local roads. Beyond this, as agriculture makes the transition from subsistence to commercial farming, there is a rapid expansion in economic activities supporting agriculture such as marketing, distribution, packaging, and supplying of inputs which add to opportunities for employment in rural regions. As the money incomes of farmers rise, other kinds of small scale service and commercial activities for which subsistence peasant farmers cannot now pay begin to be economically viable in the countryside. Thus, while a growing industrial sector is necessary for a prosperous agriculture, it is also true that without progress in agriculture, all economic, social, and political problems remain very difficult to solve.

Since the strategy of increasing food production in developing countries has so much to recommend it, what are the prospects for success? It is our conviction that the potential for increases in per acre productivity in the major food crops is high in substantial areas of the developing world. Exploitation of this potential will require a major effort by each of the developing countries. It is not clear precisely which areas in an ideal free trade world would have the maximum comparative advantage in the production of each particular foodstuff. The capital-intensive agriculture of the developed world, however, does not necessarily have a significant advantage in efficiency over the optimal labor-intensive techniques which can be used

in developing countries. In summary, the strategy of promoting a major expansion of food production in the developing world, as spelled out elsewhere in this report, seems to be the most sensible course.

*2.5.1.4 United States Role.* If the above view is accepted, it follows that the United States should assist in promoting increased agricultural productivity in the developing countries. It is important not to undertake modernization of agriculture in ways which will reinforce the tendencies which already exist in several developing countries to seek self-sufficiency across the whole range of their food requirements. The strategy proposed would be greatly strengthened by specialization by countries in producing food items for which they are particularly well suited and by a major expansion of trade in food commodities among the developing countries themselves.

*2.5.1.5 Process a Long One.* The proposed strategy cannot be expected to result in a sudden improvement in the agricultural performance of the developing countries. A major transformation of agriculture is required and, while the beginnings of this are underway in some areas, it will be a long and slow process. Food aid will undoubtedly have to be continued for a number of years. If there is an acceleration in the rate of general economic development, bringing with it an increase in the rate of growth in food demand that is to be expected in such circumstances, the gap between this demand and the maximum achievable growth in agricultural productivity may widen before it narrows. To avoid conflict between short-term measures and long-term goals, it is imperative that food aid be used in ways which will not inhibit the growth of agricultural productivity in the developing countries.

*2.5.1.6 Food Aid Impact on Recipients.* Food aid may influence the price behavior of agricultural products in the recipient countries. The governments of these countries, under strong political pressures from urban consuming groups, may be tempted to use food aid to keep market prices for food below the level required to provide adequate incentives for their own agricultural producers.

One of the key inhibitions to innovative investment by farmers in new agricultural techniques is the extreme uncertainty and variability of the prices of the major food crops. The subsistence farmer is relatively independent of these fluctuations, but the commercial farmer who goes into debt to purchase inputs may be wiped out either by bad weather or by unusually good weather which causes prices to plunge downward. Policies which stabilize the short-term price fluctuations of major food crops are important, but price stabilization programs are most effective when they are buttressed by a substantial accumulation of food stocks which can be drawn upon in bad years.

Appropriately designed food aid can be used to support price stabilization policies by the building of food stocks in the recipient countries (where storage facilities exist or can be created at reasonable costs) or by using stocks held in the developed countries as a "buffer." There will probably have to be some carefully designed combination of these methods with the emphasis shifting steadily toward stocking in the developing countries as their storage capacity expands.

Exploration of special temporary uses of food aid to support labor intensive rural projects is desirable. The governments of the developing countries are frequently inhibited from launching such projects because they fear that the purchasing power created by paying even very low wages to large numbers of people for road construction, irrigation, terracing, bunding, and similar activities will generate demands for food that cannot be met and will trigger inflation. Frequently projects of this kind are necessary to the expansion of agricultural productivity but cannot be undertaken because their yield emerges slowly and lags behind the additional food demand they generate. Situations of this kind provide an ideal opportunity to use food aid as a form of temporary capital investment in the improvement of agriculture.

*2.5.1.7 World-Wide Exchange Necessary.* Strategies suggested in support of national specialization and expanded trade imply, first, that productivity increases should be promoted as actively in countries that traditionally have food surplus such as Burma, Thailand, and Ceylon, as they are in countries which have recently been food deficient such as India and Pakistan.

Second, countries should be encouraged to design agricultural development policies that will be consistent with the expansion of trade. Explicit tariff or quota barriers to agricultural imports should be shunned where possible and promotion for export should be given as much attention as needs of domestic markets.

Beyond this, the developing countries should be aware of the plans and policies of other nations with whom they might be engaged in trade. Frequent consultation among agricultural planners of the developing countries should be encouraged, possibly under the auspices of international organizations, so their plans and projections will be reasonably consistent with each other and opportunities for regional specialization and exchange will be recognized.

*2.5.2 Implications for the Industrialized Nations*

Citizens of the developed world have enjoyed sustained rises in income in recent years. As a result, they have been able substantially to increase their farm product consumption and to improve their diets. This demand has been met by a rise in both domestic farm output and in international trade in farm products.

It is highly probable that growth of both income and population will continue in the developed countries sustaining a high level of demand for farm products. In Western Europe and Canada, however, most of the growth in demand will come from an increase in the quality rather than in quantity of food just as has been true in the United States in recent years. Thus, the increased demand in these countries will be largely for livestock products, feedstuffs, and fruits and vegetables. The United States can be expected to benefit from this trend because of our great efficiency in feed-grain production.

The other developed countries of the free world show many of the characteristics of the United States. First, while they are not primarily agricultural, their agriculture is technically advanced and involves large capital inputs and makes relatively efficient use of labor. Second, most countries have an elaborate governmental or quasi-governmental structure to protect the income of farm producers from the impact of outside competition. Third, most developed countries view their domestic markets for food and fiber as a preserve for their domestic producers and engage in international trade in farm products only as a residual source of supplies or as an outlet for surpluses.

There is little question that these policies tend to increase the cost of food and fiber to the developed countries by inducing high cost domestic production of farm products that might be obtained at a lower real cost through international trade. Countries that are relatively wealthy can afford this resource cost to protect their farmers and thus avoid or respond to the domestic political pressures brought by farm producers and allied interests. The developing countries cannot afford such resource costs, however, and some of the agricultural and trade policies of the developed countries work to their detriment.

It is unrealistic to assume that the developed countries will withdraw substantial portions of their agricultural protectionism in the near future. It is hoped, however, that they will examine those policies which have a particularly adverse effect upon the developing countries with a view toward modifying them.

Three major policy considerations for the developed countries are:

1. Large-scale and vigorous attempts to adapt and transplant their advanced technology in agriculture to the production of food and fiber in the developing countries.
2. The reduction of barriers to the markets in the developed countries for primary products from the developing countries.
3. The international organization and financing of those concessional sales of food and fiber deemed necessary to deal with the population and economic growth problems of the developing countries.

*2.5.2.1 The Reduction of Barriers to Markets for Primary Products.* The developing countries should attempt to produce those products for international trade for which they have a comparative advantage and to use the exchange thus earned to buy those products which can be produced more efficiently elsewhere. This should give them the most products for their resources and the greatest political and economic independence. Such action however is obviously dependent upon the availability of export markets for their products and hard currency markets are largely in the developed countries. In general, the present policies of the developed countries provide major barriers to these lucrative markets.

First, the agricultural policies of most developed countries encourage the production of products which are directly competitive with those produced by the developing countries. For instance, nearly every developed country has a policy to encourage and protect high-cost beet sugar production, thereby reducing the market for one of the products in which the tropical developing countries have a clear production advantage. Moreover, sugar usually has to be imported in raw form, thereby removing the possibility of employing some of the excess labor in the developing countries for refinement. The extent of such policies varies widely among the developed countries, but similar problems can be cited in the protection of rice, oilseeds, cotton, and fruits.

A second barrier to the markets of the developed countries is the high taxes and/or import duties levied by many of the developed countries upon products imported from the developing countries. These taxes are generally intended not so much to protect domestic producers but to generate revenue or alter consumption patterns. Examples of such products affected by these taxes are coffee, cocoa, and tobacco. Duties discourage consumption and thereby reduce the market for products which could be produced more advantageously in developing countries.

Many developed countries have discriminatory trade policies favoring one or a few of the developing countries. Such arrangements are favored by nations receiving them, but, in general, they may distort production and trade patterns among the developing countries, encouraging uneconomic production and adding to the exchange problems of developing countries as a group.

United States policies in regard to these factors are neither the most permissive nor the more restrictive. Because of our position as one of the world's major producers of farm products, we can hardly expect that other developed countries will take the initiative to reduce trade barriers to the products of developing countries.

There has been heavy pressure from the developing countries for the developed countries to give them general trade preference. Some

kind of price stabilization for export products from developing countries also is frequently demanded. If preferential treatment and price stabilization mean, as they appear to, price increases for farm products produced by developing countries, it is doubtful that such devices would prove either feasible or desirable in the long run. The demonstrated inability of such schemes to achieve effective production control and the tendency to divert scarce resources to commodities already in excess supply in world markets suggest that other means of stabilizing the export earnings of the developing countries should be sought. Actually, liberalization of trade relations among the developed nations may be fully as important as between the developed and developing nations.

*2.5.2.2. The Organization of Concessional Sales.* Some kind of well-organized, long-range program of concessional sales from developed countries to developing countries should be a part of world food planning.

Until very recently, the major concessional sales have involved commodities considered as "surplus" by the selling country. This has meant that the developed countries that are not major exporters of farm products have viewed this as a program for which they had no responsibility. The sharp reduction in the stocks held by the United States drastically changes this picture. A major effort should be directed to obtaining coordinated support from the other developed countries to finance a continuing program of concessional sales. Several considerations should guide this effort:

1. The principle of comparative advantage should be considered in these sales as in normal trade. It makes very little sense for the wealthy countries to finance an expansion of high-cost grain production in Western Europe when grain for concessional sales clearly can be obtained at a lower cost from the Western Hemisphere and Australia. Similarly, it is unwise to encourage the production of high-cost dairy products in the United States to obtain dried-milk products when expanded output might make them available more cheaply in Western Europe, the United Kingdom, or New Zealand due to better forage conditions and lower labor costs.

2. The pre-eminence of the United States in the area of concessional sales means that we should encourage greater international planning and cooperation in these endeavors. In doing so, however, we should recognize that, while past surplus disposal programs have provided valuable experience, they are not models for future plans.

3. The United States and Canadian grain stocks also brings to the fore new questions about the responsibility for stock-holding for concessional sales. Since such sales are by their nature unpredictable and require variations in product flows not easily programmed into cur-

263-888 O—67——14

rent agricultural production, a clear and consistent policy of stocks for concessional sales needs to be developed.

There are no clear economic reasons why such stocks should be financed and held exclusively by the United States and the other major exporting countries. Eventually, the developing countries should help finance a program for handling concessional sales that will isolate such stocks from normal commercial trade channels.

*2.5.3 Implications for the United States*

If the nature and the volume of trade envisioned in the foregoing analysis were to come about—that is, if there were to be a growing volume of both conventional trade and trade on concessional terms—the United States would experience a mixture of effects.

Among the favorable factors would be the more nearly full utilization of our agricultural and agri-business resources. Sharp restrictions on the use of our agricultural capabilities are expensive and distasteful to farmers and to those who serve them. In 1966, the Federal Government made direct payments to farmers which totaled about $3.5 billions, a sum equal to approximately 25 percent of the net income of United States farmers, most of it in connection with programs which held out of production some 56 million acres of a total of about 350 million acres of cropland. There is a deep desire of farmers to use their land and an equally strong wish on the part of the agri-business community to provide farmers with additional amounts of fuel, machinery, fertilizer, processing, storage and transportation facilities, and a host of associated services.

Any increase in commercial dollar exports would be helpful to agriculture, to our trade balance, and to the country generally. However, if these resources are put to uses that involve little or no financial return to this country—as is often the case for those commodities moved under P.L. 480—then their release will result in an increase in cost rather than a reduction. Rather than pay the farmers for not producing the crops, we would be paying them for producing the commodities and adding both processing costs and a considerable outlay for transportation. Research findings generally agree that producing and donating is the more expensive. Some studies place the cost at about twice that of preventing production but other estimates are lower. In any case, it is safe to say that the unrequited transfer of increasing quantities of United States farm products would add considerably to the present outlay.

There is an additional difficulty which the United States would encounter if the projected trends were to come about. Our agriculture and agri-business complex would become heavily dependent upon special export outlets. This would make curtailment or termination difficult even if the best interests of the United States and the recipient

countries indicate the reduction or the end of the program to be the best long-term course. To terminate the program after we and they had both become reliant on it would be a jolt to the receiving nation, an economic shock to us, and a setback for this country in the councils of world opinion.

The following actions should be taken to prevent the occurrence of difficulties apt to arise from excessive food aid commitments.

1. Special agricultural exports should continue with the following principles, which are to be found in the new Food For Peace legislation:

*a.* Food aid should be associated with assistance in family planning.

*b.* Special food aid exports should be held to a bare practical minimum. They should take into account the real needs of the recipient countries; whether these needs relate to commodities in United States government stocks, commodities which are not in stock but might be procured in the market, or production goods like fertilizer and insecticides that could help the developing countries increase their own output.

*c.* Food aid other than disaster relief should be considered as an interim program to buy the time needed for agricultural development to occur abroad. It should not be looked upon as a long-range permanently-subsidized program which couples our excess production capacity with the food needs of the developing countries.

*d.* Food aid should be conditioned by the demonstrated intent of the receiving countries to improve their own agriculture.

*e.* Food aid should be coupled with a very substantial increase in technical agricultural assistance supplied by the United States.

2. Our agricultural production policies, and hence our foreign trade policies, should be related more closely to the principle of comparative advantage. That is, each country should produce the commodities for which its costs are lowest and should trade these products for others which are produced at low cost in other countries.

*a.* In accordance with this principle, the United States should emphasize the production of those commodities which are or can be competitive in world markets or in United States markets without protection: wheat, cotton, plant proteins, and especially soybeans. We should de-emphasize those commodities which can be more economically supplied by other countries, such as sugar and wool. In working out these adjustments of farm and trade policy, we should negotiate for and obtain

similar adjustments from other countries, many of which have agricultural and trade policies that depart further from the principle of comparative advantage do our own.

*b.* We should, on the whole, avoid preferential trading arrangements, giving as near equal treatment as possible to our trading partners. Some deviations from this policy are inevitable, but they should be limited in number and scope. For example, there is danger in giving trade preferences to the developing nations because it tends to overstimulate their production of commodities for export at the expense of much-needed food production for domestic use. This would be to their disadvantage and ours. Trade preferences can result in uneconomic production, a luxury the developing nations cannot afford and a threat to our own export markets.

# CHAPTER 3

# INTENSIFICATION OF PLANT PRODUCTION

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## Contents

| | | Page |
|---|---|---|
| 3.1.0 | Summary | 193 |
| 3.2.0 | Introduction | 195 |
| 3.3.0 | Progress and Limitations in Production in the United States | 196 |
| 3.3.1 | Development of Germ Plasm and Varieties with Superior Performance by Conventional Plant Breeding Techniques | 198 |
| 3.3.2 | Utilization of Hybrid Vigor For Intensifying Plant Production | 200 |
| 3.3.3 | Breeding Systems to Broaden the Germ Plasm Base | 202 |
| 3.3.4 | Plant Nutrition and Fertilization | 203 |
| 3.3.4.1 | Plant Nutrition Research | 204 |
| 3.3.4.2 | Advances in Fertilizer Technology | 204 |
| 3.3.4.3 | Soil and Water Management | 205 |
| 3.3.5 | Plant Protection | 205 |
| 3.4.0 | Present Status and Potential for Increased Production in the Developing Countries Utilizing Existing Knowledge | 208 |
| 3.4.1 | Mexico's Wheat Program | 210 |
| 3.4.2 | Pakistan's Wheat Program | 211 |
| 3.4.3 | Other Action Programs | 212 |
| 3.4.4 | Plant Protection | 213 |
| 3.5.0 | Research and Development for Improved Strains and New Crops in the Developing Countries by Application of Genetic Principles and Plant Breeding Techniques | 215 |
| 3.5.1 | Program for the Immediate Future | 215 |
| 3.5.2 | The Long-Term Approach | 219 |

Page

3.6.0 Factors Limiting Progress in Developing Countries ..... 225
3.7.0 Research on Improved Crop Production and Plant Protection Practices for Developing Countries ..... 228
3.7.1 Short-Term Program for Food Production ..... 228
3.7.2 Long Range Agronomic and Plant Protection Investigations ..... 232
3.8.0 Dissemination of Information In the Developing Countries ..... 233
3.8.1 Organization ..... 233
3.8.2 Personnel ..... 234
3.8.3 Extension Programs ..... 235
3.8.4 Relation to research ..... 236
3.9.0 Education ..... 236
3.9.1 Role of Universities of the USA ..... 237
3.9.2 Support Needed by the Universities ..... 238
3.9.3 Support for Foreign Trainees ..... 238

# 3.0 INTENSIFICATION OF PLANT PRODUCTION

## *3.1.0 Summary*

Production of major food crops can be increased substantially in both developed and developing countries. Application of existing knowledge in the form of coordinated, crop-oriented research and production programs will be needed—especially in the food-deficit nations—if food requirements of the 1970's and 1980's are to be satisfied. Even under the most favorable circumstances, the interval between inauguration of such programs and their realization will be at least 5 to 10 years.

National programs such as the wheat programs of Mexico and Pakistan, the All-India Crops Scheme, and the Kenya maize program should be considered as models for developing similar programs in other countries. No campaign for accelerating food production should be initiated, however, before accomplishment of applied research has shown that new plants can be adapted to practices under specific, local conditions. Application of genetic principles and plant breeding techniques will play a major role in programs for intensifying plant production. For the immediate future, advantage should be taken of present knowledge of the geographic adaptation of many of the world's improved crop varieties. They should be tested widely in areas where they are likely to prove useful. Special attention should be given to the following:

1. Rice varieties from Taiwan that have been improved at the International Rice Research Institute which have short stature, stiff straw, and respond to high levels of fertilizers.
2. Dwarf wheat varieties developed in Mexico which have wide geographic adaptation.
3. Maize varieties and hybrids, developed in tropical America and Southeastern United States, which appear to be adapted to areas of Southeast Asia and Africa.
4. Sorghum genotypes which have unusually wide ranges of geographic adaptation.

For the long-term approach, five major considerations are involved:

1. Attention to basic food crops that can be propagated rapidly—wheat, rice, maize, pulses, oil-seed legumes, sorghum, millet, potato, sweet potato, yams, cassava and banana. Attempts toward self-sufficiency in specialized, poorly adapted crops should be avoided.

2. Substantial breeding efforts, in the regions and by the nations where the crops are to be used, should be encouraged.

3. Establishment of organizations that can produce and supply adequate and dependable quantities of high quality seed. Generally, private enterprise has been much more effective than government monopolies in producing and distributing seeds of improved varieties or hybrids.

4. Establishment of integrated national crop-oriented programs under unified leadership.

5. Plant breeders must utilize high levels of soil fertility in breeding programs in order to develop plant types capable of converting large amounts of nutrients into end products of better nutritional quality. Attempts now being made to isolate cereal genotypes with a better balance of amino acids should be greatly expanded, especially the transfer of the genes opaque-2, or floury-2, or both, into maize varieties. These genes are capable of increasing the lysine content of maize by about 100 percent and tryptophan by almost 65 percent.

The full potential of improved varieties cannot be realized unless adequate quantities of mineral nutrients and water and protection from pests are provided. Use of fertilizers is probably the quickest and most dramatic way to increase crop yields. Doubling or tripling yields of some crops by adequate fertilization is not uncommon. Response to fertilizers by improved varieties in the national wheat programs of Mexico, India, and Pakistan have ranged from 17 to 30 pounds of grain for each pound of nutrients applied compared to 11 to 16 pounds for the locally grown varieties.

The key to success in accelerated food production programs is the adoption of the "package of practices" approach including the use of new, high-yielding varieties, adequate fertilization and irrigation, and improved cultural and plant protection practices.

Agricultural progress is being impeded in many developing nations by the following problems:

1. Lack of personnel properly trained for effective participation in national crop-production efforts.

2. Failure to emphasize yield concepts based on production per unit area per unit of time instead of fixed crop growing seasons. This is especially important in tropical and subtropical areas.

3. Lack of capability of the United States in tropical agriculture commensurate with the expressed willingness to respond to the needs of less developed nations in the improvement of their agriculture.

4. An erroneous concept that agricultural technology can be transferred from temperate to tropical areas as effectively as principles of crop production.

5. Donation of food grains by the United States, or sale for soft currency, appears to have permitted some nations to hold down prices

of grain, or to adopt other policies which discourage production by their own farmers.

In view of the potentials of tropical agriculture, it appears desirable to establish one or more tropical research and training institutes in the tropics. Such institutes should be supported by an appropriate agency of the Federal Government, and be established on territory owned or controlled by the United States. They should serve for research and training centers in tropical agriculture for citizens of the United States and foreign countries.

The practical limits to intensified plant production are likely to be economic and socio-political rather than biological. Economic and socio- political factors range all the way from deep-seated traditions of rural societies to policies of governments. Rural societies are slow to change and their traditions are difficult to attack directly; but governments, by making appropriate policy decisions, can provide the impetus to bring about change. The formulation of agricultural policy giving agriculture the status, prominence, and priority which its importance demands is the first step in creating conditions for increasing production. Other policies—pricing, marketing, taxation, import-export duties, allocation of public investment, regulation of private investment, and wage scales—also are relevant to the problem of achieving maximum agricultural production. Agricultural policy should aim to achieve the greatest positive influence and to minimize the negative influence.

### *3.2.0 Introduction*

Existing food deficits, and the possibility that these may further increase within the forseeable future, emphasize the critical need for intensifcation of plant production. That plant production can be intensified appears to be obvious from a comparison of yields between developed and developing countries, of current yields with those of a few decades ago, and of the rates at which yields are increasing in some countries. For example, yields of basic food crops, such as the cereal grains and potatoes, are from 50 to 350 percent higher in many of the developed countries than in most of the developing ones. During the past decade and a half, increases in yields differ by the same general order of magnitude. Even in the most agriculturally advanced countries, average yields are much less than the theoretical limits based on absorption and utilization of solar radiation.[1]

The United States has committed itself to help those countries which are in need and which are willing to do what they can to help themselves. The ultimate aim should be to help the developing countries toward independent and continuous progress, and to help transform

[1] Loomis, R. S., and W. A. Williams. Maximum Crop Productivity: An Estimate. Crop Science, 3: 67–72, 1963.

them into advanced and continuously advancing countries. At best, this must be an evolutionary process, one involving not only intensification of plant production but the overall problem of total economic and sociologic development.

Can emergency measures alleviate the present food emergency quickly, while furnishing, at the same time, the ingredients of a developing system for preventing future emergencies? Perhaps there is no answer to this question, but marked improvements are possible. Emergency measures based on a series of unknowns are foredoomed to failure or worse; to advocate the use of agricultural materials and methods in any area without prior knowledge of their suitability for that area is futile and can be dangerous.

The extent to which massive action programs can make a quick, strong, and continuing impact on food production, and the possible ways by which this can be done are considered in this report.

### *3.3.0 Progress & Limitations in Production in the United States*

In recent years, agricultural production of the United States has increased while acreage planted to crops has decreased. The area planted to all cereals during the period 1948–53 was 81 million hectares, with a yield of 136 million metric tons. In 1964–65, 62 million hectares were planted to these crops and the yield was 164 million metric tons. The key to such a high level of production lies in fertile soils, favorable climate, and the combination of desirable practices. The yield potential of improved varieties, for example, can be realized only if adequate fertility, water, and pest control are provided.

Over a 30-year period, corn yields have trebled but soybean yields have increased merely 60 percent (Table 3–1). The difference in progress in achieving higher yields with corn and soybeans bears examination.

TABLE 3–1.—*Trends in yields of corn and soybeans in the United States, 1931–65* [1]

| Years averaged | Kilograms per hectare | |
|---|---|---|
| | Corn | Soybeans |
| 1931–35 | 1,520 | 1,009 |
| 1941–45 | 2,206 | 1,244 |
| 1951–55 | 2,690 | 1,345 |
| 1961–65 | 4,426 | 1,628 |

[1] U.S. Department of Agriculture. Agricultural Statistics (annual).

In the 30-year period corn hybrids replaced open-pollinated varieties. Replacement started in the early 1930's, reached 50 percent by 1943, and 90 percent by 1955. Although hybrids gave increased yields, the rise in unit production was attributable to a combination of fac-

tors. Hybrids provided the impetus which made other changes in production practices feasible. Hybrids responded more readily to fertilization, minimized lodging and dropping of ears, and tolerated increased plant populations, thus making profitable the practice of heavy fertilization. Hybrids also made profitable the use of more herbicides and insecticides for pest control. Average applications of nitrogenous fertilizers increased from 2 to 47 pounds per acre during the 30-year period. The combination of desirable practices provided the phenomenal yield increases.

Soybean yield increases are much more modest. In contrast to corn, hybrid vigor cannot be used directly in soybeans. Soybeans are self-pollinated, and no method has been found to produce hybrid seed for commercial production. Development of varieties with improved yield potential has been limited to conventional breeding methods.

Fertilizer utilization by soybeans also imposes a barrier. When leguminous crops such as soybeans are inoculated with efficient nitrogen-fixing bacteria, the plants obtain much of their nitrogen from the bacterial organisms. Application of nitrogenous fertilizers merely reduces activity of the beneficial organisms and does not increase yield appreciably. The response to potassium and phosphorus fertilizers is also somewhat less than that for corn. Fertilization, particularly with nitrogen, is therefore not practiced extensively in soybeans.

The factors responsible for increased yields in soybeans are largely attributable to improved varieties and improved management practices. Weed control, for instance, has been vastly improved in the past 30 years. As in corn, the yield increases are attributable to a combination of improved practices. The smaller increase in yields of soybeans is due to lack of hybrid vigor and lack of response to nitrogen fertilization.

The trend of increasing rice yields in the United States during the last two decades (Table 3–2) results from a combination of desirable practices. These practices include higher fertilization rates, improved water management, availability for the first time of herbicides effective

TABLE 3–2.—*Trends in yields (kilograms per hectare) of rice and wheat in 5 countries since 1948* [1]

| | Rice | | | | Wheat | | | |
|---|---|---|---|---|---|---|---|---|
| | 1948–53 | 1962–63 | 1963–64 | 1964–65 | 1948–53 | 1962–63 | 1963–64 | 1964–65 |
| Brazil | 1,570 | 1,540 | 1,520 | ---------- | 740 | 950 | 490 | 880 |
| India | 1,110 | 1,370 | 1,550 | 1,610 | 660 | 890 | 790 | 730 |
| Japan | 4,250 | 5,280 | 5,230 | 5,150 | 1,850 | 2,540 | 1,230 | 2,450 |
| Pakistan | 1,380 | 1,510 | 1,720 | 1,680 | 870 | 820 | 830 | 830 |
| United States | 2,560 | 4,180 | 4,440 | 4,590 | 1,120 | 1,690 | 1,700 | 1,770 |

[1] Food and Agriculture Organization of the United Nations. Production Yearbook, 1965.

for control of weeds such as *Echinochloa* spp., and the development of better varieties, especially those that mature in about 100 days, thus allowing a considerable part of the total acreage to produce a second crop.

### *3.3.1 Development of Germ Plasm and Varieties With Superior Performance by Conventional Plant Breeding Techniques*

The practice of hybridizing one parent with another which complements its characteristics, and selecting from among the progeny those plants that carry the desirable characteristics of each parent has been of tremendous importance in improving varieties within the United States. Progress has been made to a varying degree in increasing quantity and quality of production in all crops.

Much effort has been devoted to the adaptation of economic plants to specific environmental conditions. Tolerance to drought, severe winters, salinity, and poor drainage are examples of improved adaptation. Development of soybean varieties that yield satisfactorily at both shorter and longer photoperiods has allowed the profitable production of this crop in regions south and north of the original areas of adaptation.

In most economic species within the United States, the most readily attainable improvements have been made through conventional breeding within the germ plasm available. Exploration for and introduction into the breeding program of germ plasm carrying additional desirable characters are required for further progress.

The environment in which plants are produced has been altered in recent years by high levels of fertilization, supplemental irrigation, and other improved practices. A great deal of success has been attained in developing varieties which can fully utilize such improved practices.

Genetic resistance to pests, a form of biological control, is usually the most economical control measure. In most field crops, the economy permitted by genetic control of pests is particularly important. Control of the many damaging species of rust that attack cereal grains and flax is the outstanding example of pest control. Excellent progress has been made in developing varieties resistant to diseases in most economic species. Resistance to certain diseases, however, has not been found within available germ plasm.

Genetic resistance to attack by insects has been studied for a short period of time, but good progress is being made. An outstanding example is resistance of winter wheat varieties to the Hessian fly. Significant progress has been made recently, in the development of resistance in alfalfa to the spotted alfalfa aphid and to the pea aphid, and resistance of corn to the European corn borer.[2] Resistance to

[2] Painter, R. H. Lessons to be learned from past experience in breeding plants for insect resistance. *IN:* Breeding Pest-Resistant Trees. Proc. N.A.T.O. and N.S.F. Symposium Pergamon Press, London, 1966, pp. 349–362.

nematodes has also received attention recently. High resistance to the root-knot nematode has been found in Korean lespedeza and in soybeans, and resistant varieties have been developed. Alfalfa varieties resistant to the stem nematode have been released. Very recently, soybean varieties, which carry resistance to the soybean-cyst nematode, have been released. In many crops resistance to parasitic nematodes has not been found in available germ plasm.

Gossypol in cottonseed restricts cottonseed meal from being consumed by humans and other non-ruminant animals. Processing methods have been developed for removal of gossypol but these are expensive. Recently, genetic stocks have been found that lack the gossypol-producing glands.[3] The practicality of developing gossypol-free varieties still remains to be determined.

Through interspecific hybridization, the coumarin content of sweet clover has been drastically reduced. Genetic strains of Sudangrass and forage sorghum with low prussic acid content have been used to develop varieties that minimize prussic acid poisoning of livestock. There are great potentialities for further improvements in this area.

Dwarf plants can be used to increase production. They can be planted more densely and therefore utilize sunlight more efficiently. They also respond to high rates of fertilization for maximum production without the resultant tall growth which stimulates lodging and reduces efficiency of mechanical harvesting. Dwarf genes have been used with great success in grain sorghum. Semi-dwarf wheat varieties obtained from Japan have short internodes of the straw without deforming the head. Germ plasm from these varieties was used to develop a white winter wheat variety, Gaines, for the Pacific Northwest. Improved response to high levels of plant nutrients and yields up to 209 bushels per acre have been obtained from this variety. This germ plasm has also been used to develop varieties with three times the normal yield in Mexico and shows great promise for use in achieving increased wheat production in Pakistan and India.

Recently, dwarf corn inbreds have been released in the Southern United States. These inbreds produce hybrids with low ear placement which induces less lodging and adapts the plant to mechanical harvesting.

Quality has characteristically been sought in such crops as wheat, where good milling and baking properties are essential and, in barley, where malting quality is important. In many important food and feed crops, such as corn and sorghum, minimum research accomplishments can be reported. Vastly improved instrumentation now permits more detailed studies of quality in plant products. Gas chromatography has expedited analyses of the fatty acids that constitute vegetable

[3] Hyer, A. H. Breeding for glandless cottonseed in California. IN: Proc. Cotton Improvement Conf., Memphis, 1966, pp. 202–208.

oils. Improved instrumentation also permits amino acid analysis. Amino acid composition determines the quality of protein for the nutrition of humans and non-ruminant animals. In corn, germ plasm has been isolated which greatly alters the characteristic balance among the amino acids. Amino acids such as lysine and tryptophan, which are characteristically low in corn, can be substantially increased.

Plants can be improved only to the extent that desirable genetic characteristics can be identified and isolated in available germ plasm. This points up the importance of extensive world collections and germ plasm banks of economic plants and related species to permit vast screening programs for desirable characteristics.

The ability of pests such as microbial pathogens and insects to mutate and develop strains that will attack previously resistant crop plants must be considered as a limitation in breeding plants for resistance to disease. The occurrence of new varieties of rust organisms that attack cereals has necessitated a never-ending replacement of the crop varieties that will cope with the new strains of rusts. Wheat varieties resistant to the Hessian fly have been attacked recently by new strains of the insect. Pest control through utilization of plant breeding techniques requires constant vigilance and is a never-ending task.

### *3.3.2 Utilization of Hybrid Vigor for Intensifying Plant Production*

The potential for application of heterosis, or hybrid vigor, in plant breeding was demonstrated shortly after the turn of the twentieth century. Since then vast plant breeding programs have been conducted to utilize hybrids. In crops where first generation hybrids can be used for commercial production, the first hybrids developed have yielded approximately 25 percent more than the conventional varieties. Further improvements of parental stocks have frequently permitted production increases of 40 percent.

The hybrid corn industry was made possible by the ease of removing the male flowers—the tassels—from seed rows. Few plants, however, bear male and female flowers separately. In certain normally cross-pollinated crops, plants exhibit a high degree of self-sterility. A high incidence of cross-pollination occurs when self-sterile plants are interplanted. Unfortunately, not many species exhibit a high-degree of self-sterility and this practice cannot be used extensively.

Even when plants are not self-sterile, the interplanting method of hybridization has sometimes been used. In pearl millet, for example, successful hybrids have been produced by interplanting high-combining inbred lines. A high proportion of seed harvested is hybrid due to chance cross-pollination. The small portion from self-pollination produces inbred plants which have low competing ability and are crowded out in the subsequent generation. This method has not been

used extensively as it is feasible only if a high degree of cross-pollination occurs normally and if high rates of seeding are employed.

Male-sterility, which is transmitted from one generation to the next in the cytoplasm or the fluid portion of the female sex cells, has been discovered in some crops. In the 1920's, cytoplasmic male sterility of onions was first used for the production of commercial hybrids. Cytoplasmic male-sterility was subsequently found in maize. Although the onion technique was used, there was one additional problem. Because corn depends on seed production in the commercial field, fertility must be restored when the hybrid is grown, or seed of non-sterile types must be blended with the hybrid seed. Fertility was restored by incorporating in the male lines fertility restoring genes which overcome the sterilizing effect of the female cytoplasm. In the interest of eliminating the costly hand-emasculation operation, corn hybrids were rapidly converted to this system of hybridization.

During the early 1950's cytoplasmic male-sterility and genetic fertility restorer genes also were found in grain sorghum. This led to rapid development of grain sorghum hybrids. More recently, this system has been transferred to Sudangrass and Sudangrass hybrids are being developed. Also sorghum × Sudangrass hybrids have been produced for livestock feeds.

In the early 1960's, germ plasm was found for hybridization in wheat. As wheat is normally a self-pollinated crop, difficulties may be experienced in obtaining a high set of hybrid seed. Because of higher seeding rates of the commercial crop, the cost of hybrid seed may be high relative to crops such as sorghum and corn. Nevertheless, the system is being investigated intensively at the present time. Planting of hybrid wheat can be anticipated by 1970.

In those crops where cytoplasmic male-sterility has not been discovered, attempts are being made to develop hybrids through the use of germ plasm carrying genetic factors in the chromosomes which cause male-sterility. In the case of genetic male-sterility, the seed rows segregate for the male-sterile character and some means must be developed to eliminate the fertile plants so that hybrid seed production is assured. Hand roguing has a heavy labor requirement and is expensive. Means of roguing adapted to mechanical means are being investigated.

In barley, a gene has been located which renders the plant highly susceptible to DDT. If close linkage can be established between susceptibility to DDT and the fertility gene, spraying with DDT would eliminate all fertile plants. Other means are being investigated, such as close-linkage of genetic factors for seed color with the gene causing sterility. Fertile and sterile seeds might then be separated by photoelectric devices. Incorporation of an extra chromosome carrying the fertile gene might permit sorting of fertile and sterile seeds by means

of kernel size, since those carrying the extra chromosomes are less plump.

At present, limited use is being made of genetic male-sterility to produce commercial hybrids. It is being used for the production of castor-bean hybrids and, to some extent, spinach hybrids. It is being investigated intensively in such crops as barley. Although the system is more cumbersome than that of cytoplasmic male-sterility, it has a great potential in some of the major crops.

Utilization of hybrid vigor depends almost entirely on the availability of suitable genetic characters. It is not economical to remove by hand the male flowers on most crops—particularly those crops in which the male and female components occur in the same flower. There is a strong possibility of finding cytoplasmic male-sterility in normally cross-pollinated crops. In the normally self-pollinated crops, natural selection against self-sterility has been so intense that it is not likely to be found within a species. Only through crossing with exotic species, as was done in wheat, can this factor be expected. Exotic species which will cross with domestic species have not yet been found for some of our crops. Similarly, genetic male-sterility has not been discovered in some of the important crops—particularly those that are self-pollinated.

### *3.3.3 Breeding Systems To Broaden the Germ Plasm Base*

Improvement in crops through plant breeding is limited to the breadth of available genetic diversity. When desired characters do not occur within the germ plasm of a crop, this limitation becomes critical. The plant breeder must then look to other sources to broaden the germ plasm base. Several avenues are available to the breeder.

Alteration of germ plasm by irradiation has been practiced for some time. During the early history of plant breeding, X-rays and ultraviolet rays were utilized. Since the advent of nuclear energy, gamma rays and neutrons have been used. Various chemical mutagens are used also.

Several types of genetic mutations, which include alteration of single genes or breakage of chromosomes and rearrangement of the segments, may occur. Single gene changes which give genetic resistance to pests are sought. Experience has shown that the greatest progress can be made for characters that can be detected by screening large numbers of plants. Massive screening, for instance, has isolated oats that are resistant to Helminthosporium blight. Screening irradiated Merion bluegrass has been used to find rust resistant plants. Disease resistant and superior plant forms have been developed through irradiation of peanuts. Except for isolated cases, success in inducing single genes to mutate to desirable forms has been limited.

Phenomenal results have been obtained through breakage of chromosomes and reassortment of the fragments. As an illustration, leaf rust

resistance was transferred to wheat from a weedy wild relative. Close linkage of the rust-resistant gene to undesirable characters precluded its use. Through irradiation, the chromosome was broken, thereby freeing the resistant gene from the undesirable genes and providing a high type of resistance to leaf rust in wheat. Segments of rye chromosomes also have been incorporated into wheat leading to germ plasm with higher protein and rust-resistance. The vast potential of this system of breeding has been realized only to a limited degree.

The germ plasm base of certain crops has been greatly broadened through the use of wide crosses—crosses among different species or genera. An early illustration was the development of Hope wheat from crossing two wheat species. The stem rust resistance of that variety is still used in breeding programs. Some of the wild species of oats collected in Israel are furnishing oat breeders with an important source of rust resistance.

Wild progenitors of domestic crops frequently are sources of desirable traits which are no longer present in the domestic species. Many of today's important food crops are polyploids of wild progenitors. Germ plasm from wild progenitors can be utilized to create artificial polyploids by crossing two progenitors and doubling the chromosome number by chemical means. Crossing wild types with domestic strains is valuable because it facilitates transfer of desirable germ plasm from wild progenitors to domestic crops. In some cases, the transfer has consisted of genes for desirable characters; in other cases, it has resulted in the recovery of cytoplasmic male sterility which is used to obtain hybrid vigor in domestic crops.

The need for extremely large populations is one of the most serious limitations of mutation breeding. More than 99 percent of the mutations are economically undesirable. Even though a desirable change may have been induced in one character, an undesirable effect is frequently noted in a second. Progress can be made only if vast populations can be screened for the character in question.

Wide crosses pose several serious problems. In some cases, hybrid seeds will not form. In other cases, extreme sterility results in the hybrid plant. Various techniques are available to overcome these problems but in some cases they are insurmountable. Despite these limitations, much progress has been made and there is great future potential in these methods of breeding.

### *3.3.4 Plant Nutrition and Fertilization*

Plant nutrition and soil fertility research, with high yielding varieties, has set the stage for increased requirements of fertilizers. Rapid advances in fertilizer technology have kept fertilizer prices relatively low. This combination has resulted in phenomenal increases in fertilizer use and food, feed, and fiber production.

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*3.3.4.1 Plant Nutrition Research.* Plant nutrition and soil fertility research involving all aspects of fertilizer use have been the backbone of the development of sound fertilization practices. These studies have involved hundreds of different crops over a wide range of soil and climatic conditions. In the early 40's the corn yields in the Southeastern United States were about the same as those of many of the developing countries today. Adaptive research involving plant breeding, plant nutrition, crop management, and crop protection was used to increase yields of corn greatly. For example, in 40 experiments conducted from 1944 to 1952 in North Carolina, the average yields increased from 28 bushels per acre with no nitrogen, to 101 bushels per acre with 160 pounds of nitrogen per acre. In 1945, a vigorous extension program was launched in cooperation with other State agencies and the seed and fertilizer industry. The average corn yield before initiation of the program was 21 bushels. By the years 1950, 1958, and 1965 the yield had increased to 33, 44, and 70 bushels per acre, respectively.

Soil and plant analyses have provided good aids to proper fertilization of crops. In many cases, soil analyses have been used to pinpoint deficiencies of various nutrients. Plant analysis has been further useful in adjusting and guiding fertilization programs. In most cases, its value has been in discovering areas of nutrient deficiencies. In recent years plant analysis has also been very useful in avoiding excessive use of nitrogen in such crops as citrus and sugar beets where excessive nitrogen in the plant may reduce quality. Plant analysis has also been useful in programming the harvest of sugar beets in California.

Micronutrient fertilization, as such, is relatively new. This need for micronutrient fertilization has been brought about by increased crop removal of micronutrients from the soil, the use of high analysis fertilizers which contain smaller quantities of micronutrients as impurities, and the expansion of agriculture into the less fertile soils. Micronutrient deficiencies are widespread and their correction is becoming an integral part of the fertilization program of many growers. Examples are boron in alfalfa, zinc in corn and tree fruits, and iron in fruits, ornamentals, grasses and sorghum. Soil and plant analyses have been useful in identifying deficiencies but research is needed to develop better diagnostic tools for sound micronutrient fertilization programs.

*3.3.4.2 Advances in Fertilizer Technology.* Rapid advances in fertilizer technology, including mining, manufacturing, handling, and distribution systems, have kept the price of fertilizer to the farmer at a very low level. For example, from 1950 to 1961, fertilizer costs increased only 6 percent, while farm real estate values increased 70 percent, farm wages increased 52 percent, and farm machinery increased 41 percent. Many agricultural authorities believe that development of the fertilizer industry represents the most important advance ever

made toward providing plenty of food for the peoples of the earth. In the continental United States between 1940 and 1966, the consumption of fertilizer increased as follows: nitrogen—13.9 fold; phosphorus—4.2 fold; and potassium—7.7 fold.

*3.3.4.3 Soil and Water Management.* Research has shown that water can be used more efficiently if fertilizer is used also. In Texas, adequate nitrogen markedly increased the yield of coastal Bermuda hay. The amount of water needed to produce 1 ton of hay per acre was reduced from 18 inches with no applied nitrogen, to 3 inches with adequate nitrogen. The amount of water required to produce 1 ton of alfalfa hay in Arizona was reduced from 7.7 to 5.4 inches by applying adequate amounts of phosphorus fertilizer.

The potential of greatly increased crop yields due to improved varieties and production practices has renewed interest in soil management to improve soil tilth and water infiltration. Research in California showed greater improvement in irrigation infiltration following the growth of fibrous grass crops as compared to legume crops. This work also indicated that the incorporation of mature grass crops or residues was more effective than that of the same crop in the succulent stage.

### *3.3.5 Plant Protection*

Losses to insects, diseases, and weeds in the production of maize, wheat, rice, grain sorghums, soybeans, and potatoes in the United States from 1951 to 1960 have been estimated as percentage of potential yield as shown in Table 3–3. Losses of this magnitude may be overestimated but they are the best available estimates of the impact of pests upon potential production. Even if estimated losses are twice as high as actual losses, they are of such magnitude that substantial improvements in pest control would be a major contribution toward intensification of plant production. If losses to pests could be reduced by half, annual increases in production of maize, wheat, rice, grain sorghums, soybeans and potatoes, would be about 25 million metric tons at current levels of production.

TABLE 3–3.—*Estimated losses to insect, disease, and weed pests in production of selected crops in the United States, 1951–60* [1] [2]

[Percent loss]

| | Insects | Diseases | Weeds |
|---|---|---|---|
| Maize | 12 | 12 | 10 |
| Wheat | 6 | 14 | 12 |
| Rice | 4 | 7 | 17 |
| Grain sorghum | 9 | 9 | 13 |
| Soybean | 8 | 14 | 17 |
| Potato | 14 | 19 | 3 |

[1] Estimate based on full production with causes eliminated.
[2] Agriculture Handbook No. 291, ARS, USDA, 1965.

Plant protection practices are probably as effective in the United States as any other country in the world. Revolutionary developments in agricultural chemicals since 1945 have provided growers with highly effective, economical pesticides that have been used with increasing frequency for control of agricultural pests. For example, during the crop year of 1959, 4 million acres were treated with preemergence herbicides and 49 million acres were treated with postemergence herbicides at a combined cost of $128 million. Insecticides are currently used at annual amounts in excess of 150 million pounds [4] and fungicides are used as heavily on a few crops; although, the total acreage treated with these pesticides is considerably less than that treated with herbicides and insecticides.

The average return measured as yield increase per dollar invested for these pesticides is usually considered to be about 5 to 1. Use of agricultural chemicals for pest control during the last two decades has been one of the significant factors contributing to the "take-off" in yields of major crops in the United States.

The advances made in pest control have been accompanied by some serious problems. Undesirable side effects resulting from large-scale use of highly toxic, persistent chemicals, especially some of the synthetic organic insecticides, have become increasingly evident. Among these are the following: (1) contamination of the environment with residues, (2) storage of chlorinated hydrocarbon insecticides in the fat of animals including man, (3) toxic effects on desirable species such as predatory and parasitic insects, pollinating insects, fish and other wildlife, and crop plants, (4) emergence of resistant strains of pests, (5) resurgences of treated populations, (6) stimulation of weed growth, (7) nitrification lag, and (8) elevation of formerly minor pests to the status of major importance.

The ubiquitous occurrence of residues of these biologically potent chemicals has been the cause of grave concern in the United States and elsewhere. Chlorinated hydrocarbon insecticides are stored in the tissues of plants and animals. They may be concentrated in food chains to amounts in excess of the concentrations of residues to which the organisms are exposed. This feature creates some unique and important problems. For example, fish in some of the streams of the lower Mississippi Valley contain residues of chlorinated hydrocarbon insecticides greatly in excess of permissible levels in meat and poultry.

Absorption and translocation into plants of chlorinated hydrocarbon insecticide residues in soils has become a major problem. For example, aldrin used in soils of Illinois for control of seedling pests of corn has been responsible for average increases in yield of more than

[4] Hall, D. G., Use of insecticides in the United States. Entomol. Soc. Amer. Bull. 8(2): 90–92, June 1962.

5 bushels per acre;[5] but it is epoxidized to dieldrin in soils, and residues of this material amounting to as much as 1 p.p.m. may be present in soils devoted to corn production.[6]

Soybeans have the ability to absorb and translocate dieldrin and other chlorinated hydrocarbon insecticides, into tissues and seeds at about one-tenth of the amount of residue in the soil.[7] Soybeans grown in rotation with corn in Illinois, therefore, may contain residues of an insecticide for which there is no tolerance. Other oil seed crops—peanuts especially—and some root crops such as carrots, also absorb and translocate relatively high percentages of chlorinated hydrocarbon residues present in soils.

Residues of fungicides, nematocides, and herbicides have not, thus far, created any known serious problems. However, some of the herbicides are highly toxic to plankton and to fish.

No acceptable evidence has been presented to show that any hazard to man or his livestock is posed by the presence of residues resulting from use of agricultural chemicals. Nevertheless, their general occurrence throughout the environment is cause for concern. This, plus the problems created by resistance to insecticides in many populations of most of the major insect pests, has made it obvious that we can no longer afford to rely as completely on the use of chemicals for pest control as we have done for the last two decades.

Systems of pest management based on the principles of applied ecology are being developed. The concept of integrating other techniques of pest control with chemical control measures is the subject of intensive research. This concept offers the most obvious possibility for long-term solutions to pest problems. It considers pest control to be a problem of population management that can best be solved by application of the same basic ecological principles as those used in managing crops and wildlife populations.

Research during the last decade has resulted in the discovery of many exciting new techniques, and the rediscovery of some old ones, that show great promise for the more effective control of pest species. The potential of the male-sterile technique—demonstrated in the classic example of screw-worm eradication from the Southeastern United States—appears to be vast. Other especially promising tools for pest control are gametocides, chemosterilants, sex attractants, and microbial pathogens. More attention is being devoted to the use of varietal resistance, predators and parasites, both indigenous and exotic, and cultural control measures than ever before.

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[5] Bigger, J. H., and Decker, G. C., Controlling root-feeding insects of corn. Ill. Agr. Exp. Sta. Bull. 716. 1966.

[6] Decker, G. C., Bruce, W. N., and Bigger, J. H., The accumulation and dissipation of residues resulting from the use of aldrin in soils. J. Econ. Entomol. 58(2) : 266–271. Apr. 1965.

[7] Bruce, W. N., Decker, G. C., and Wilson, J. G., The relationship of the levels of insecticide contamination of crop seeds to the fat content and soil concentration of aldrin, heptachlor and their epoxides. J. Econ. Entomol. 59(1) : 179–181. Feb. 1966.

All of these techniques can contribute substantially in reducing the tremendous crop losses caused by pests. For the forseeable future, however, we must continue to rely principally upon the use of conventional chemical pesticides.

### *34.0 Present Status and Potential for Increased Production In the Developing Countries Utilizing Existing Knowledge*

The critical need to increase food production in the developing countries requires that an immediate start be made. That food production can be increased by raising the efficiency of production on lands now under cultivation has been shown repeatedly by experiments in virtually all developing areas, and it has been done on a larger scale in many countries. Most of the developing countries have the physical potential for increasing yields of their principal food crops by at least 50 percent. For example, India increased food grain production over 40 percent during the decade of 1950. This increase was attributed to the following factors: 35 percent to additions of unirrigated crop lands, 22 percent to added irrigation, 18 percent to fertilizers and related management factors, and 25 percent to the application of more labor from the growing labor source.[8] At the close of the decade it became apparent that there was little more land that could be brought into production and that further increases in production would have to come from increasing the yields on those soils that were being used at low levels of management. This will most likely apply to many of the developing countries in Asia.

Examples of the great disparity between crop yields of developed and developing countries are provided in the statistics for the period 1948–64. From 1961–62 to 1963–64 yields of wheat in kilograms per hectare ranged from 1,985 in Europe and 1,560 in North America, to 910 in Asia and 820 in Africa. They were intermediate in South America and Oceania, being 1,250 and 1,260 kg/ha., respectively. The increases over the average for the period 1948–53 were greatest in Europe and North America, where yields already were relatively high. In these two areas the actual increases were 500 and 400 kg/ha., respectively, as contrasted with 110 kg. in Africa and only 90 in Asia. Increases were intermediate in South America and Oceania, 180 and 130 kg/ha., respectively.

The story for rice is much the same as for wheat. Yields are deplorably low where food is needed most. During the 3-year period, 1961–64, yields averaged about 4,870 kilograms per hectare in Europe and 4,140 in the United States, but they were only 1,780 in South America and 1,740 in Asia (excluding mainland China). India, Paki-

[8] Lele, U. J., and Mellor, J. W. Estimates of change and causes of change in foodgrains production, India, 1949–50 to 1960–61. Ithaca, N.Y., State Coll. Agr., 1964. 41 pp. (Cornell Int. Agr. Develop. Bull. No. 2).

stan, and Burma are among the main rice producers in Asia, but yields in these countries averaged only about 1,500 kilograms per hectare, as contrasted with more than 5,000 in Japan. Yields in the developing countries are also low for other food crops, such as sorghums, millets, potatoes, pulses, and oilseed as shown in Table 3–4.

TABLE 3–4.—*Comparative yields of major food crops in selected countries, 1964–65* [1]

| Crop | Kilograms per hectare | | | | |
|---|---|---|---|---|---|
| | Brazil | India | Japan | Pakistan | U.S.A. |
| Wheat | 880 | 730 | 2,450 | 830 | 1,770 |
| Maize | 1,160 | 990 | 2,330 | 1,080 | 3,930 |
| Rice | 1,520 | 1,610 | 5,150 | 1,680 | 4,590 |
| Sorghums and millets | ---------- | 990 | 2,560 | 990 | 2,580 |
| Potatoes | 6,000 | 8,300 | 17,800 | 7,700 | 20,700 |
| Sweet potatoes and yams | 10,100 | 6,400 | 19,800 | ---------- | 9,400 |
| Dry beans | 620 | 280 | 770 | 530 | 1,360 |
| Dry peas | ---------- | 520 | 1,000 | ---------- | 1,730 |
| Dry broad beans | 370 | ---------- | 1,060 | ---------- | ---------- |
| Chick peas | ---------- | 450 | ---------- | 550 | ---------- |
| Lentils | ---------- | 370 | ---------- | 560 | ---------- |
| Soybeans | 850 | ---------- | 1,110 | ---------- | 1,530 |
| Peanuts | 1,440 | 870 | 2,070 | 980 | 1,760 |

[1] Food and agriculture organization of the United Nations, production yearbook, 1965.

Substantial improvement in yields per unit area will require a radical departure from systems employed in traditional or subsistence agriculture. In such systems all production factors are in virtual equilibrium. Soil fertility has been reduced to a very low level, and this is often the production factor that is most limiting to yields. Varieties which perform best under such conditions are those which have survived under unfavorable natural conditions, often referred to as "status quo" varieties. These varieties generally have evolved as the result of centuries of unconscious selection through repeated harvesting and replanting survivors which have persisted under these adverse soil and climatic conditions.

Selection and breeding, in wheat for example, have resulted in the development of improved varieties capable of producing slightly higher yields than their predecessors from 1,000 to 1,200 kilograms per hectare. This is about the practical limit of improvement that can be achieved with "status quo" varieties. Obviously, such varieties cannot be relied upon for significant contributions to the hunger problem.[9]

One of the great needs, if not the most urgent in nations with food deficits, is the rapid development of coordinated, crop-oriented re-

[9] Qureshi, S. A., and Narvaez, Ignacio. Annual Technical Report Accelerated Wheat Improvement Program West Pakistan 1965–66. The Planning Cell, Agriculture Department, Government of West Pakistan, Lahore, 1966.

search and production programs in each of these nations. These programs should have all relevant agricultural facilities and technical personnel involved in a single national effort under unified leadership. The goal of such programs should be the rapidly increased preduction of each key crop—usually through increased average yields. In many countries, doubling or tripling production of basic grains within 5 to 10 years is a realistic objective.

### *3.1.4 Mexico's Wheat Program*

The structure and the essential components of a successful crop program can be illustrated by cooperative programs conducted by the Rockefeller Foundation and the Government of Mexico which resulted in a substantial breakthrough in wheat production after 20 years of intensive research.[10] The wheat project of the Office of Special Studies, Ministry of Argiculture of Mexico, was initiated in 1943 when national average wheat yields were 11 bushels per acre, and when Mexico was importing half of all the wheat it consumed. By 1964 yields had climbed to 37 bushels per acre, a 3½ fold increase. Mexico now has a surplus of wheat and is beginning to assist other nations by providing its high-yielding wheat varieties, by training young scientists, and by lending its own wheat specialists to lead programs elsewhere.

Eight important components of this successful program were:

1. Ambitious objectives were established. The program was designed to eliminate Mexico's substantial wheat deficit of the early '40's by making every effort to raise production in the shortest possible time.

2. Research was emphasized. In 1943 most of Mexico's wheat was grown during the dry season, under irrigation, to escape the ravages of stem rust. New varieties which were rust-resistant were developed and continue to be developed; they had short stiff straw to permit profitable use of high levels of nitrogenous fertilizers, and they were insensitive to photoperiod, thus adding considerably to their range of adaptation. Soil management, weed control, and irrigation techniques were developed. By use of two and sometimes three generations, or crops, a year, the research progressed rapidly. Although completely new varieties had to be produced, by 1954, 70 percent of Mexico's wheat acreage was planted with these varieties. Research was clearly prerequisite to increased production.

3. In-service training was emphasized. About 700 nationals were locally trained to be proficient in techniques for crop production. Over 40 graduates of Mexico's colleges of agriculture were given one or more years of local experience, working as members of the staff of the wheat project. A small fraction of these men stayed in research, but many

[10] U.S. Department of Agriculture. Economic Research Service. The 1964 western hemisphere agricultural situation. U.S. Dep. Agr. Econ. Res. Serv. ERS-Foreign 71, 63 p. Feb. 1964.

others accepted positions in extension, in teaching, and in seed production, or with agricultural banks or industrial firms.

4. Competent leadership was continuous.

5. Outstanding and dedicated young scientists—graduates of Mexico's agricultural colleges, *most of whom had received additional field experience*—were sent abroad for advanced studies, primarily to universities in the United States. This permitted development of the competent leadership needed to assume the direction for the wheat improvement work.

6. As trained men became available, the research program was systematically broadened to all of the important wheat-growing regions, seed production was intensified through private growers and on government farms, and extension of varieties and practices was accomplished effectively by young men who had become proficient in wheat production techniques.

7. Research and extension were combined. As the research team solved the problems limiting production, they demonstrated repeatedly—at field days, on private farms, to national leaders, and to farm groups—that higher yields could be obtained and how to do it. There was little separation of research and extension; it was one unified program that began instead on the research station and ended with use of the varieties and practices by the farmers.

8. Government and private sector services and policies improved to encourage wheat production. Price supports were provided, farm credit became more widely available, extension services were expanded, and supplies of farm machinery, fertilizers, and agricultural chemicals increased. Wheat farming was profitable. Without the interest and support of leaders of the Mexican government, this record of unusual achievement could not have occurred.

### *3.4.2 Pakistan's Wheat Program*

An accelerated wheat improvement program, patterned after the Mexican program, was initiated by Pakistan in 1965 with the objective of achieving a surplus by 1970. Results during the first year were highly successful in spite of abnormally low irrigation water and use of inadequate amounts of fertilizers.[11]

None of the varieties of wheat in Pakistan have short (about 30–40 inches), stiff straw, and the capability of converting large amounts of plant nutrients into a heavy head of grain without lodging, so 350 tons of dwarf wheat seed were imported from Mexico. This was multiplied to about 16,000 tons in the first harvest. The dwarf seed was produced on 30 government farms and 2,500 privately owned farms. Average yields of the Mexican dwarf varieties were 3,226 to 3,411

[11] Qureshi, S. A., and Narvaez, Ignacio. Annual Technical Report Accelerated Wheat Improvement Program West Pakistan 1965–66. The Planning Cell, Agriculture Department, Government of West Pakistan, Lahore, 1966.

kilograms per hectare, and 922 to 1,106 for native varieties. The average amount of fertilizer used per hectare was about 78 pounds of nitrogen and 45 pounds of $P_2O_5$. Among private growers, 38 obtained yields of more than 4,800 kilograms per hectare.

Seed supplies of the two dwarf Mexican varieties will be multiplied again during the winter of 1966–67 to about 600,000 tons of grain, half of which will be held for seed and the remainder will be sold for food. This will make ample supplies of seed available for commercial planting in 1967. The production of dwarf wheats then will be limited only by the availability of fertilizers and the ability of the extension service to teach the farmers to use the "package" of cultural practices necessary to obtain maximum yields. Proper cultural practices for the dwarf varieties are: high fertilizer rates—up to 138 pounds of nitrogen and 40 pounds of phosphorous per acre; shallow planting depths—1½ to 2½ inches; high seeding rates—90 to 100 pounds per acre; 5 to 6 irrigations instead of 3 to 4; early harvesting to prevent shattering; and adequate control of insect and weed pests.

### *3.4.3 Other Action Programs*

Organized efforts should be made to relieve food shortages as quickly as possible by all available means and measures. Materials and methods on which massive action programs can be based are available for certain crops and for certain areas but not for others. Use of several superior, widely adapted spring wheats, produced in Mexico's cooperative wheat improvement programs, could help raise yields substantially in many countries where their superiority over native varieties has been demonstrated in repeated tests. The superiority of certain germ plasm complexes of maize have been demonstrated. New varieties of rice produced at the International Rice Research Institute also have proved their value in some areas. Campaigns should not be initiated for the large-scale introduction of crop varieties into areas where they have not been adequately tested. But progress will be made by campaigns to utilize the best materials and methods available; even if they are not perfect, they should be used if they are significantly better than those now in use.

Success in action programs for the introduction of better plant materials and better methods depends upon the following factors: competent and continuing leadership, good organization, effective cooperation by recipient nations, the provision of good seed, good cultural practices, adequate supplies of fertilizers, protection from pests, adequate price incentives to farmers, advisory services, and continuous experimentation and research.

Aid programs should concentrate on basic food crops and production-oriented research and education. Efforts should be regionalized as much as possible, rather than being compartmentalized in individual countries. The greatest immediate progress can be made by orga-

nizing coordinated campaigns for utilizing unused materials and methods wherever their value has been demonstrated. The greatest permanent progress can be made by aiding the development of functional scientists, educators, and administrators in those countries in which food is in short supply.

### *3.44 Plant Protection*

Pests—weeds, pathogens, nematodes, insects and mites, birds, and mammals—cause tremendous damage to crops in the developing countries. Total losses of food grains in India amount to about 10 percent in the field plus 5 percent in storage.[12] A 15 percent loss would amount to about 13 million tons during 1963–64, or nearly double the food grain imports in India during 1965.

The most reliable estimates of losses caused by pests have been developed for insects. For example, losses of rice from five species of rice stem borers alone are estimated to range from 3 to 95 percent in India,[13] and four species cause an estimated loss of 3 to 20 percent in East Pakistan.

Assuming that loss from rice stem borers in India amounts to 10 percent, there is an annual loss of about 5 million metric tons per year. If these pests were controlled in India to the same extent as in Japan, the loss would be less than 500 thousand metric tons.

The level of effectiveness of the rice stem borer control program in Japan, however, is probably unmatched for a major pest of a major crop.[14] It is based on a nationwide forecasting system for rice pests established in 1941 and on a Plant Protection Act promulgated in 1952. The latter established a total of 130 positions for government forecasters in the prefectural agricultural experiment stations; 540 observatory stations manned by local forecasters; 2,166 observation rice fields, averaging 1,460 hectares each, for determining the proper time for applying rice stem borer control measures; and pest control staffs totaling 10,866 personnel stationed at city, town and village levels, each operator covering an average of 300 hectares of rice fields. Insect control practices recommended are mandatory. Losses from rice stem borer have been less than 1 percent since 1955, when parathion became available in sufficient quantities for general use.

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[12] Moseman, A. H., Pest Control—its role in the United States economy and in the world. IN: Scientific Aspects of Pest Control. Nat. Res. Council Publ. 1402, pp. 26–38. 1966.

[13] Israel, P., and Abraham, T. P. Techniques and Assessment of Crop Losses by Rice Stem Bores in Tropical Areas. IN: Proc. Symposium on the Major Insect Pests of Rice, The International Rice Research Institute, Los Banos, The Philippines, Sept. 13–18, 1964 (Mimeographed) (Paper R, 14 pp.).

[14] Yoshimeki, M. A summary of the forecasting program for rice stem borer control in Japan. IN: Proc. Symposium on The Major Insect Pests of Rice, The International Rice Research Institute, Sept. 13–18, 1964 (mimeographed) (Paper H, 22 pp.).

Chemical pesticides, used properly for control of major pests, have resulted in highly profitable increases in yields in the developing countries. The principle of their use for pest control is sound and transferable to developing nations. But, an attempt to initiate a chemical pest control program without an adequate amount of adaptive research could be disastrous. For example, the Japanese encountered serious difficulties from parathion poisoning among insecticide applicators during the first few years of extensive use. The use of phenyl mercury acetate for control of rice blast in Japan is being discouraged because mercury residues are being accumulated in the human population. Where fish culture in rice fields is important, use of BHC (Benzene Hexachloride) at rates required for control of rice stem borers could cause high mortality in susceptible species such as tilapia and tawes.[15] Chlorinated hydrocarbon insecticides used on rice may be concentrated in fish. In many countries of Southeast Asia, where fish produced in rice fields constitute an important part of the human diet, insecticides may pose a serious problem.

Indiscriminate use of chemical pesticides has often created problems more serious than those for which they were used initially. An example of the pitfalls involved in attempting to transfer chemical pest control technology from one country to another, without the necessary adaptive research, is furnished by the experience of the cotton growers in the Canete Valley of Peru.[16] Major difficulties had developed within 10 years after the initial use of synthetic organic insecticides for cotton pest control by the same methods as those recommended in the United States. Resistance had developed among pest populations and insecticides were no longer effective. Several species of little or no previous importance had become major pests, and disastrous crop failures resulted. The situation was corrected by passing legislation forbidding the use of synthetic organic insecticides in the valley and by returning to control methods based on use of biological control agents and cultural practices.

Nevertheless, proper use of chemical pesticides offers tremendous possibilities for contributing to increased crop yields in developing countries. Research to adapt their use for pest control in such areas should receive high priority for short-term programs. The Japanese program for control of rice pests provides a model worthy of study by national leaders charged with responsibility for developing such pest control programs in developing countries.

The importance of agricultural pests is likely to increase in direct relation to improvement in crop yields because:

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[15] Kok, L. T., and Pathak, M. D. Toxicity of lindane used for Asiatic rice borer control to three species of fish. J. Econ. Entomol. 59, 659–663, 1966.

[16] Boza Barducci, T., Problemas de la agricultura del Valle de Canete, Vida Agr. [Lima] 36(430) : 511–525. Sept. 1959.

1. Intensification of agricultural production will tend more and more toward development of monocultures, multiple cropping, and shortening of rotations, all of which tend toward simple systems that are characterized by relatively violent oscillations of pest populations rather than the comparative stability of more complex systems.

2. The need for bringing additional land into cultivation will extend crop production to areas where pest problems are more severe than in areas now being cultivated.

3. Improved varieties will be bred to such high standards of uniformity and will occupy such comparatively large percentages of the total area planted that changes in pests can result in heavy losses.

4. Changing cultural practices, such as increasing levels of nitrogenous fertilization, irrigation, and closer spacing, favor the development of pest populations.

5. Many pest species are extending their range and invading previously uninfested areas.

For solutions to long-range problems of pest control, effort should be directed toward developing pest management systems that are based on principles of applied ecology. The possibilities of integrating into such systems methods that do not rely upon the use of chemicals should receive high priority in long-range research programs.

### *3.5.0 Research and Development for Improved Strains and New Crops in the Developing Countries by Application of Genetic Principles and Plant Breeding Techniques*

The application of genetic principles and plant breeding techniques will be a major factor in developing solutions to the problem of intensifying plant production. Consideration should be given to: (1) efforts which may be expected to have immediate impact, and (2) the long-range approach. Both should be initiated promptly, with emphasis on the long-term approach and with the expectation that time and continued effort are necessary for meaningful results.

#### *3.5.1 Program for the Immediate Future*

Emphasis should be placed on the widespread distribution and testing of improved crop varieties in areas in which they are likely to be adapted. There are a number of greatly improved crop varieties and a substantial amount of superior crop germ plasm which could be quickly utilized—directly or with slight modification—to increase crop production rapidly in many areas of the world. Certain rice varieties, orginating in Taiwan, are short in stature, have stiff straw, and produce high yields at high levels of fertilizer application. Improved versions of these varieties, developed at the International Rice Research Institute in the Philippines, are now under test in Thailand, Malaysia, India, Pakistan, and the Philippines. They may also have great value—directly or as breeding materials—in many areas of Latin

America, Africa, the Middle East, other nations of Asia, and even in the United States.

Wheat varieties developed in Mexico, in part with dwarf genotypes from Japan, are now serving as a basis of national production efforts in India,[17] Pakistan, and other countries. They may also have value in the Middle East, North Africa, and other parts of the world where they have not been exploited.

Much of the corn germ plasm of the Western Hemisphere has been collected and classified and is available to plant breeders throughout the world. Much of this germ plasm has been evaluated for yield, disease and insect resistance, and other agronomic traits. Yet utilization of this material has only begun. Certain varieties and hybrids developed in tropical America have performed well in Thailand, the Philippines, and elsewhere as can be seen from results in Tables 3–5 and 3–6. Some of the maize germ plasm from the Southeastern United States appears to be adapted to certain areas of India—especially when used in cross combinations with locally developed lines and varieties.

TABLE 3–5.—*Yields of maize varieties in yield trials in Nigeria 1952–62* [1]

| Variety | Location | | | | |
|---|---|---|---|---|---|
| | Rainforest | | Derived Savannah | Southern Guinea Savannah | Average |
| | Wet | Dry | | | |
| Number of trials | 44 | 91 | 9 | 14 | |
| Yield (kilograms per hectare) | | | | | |
| Local varieties | 1,024 | 1,510 | 1,210 | 964 | 1,309 |
| Mexico 5 | 1,411 | 2,329 | 1,847 | 1,315 | 1,898 |
| Trinidad | 1,620 | 2,329 | 1,995 | 1,283 | 1,903 |

[1] Van Eijnatten, C. L. M. Towards the improvement of maize in Nigeria. Mededelingen van de Landbouwhogeschool Wageningen, Nederland, 65–3, 1965.

TABLE 3–6.—*Increase in yields of improved varieties of maize over native varieties in Africa* [1]

| *Country or area* | *Amount of increase (kilograms per hectare)* |
|---|---|
| Dahomey | 354–382 |
| Congo Basin: | |
| Gandajika | 2,000 |
| Yangambi | 2,300 |
| Rwanda-Burundi | 2,300 |
| Rhodesia | 1,560 |
| Malawi: | |
| Central | 900 |
| Southern | 685 |

[1] Miracle, M. P. Maize in tropical Africa. The University of Wisconsin Press, Madison, 1966, p. 230.

[17] The Ford Foundation and Agricultural Development In India. The Ford Foundation Staff Document, 67 pp. New Delhi, India, 1965.

Some United States varieties and hybrids perform well in parts of southern South America (Chile and Southern Brazil, for example).

Sorghum breeding efforts are under way in India, Nigeria, East Africa, and in a number of places in Latin America but the impact of these programs still is localized. Certain genotypes of grain sorghum, unlike many varieties of maize, possess wide ranges of geographic adaptation. Preliminary tests suggest that in parts of the world many grain sorghum hybrids developed in the United States are more productive than the currently used local varieties.

Pulses supply a major part of the vegetable proteins available for the human diet in the developing countries. For the masses of people to whom meat is not available, pulses often are the only sources of high protein foods. The major oilseed legumes, soybeans and peanuts are also a valuable source of protein. The area of pulse and oilseed legume production by region is presented in Table 3–7.

TABLE 3–7.—*Area of pulse and oilseed legume production* [1]

| | 1,000 hectares, 1964–65 | | | | | |
|---|---|---|---|---|---|---|
| | Latin America | Near East | Far East | Africa | Europe | North America |
| Dry beans | 5,410 | 145 | 8,300 | 1,170 | 4,200 | 630 |
| Dry peas | 160 | 10 | 1,330 | 450 | 480 | 155 |
| Dry broad beans | ---------- | 250 | 15 | 340 | 770 | ---------- |
| Chickpeas | 145 | 175 | 10,680 | 400 | 380 | ---------- |
| Lentils | 70 | 275 | 950 | 220 | 100 | ---------- |
| Pigeonpeas [2] | 25 | ---------- | 2,550 | 100 | ---------- | ---------- |
| Cowpeas [2] | 25 | ---------- | 27 | 212 | 47 | 68 |
| Soybeans | ---------- | 6 | 1,610 | ---------- | 10 | 12,530 |
| Peanuts | 1,070 | 370 | 8,420 | 4,880 | 15 | 569 |

[1] FAO Production Yearbook 1965.
[2] Average 1958–61.

The protein content of pulses is 22 to 26 percent on a dry-weight basis. The quality of protein in chickpeas, pigeonpeas, and limabeans is comparable to that of animal proteins. Proteins in most of the other pulses have high amounts of lysine but are slightly low in the sulphur-bearing amino acids, methionine and cystine. The latter deficiencies are also present in the oilseed legume crops.

Yields of pulses in the developing countries generally are low. Average yields of dry beans and dry peas in the Far East are 310 and 520 kilograms per hectare, respectively, compared to 1,360 and 1,680 kilograms in North America. Low yields are largely attributable to inferior varieties, lack of fertilizer, inadequate control of insects and diseases, and poor management.

A pulse research center has been established at Karaj, Iran, by the U.S. Department of Agriculture with funding from AID. Research includes variety development, pest control, and soil and water man-

agement practices for dry beans, cowpeas, chickpeas, lentils, and mungbeans. A second center is being established at New Delhi, India. Research there will be on chickpeas, pigeonpeas, mungbeans, and urd-beans, and on improvement of protein quality in pulses.

The established programs are too new to permit reliable predictions of the potential production of pulse crops. Strains yielding 20 to 40 percent more than commercial varieties have been selected. Scientists believe that production in all developing nations could be increased at least 25 percent by the application of proven practices; and that yields can be increased at least 50 percent within a period of 5 to 10 years.

There is much interest in the potentialities of soybeans for developing nations. Varieties contain about 45 percent protein on a dry-weight basis. Extraction of oil and removal of seed coats increase the concentration of protein in the remaining oilmeal and oilcake to about 60 percent. By additional processing, concentrates can be made that contain more than 70 percent protein which is higher than that of meat on a dry-weight basis. One cup of soybean concentrate, approximately 170 grams, can supply the daily requirements of protein, vitamins, and minerals for an average adult.

Soybean production is concentrated in the temperate regions of the Orient and North America, but data from yield trials in Venezuela, given in Table 3-8, show that varieties can be adapted to tropical areas. The types grown in these areas are extremely sensitive to the length of daylight throughout the flowering period. When grown under the shorter day length encountered in tropical zones, flowering is stimulated at an early date, plants are short, and yields are low. Great progress has been made in broadening the lateral belt in which soybeans are adapted. Combining tall growth and adaptation to short days has resulted in varieties that produce well in the latitude of north Florida. With an adequate research program scientists believe that the belt of adaptation could be extended to include tropical zones.

TABLE 3-8.—*Yield of soybean varieties in Venezuela* [1]

| *Varieties* | *Yield, kilograms per hectare* |
|---|---|
| Pennsoy | 3, 081 |
| Manta Maria | 2, 705 |
| Improved Pelican | 2, 692 |
| Mandarin 8A | 2, 587 |
| Missoy | 2, 425 |
| Israel 14974 | 2, 250 |
| Acadian | 2, 247 |
| B.Y | 1, 930 |
| Wilson Black | 1, 822 |
| Hernon 49 | 1, 676 |

[1] Barrios, A, and Ortega, A. Comparaciones sobre el rendimiento de 11 Variedades de Soya (*Glycine max*). Agron. Trop., 13, 233–237, 1964.

Although soybeans obviously have a potential in many parts of the world, production in these areas will likely have to await the development of adapted varieties and processing facilities. Other edible legumes have a greater potential for supplying high quality protein in many of the developing countries.

A substantial collection of millets exists in India, some of which have promise for many of the low-rainfall areas of the world.

Photoperiod, temperature, rainfall, and edaphic characteristics are important factors in determining geographic adaptation of crop species and varieties; of equal importance is the reaction of introduced varieties to diseases and insect pests. Usually the latter cannot be evaluated critically until the introduced varieties have been planted on a large area and have been grown in the new environment for a period of years.

The application of our present knowledge on the geographic adaptation of many of the world's improved varieties of crop plants could be expected to make significant increases in world food production in the immediate future.

### *3.5.2 The Long-Term Approach*

Five major steps must be taken in a realistic long-term approach to intensification of crop production by genetic improvement of plants.

1. *Attention must be focused on basic food crops* that can be rapidly propagated, such as wheat, rice, maize, sorghum, millet, potato, sweet potato, yam, cassava, banana, pulses, and oilseed legumes. Other crops should receive attention by countries where the specific crops are important.

Emphasis should be placed on the improvement and production of crops best suited to the soils and climate of individual countries. Attempts to become self-sufficient in specialized crops poorly adapted to the area should be avoided. The example of a recent attempt by a small country to develop a sugar beet industry, with sugar a glut on the world market, occurs all too frequently.

In some regions, particularly in the tropics, animal production will continue to be important, yet relatively little attention has been given to forage crops or range management for such regions. A determined research effort is needed, including collection and improvement of forage grass and legume germ plasm, and their orderly evaluation (including grazing trials).

2. *Substantial plant breeding efforts must be encouraged*, primarily in the regions and by the nations where the crops are to be used. Although varieties of some crop species have wide geographic adaptation, improved varieties and hybrids developed in the temperate climate usually are of limited value for direct use in tropical regions, and vice versa, because of differences in day length, diseases, insect pests, and breeding objectives. Unadapted varieties, however, can make valuable

263-888 O—67——16

contributions to gene pools for breeding purposes. Genes for resistance to crown rust and high protein content in oats from Israel have been transferred, with excellent results, to oat varieties for Florida, Georgia, Indiana, Iowa, Minnesota, Texas, and Wisconsin. Israeli wheats, virtually immune to yellow rust, are contributing to the control of this serious diseases of wheat in western and northern Europe. Israel's location, in the "fertile crescent" where there is an abundance of wild, disease resistant wheat, oats, and barley, puts its scientists in a unique position to supply new genetic combinations for control of cereal rusts. Utilization of the world's gene pools for breeding purposes offers almost unlimited opportunities for intensifying plant production.[18]

International research and training centers should be developed to serve as headquarters for cooperative programs and to provide advanced technical training. The research program should include: (1) accumulation and evaluation of the world's germ plasm for specific crops; (2) identification and production of plant types which produce high yields at high levels of soil fertility; (3) research on prevalent plant diseases, development of plant resistance, and coordination of international studies; (4) research on prevalent insect pests, including development of varieties resistant to the insects, chemical control, and coordination of testing programs; (5) weed control; (6) quality evaluation; and (7) coordinated varietal testing programs.

National plant breeding programs are essential and should be financed by the country concerned. Such programs will be successful only if: (1) highly competent technical leadership is available on a continuing basis; (2) the breeding programs are oriented toward increasing the nation's average yields; (3) adequate financial support is provided; and (4) the success of the program can be measured by substantial increases in yields on the farms. These national programs should be backstopped by the regional centers for basic research.

For each major crop in each national program there should be a central plant breeding and training facility, plus sufficient outlying testing stations to provide for the needs of the country.

In those areas of the world where the improvement of cross-fertilized crops has reached an advanced stage of development, hybrids continue to provide higher yields and a more uniform product than do improved varieties or synthetics. But, it now seems clear that varieties themselves can be greatly improved through the application of appropriate forms of mass selection and that synthetic varieties can be developed which are far superior to most farmer-selected strains.

For countries where there is a scarcity of technically trained manpower, where distribution of seed is a problem, and where credit generally is not available, it would seem advisable to concentrate first on

[18] Science Journal 2, 11–12, 1966 (in section on development news).

the production of improved varieties and varietal crosses rather than on conventional hybrids.

Recent results obtained with maize in Mexico and Kenya should provide some guidelines to varietal improvement in developing nations. Kenya established a conventional breeding program in 1955. By 1963 a double-cross hybrid had been developed which gave yield increases of 25 percent—about the same magnitude of increase as was obtained with the first hybrids in the United States. In 1963 a varietal hybrid was produced which gave yield increases of approximately 50 percent. With encouragement and support of the newly initiated cooperative program of the Agricultural Research Service, USDA and AID, this hybrid was immediately placed in commercial production. Breeding procedures were modified that emphasized population improvement and varietal hybridization. This emphasis recognizes both short- and long-range goals. Under conditions prevailing in the developing countries, rapid improvement in populations is feasible and such improvements will be reflected in their hybrids. The long-range objectives will also be advanced as any improvement in the varietal populations should result in an increased percentage of elite inbred lines that can be obtained from them whenever the production of conventional hybrids becomes desirable.

The yield increases achieved and the acceptance of hybrids in Kenya has been significant as shown in Tables 3–9 and 3–10. The double-cross

TABLE 3–9.—*Comparative yield of a double-cross hybrid and varietal hybrids of corn in Kenya* [1]

| Year of release | Type of corn | Yield in percent of local variety |
|---|---|---|
| | Local variety | 100 |
| 1963 | Double cross hybrid | 125 |
| 1964 | Varietal hybrid 611 | 142 |
| 1965 | Varietal hybrid 611B | 154 |
| 1966 | Varietal hybrid 612 | 157 |
| 1967 | Varietal hybrid 613 | 166 |
| 1968 | Varietal hybrid 614 | 194 |

[1] Unpublished data from the Kenya Maize Research Program.

TABLE 3–10.—*Acres planted to hybrid corn in Kenya* [1]

| Year | Large-scale farmers | Small-scale farmers | Total |
|---|---|---|---|
| 1963 | 390 | 10 | 400 |
| 1964 | 33,500 | 1,500 | 35,000 |
| 1965 | 52,000 | 18,000 | 70,000 |
| 1966 | 50,000 | 50,000 | 100,000 |
| 1967 [2] | 100,000 | 350,000 | 450,000 |

[1] Third Annual Report ARS–AID Project "Major Cereals In Africa."
[2] Seed is available from the 1966 crop to plant the estimated 1967 acreage.

hybrid was developed from a single variety, Kitale Flat White. Each of the varietal hybrids, 611–614, involve crosses between Kitale Flat White x Ecuador 573. The crosses 611B–613 represent successive improvements within the Kitale variety. The hybrid 614 involves improvements in both parental types.

The personnel involved with this development have had close cooperation among the following agencies: The Kenya Ministry of Agriculture, the Rockefeller Foundation, the Kenya Seed Company, and the USDA/ARS, and AID. The success achieved was dependent upon the incorporation of all essential factors: (1) the development of improved types; (2) the availability of research information on proper time of planting, fertilization practices, and weed control; (3) an effective demonstration program; and (4) provision of adequate facilities for hybrid seed production and distribution.

Initially hybrid seed was sold as a package deal. The purchaser of a bag of seed was required to buy fertilizer of the recommended formulation and amount, and to follow additional prescribed cultural practices including the recommended time of planting and weed control. As a result of this combined approach the better farmers are achieving yields ranging up to 10,000 kilograms per hectare. If hybrids are accepted at the present rate, it is predicted that by 1968 half of the highland corn area of Kenya will be planted to hybrid seed.

Conventional hybrids, unfortunately, have become a status symbol in many developing countries because this type of hybrid is used universally in the United States. Many breeders lack sufficient background to recognize that varietal hybrids are feasible only when genetic diversity is available and that such diversity does not exist among acceptable United States types.

A maize improvement program was initiated in Mexico in 1943 and has continued to the present. During this period a number of high-yielding conventional hybrids and varieties have been developed. In recent years emphasis has been placed on the development of synthetics and synthetic crosses, some of which have equalled or excelled the yields obtained from the best double cross hybrids. In contrast to the fully coordinated program in Kenya, the full benefits of varietal improvement in Mexico have not reached the majority of Mexican farmers. Seed production and distribution in Mexico has been through a government agency which has failed to produce either the quantity or quality of seed required by progressive Mexican farmers. Mexico uses approximately 100,000 tons of maize seed annually of which only about 14,000 tons are hybrid. However, a considerable area is being planted to advanced generation seed of improved varieties. It has been estimated that at present not more than half of the total maize area of Mexico is planted to improved seed.

3. *Adequate and dependable supplies of high quality seeds must be readily available to the farmer if the superior varieties are to be of value.* As important as breeding, and often more difficult to establish, is an effective organization for the production and distribution of seed. Attempts by a number of nations to produce and distribute hybrid corn through government monopolies have failed, whereas production and distribution of hybrid corn seed by private companies generally has been successful. Where hybrids are now feasible, or where any type of seed from large-scale, controlled hybridization is used, production and distribution of such seed should be placed in the hands of private industry. If, as a part of our effort to aid world food production, seed firms in the United States are to become more involved in foreign production and distribution (either directly or in cooperation with local organizations), consideration should be given to providing satisfactory investment guarantees by appropriate Federal agencies.

4. *Integrated national crop-oriented programs must be established under unified leadership.* The research program, of which varietal improvement must be one important component, must be integrated with the Nation's training and extension efforts. Concerted efforts must be made to improve irrigation facilities and water use, to develop adequate supplies of fertilizers, and to obtain adequate control of diseases and insect pests. Fertilizer requirements must be determined for each variety in each season of each region of the country. Adequate agricultural credit must be available and the supply of all necessary inputs must be assured.

The exact nature of each Nation's crop-oriented program will depend on available facilities and on the training of crop specialists. National programs which deserve study, as models, include the all-India crop schemes, Pakistan's current wheat program, Thailand's proposed national maize program, the Philippines' present effort to improve rice and maize production, and Mexico's programs which led to major increases in production of wheat, potatoes, maize, and sorghum.

5. *Plant breeders must be encouraged to develop plants adapted to high levels of soil fertility or to high levels of applied nutrients.* It is abundantly clear that crop production in the world cannot go up substantially unless adequate amounts of nitrogen, phosphorus, potassium, and in some instances other nutrients are supplied; and unless high levels of fertilizer produce greater grain yields instead of an increased amount of foliage. Plant breeders must be increasingly concerned with development of plant types which can convert high amounts of nutrients into grain instead of contenting themselves with identifying the best combinations of variety and nutrient within existing or commonly used plant types. Response to fertilizers also will depend greatly upon water management, spacing and other cultural factors, and control of diseases and insect pests.

Breeders engaged in quality improvement should emphasize *nutritional quality*, and should be encouraged not to waste time and effort in selecting for certain milling and baking traits which have little relation to the nutritional value of the crop.

The manner in which cereals are used varies from region to region. In the highlands of South America, for example, floury types of corn are utilized and it is often eaten while still green. In most of the humid tropics, flint corn is generally utilized because it is more resistant to insect attack than are the dent and floury types. In the United States and many other parts of the world, dents or semi-dents are desired, yet little is known about the nutritional quality of these various kernal types.

Current efforts to isolate cereal genotypes with a better balance of amino acids should be greatly expanded. It has been shown that the genes opaque-2 and floury-2 increase the lysine content of corn grain about 100 percent and tryptophan almost 65 percent. Opaque-2 and floury-2 are single recessive genes and as such can be easily introduced into any type of corn through the use of appropriate breeding techniques. In rat feeding tests it has been found that genotypes homozygous for opaque-2 give a 3.5-fold increase in rate of gain over that obtained with normal corn alone.[19] Comparable results have been obtained with swine. In one experiment with Hampshire-Yorkshire cross-bred pigs averaging 30 pounds, normal corn was compared with opaque-2. The average daily rates of gain for a four-week period were 0.26 and 0.94 pound, respectively. In a second experiment, pigs weighing an average of 130 pounds were used to evaluate opaque-2, normal hybrid corn, and hybrid corn supplemented with soybean meal. In this trial, opaque-2 corn of 11.2 percent protein was compared with hybrid corn of 8.88 percent protein and the hybrid corn supplemented with soybean meal to 11.2 percent protein. The average daily rates of gain for a three-week period were 2.27, 1.50 and 1.94 pounds, respectively. On the basis of these tests, it appears that opaque-2 corn can supply the total protein requirement for swine.[20]

Tests conducted in Guatemala with children aged 2 to 6 years indicated that the protein value of opaque-2 corn is about 90 percent that of skim milk.[21] It has been estimated that a daily intake of 300 grams of opaque-2 corn, with adequate caloric needs provided from other sources, would meet minimum protein requirements of men weighing approximately 70 kilograms.[22]

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[19] Proceedings high Lysine Corn Conference, Purdue University, June 21–22, 1966. Corn Refiners Association, Inc., Washington, D.C., pp. 12–22.

[20] Pickett, R. A. Opaque-2 corn in swine nutrition. IN: Proc. High Lysine Corn Conference, June 21–22, 1966, Purdue University, pp. 19–22. Corn Refiners Assoc., Inc., Washington, D.C.

[21] Bressani, Ricardo. Protein Quality of opaque-2 maize in children. Ibid, pp. 34–39.

[22] Clark, H. E. Opaque-2 corn as a source of protein for adult human subjects. Ibid., pp. 40–44.

The most significant contribution of high quality protein maize to improved nutrition may be in those areas of the world where maize is an important part of the human diet. Such areas include much of Latin America, parts of Africa, southern and eastern Europe, and parts of Asia.

Although much remains to be learned, the new varieties offer considerable promise of improved nutritive value. If yields and other important agronomic traits are satisfactory, corn could be transformed from a poorly balanced to a well balanced source of food and feed for man and his domestic animals.

Work on the incorporation of new genetic types into otherwise desirable maize varieties is now under way in most parts of the world where maize breeding is in progress, including Mexico, parts of Central and South America, India, the Philippines, parts of Africa, eastern and western Europe, and the United States.

The search for improved nutritional characters in other cereals has either been initiated or is planned. Such projects include programs in Mexico for wheat and maize, in the Philippines for rice, and in India for sorghums and millets. AID-grants have recently been made to Purdue University for the study of both protein quantity and quality in sorghum, and to the University of Nebraska for the study of protein quantity in wheat. AID has made an additional grant to Purdue University for the incorporation of opaque-2 into Brazilian maize varieties and subsequent evaluation of their acceptability and nutritional adequacy. A new laboratory is being installed at Beltsville, Maryland for the study of protein quality in cereals. In this program attention will also be given to the wild relatives of wheat and oats.

### *3.6.0 Factors Limiting Progress in Developing Countries*

There is need for an immediate and widespread awareness of the following problems which are now restricting agricultural progress in many of the nations of the world:

1. There are few people properly trained for participation in national crop-production efforts. In most of the developing countries there is a serious shortage of qualified plant breeders—persons trained to conduct dynamic, useful, varietal improvement programs in the field. Many of the young men who have received advanced training in the United States or Europe have become specialists in the more basic field of genetics or in other fundamental areas.

There is a similar scarcity of applied entomologists to cooperate with plant breeders in developing varieties resistant to insect pests, and to develop effective chemical control programs for species that cannot be controlled by means of varietal resistance or biological control agents.

There are too few plant pathologists directly involved in the struggle to obtain plant resistance to the disease organisms—the only economical means known of controlling the most destructive diseases of most field crops.

There are not enough soils specialists trained for, and interested in, cooperating with plant breeders for rapid identification of the appropriate fertilizers and fertilizer levels needed for crop varieties in each season, in each region, and in each country. This need is particularly acute in the tropics.

Biochemists are needed to work with plant breeders in the improvement of quality of experimental varieties.

Finally, there is a critical shortage of crop specialists to lead national and regional crop-oriented production programs—persons who can integrate, stimulate, and coordinate work on varietal improvement, soil and water management, weed control, disease and insect control, training and extension. Persons who are equally aware of the need for credit, for a timely supply of fertilizers and other agricultural chemicals, and for production incentives are also needed.

2. Yield concepts differ in the tropics and in temperate climatic areas. In temperate climatic areas such as the United States, most plant breeders are concerned with production of maximum yields during a *fixed crop-growing season*—a season determined for some crops by the dates of first and last frost. In most regions of the tropics, particularly where availability of water can be controlled, emphasis can and should be placed upon maximum yield per unit area *per unit of time*. By growing two crops annually maize yields per unit area *per year* have, in parts of Jamaica, Mexico, and South America, exceeded those of the United States. In the Philippines it has been customary, in many regions, for farmers to grow a single rice crop in 150 to 170 days and yields of 3,000 to 4,000 kilograms per hectare have been obtained by good farmers. The International Rice Research Institute has found that maximum yield *per day* can be obtained with faster developing varieties that can be grown in 110 to 120 days. With control of water, three crops a year have been obtained for a total annual production exceeding 20,000 kilograms per hectare. Plant breeders must be encouraged to strive for maximum yields per unit of time. Attention must be directed to the development of new cropping patterns for the tropical areas of the world, with maximum food production per day the goal in each situation.

We need to recognize, however, that intensified production practices usually bring with them serious increases in insect populations and intensification of disease problems. This necessitates, therefore, the adoption of a complete production program designed to cope with anticipated increases in problems of this nature.

3. Although the United States Government has indicated its willingness to respond to the needs of developing nations in the improvement of their agriculture, the United States has very little capability in tropical agriculture. It has no corps of agricultural scientists specialized in tropical crop production and no first-class agricultural experiment stations in the tropical areas. The United States varieties of corn, wheat, rice, and other crops are generally not adapted to tropical latitudes.

In recent years agricultural research in the United States has been oriented away from production and toward more basic and academic pursuits. Consequently, fewer of the nation's universities are now offering the type of training which equips either our own or foreign students for the type of service most needed abroad today.

4. There is no Federal agency to which a developing nation can turn for the type of assistance needed in initiating properly oriented crop production programs—agencies which can offer first-class technical leadership for the substantial periods of time so essential to success.

AID has been able to offer advisors rather than leaders and then for only relatively short periods of time. Our assistance abroad has not resulted in the establishment of the research and training centers now so vital to success of national programs in developing countries.

The Rockefeller Foundation has been able to provide scientists abroad on a career basis, but it has not been able to supply more than a very small fraction of those needed.

FAO primarily offers advisory services, rather than the leadership for national programs that so often is necessary until a nation in need can prepare its own people for these responsibilities.

In view of these needs it would seem desirable that one, or more, tropical research and training institutes, supported by an appropriate agency of the Federal Government, be established in the tropics on United States owned or controlled territory. Such an Institute should support research in depth on all aspects of tropical crop improvement and production and it should function as a training center in tropical agriculture for scientists from the United States and foreign countries.

5. The supply of United States food grains, whether by donation or by sale for soft currency, appears to have permitted some nations to hold down the prices of grain, or to adopt other policies which discourage agricultural production. The United States must be careful that it does not seek to assist and encourage national crop production programs on the one hand while at the same time through shipment of grain discourage production by the farmers of the recipient country.

### *3.7.0 Research on Improved Crop Production and Plant Protection Practices for Developing Countries*

It has been assumed erroneously that agricultural technology can be transferred directly from the developed to the developing countries. In many developing countries, the crop varieties and production practices that have evolved are those which will survive the existing conditions and still produce something each year, although the yield potential is low. In the traditional agriculture of developing countries, these varieties and practices are in equilibrium with the physical, biological, and social environment of the country. In order to intensify crop production, it is necessary to develop new crop varieties which will have high yield potentials. Agronomic and plant protection practices applicable to the environment of the given country must be developed in order to maximize production of the new varieties. Hybrids or varieties from the United States rarely perform satisfactorily in other countries; and likewise, agronomic or plant protection practices cannot be used without some adaptation and modification. We can, however, *transfer principles* of plant breeding, plant nutrition, soil management, and plant protection, and through applied research we can develop adapted varieties and sound cultural practices. This philosophy must permeate the thinking of the agricultural leaders in both the developing countries and the aiding countries. The importance of this philosophy is obvious in a long-term program and, even in a short-term program for immediate impact, it is essential that some preliminary adaptive research be initiated to precede large-scale extension programs.

Attention should be given to both short-term and long-term programs for improved food crop production. The short-term programs are those which can have immediate impact to meet emergency food needs. The long-term programs should be designed to improve crop production to meet dietary needs and to improve the economy of the country.

#### *3.7.1 Short-Term Program for Food Production*

In most developing countries where yields of food crops are low, the use of fertilizer is one of the fastest and most dramatic ways of increasing yields. Doubling or tripling of yields by adequate fertilization is not uncommon. In the Freedom From Hunger Campaign cosponsored by FAO and the fertilizer industries in the United States, a moderate fertilizer treatment increased yields of food crops by 74 percent. This increase was the average of 9,500 demonstrations carried out in 14 developing countries in Asia, Africa, and Latin America. The ratio of increased crop value to cost of fertilizer varied from 2.3 to 1.0 for food grains and beans and from 10 to 13 for potatoes. These demonstrations were carried out using the local variety

and local management practices. Results of this study also demonstrated that the use of fertilizer tended to *encourage* other improved production practices. Experience, however, has shown that a "package of practices" including new varieties, adequate fertilizer, and other inputs is the best "vehicle" for encouraging greatly improved production practices. It has also demonstrated that the effectiveness of adequate fertilization is greatly enhanced by the use of high-yielding varieties and improved cultural and plant protection practices.

Potato production in Honduras from 1951 to 1960 averaged 1,950 kilograms per hectare. Yields in experimental plots were increased 3-fold by control of diseases and pests plus irrigation when needed; about 4-fold by the application of nitrogen; 8-fold by the application of phosphorus; and 8-fold by the application of potassium. When adequate amounts of all three nutrients were provided, with irrigation and protection from insect and disease pests, increases in yields were nearly 30-fold. The dramatic effects on yield by increasing levels of nutrients is shown in Table 3–11.

TABLE 3–11.—*Effect of fertilization on potato yields in Honduras, 1961–63* [1]

| Treatment, kilograms per hectare | | | Yield, kilograms per hectare | |
|---|---|---|---|---|
| N | P | K | 1961–62 | 1962–63 |
| 0 | 0 | 0 | 5,500 | 5,800 |
| 80 | 0 | 0 | 8,700 | 10,000 |
| 0 | 53 | 0 | 15,400 | 19,700 |
| 0 | 0 | 66 | 17,100 | 17,900 |
| 80 | 53 | 0 | 17,600 | 16,600 |
| 80 | 0 | 66 | 18,800 | 18,000 |
| 0 | 53 | 66 | 21,700 | 22,500 |
| 80 | 53 | 66 | 26,500 | 32,400 |

[1] Awan, A. B. The effect of fertilization on potato yields. CEIBA, 11, 18–21, 1964.

An increase of 30 pounds of grain for each pound of applied nitrogen was obtained in India when dwarf wheats, adequate irrigation, and improved production practices were used.[23] Under less favorable conditions the grain: nitrogen ratio may be between 10 and 20, but it is obvious that adequate fertilization is important and profitable. Also it is cheaper and easier for a country to import fertilizer than to import food. Even taking a ratio of 10 pounds of food per 1 pound of applied nitrogen, an additional annual application of 3 million tons of nitrogen would produce 30 million tons of additional grain. This is well above the present needs for world food aid.

[23] Under prevailing prices for wheat and nitrogen, only three pounds of wheat were required to pay for one pound of nitrogen. Thus, the ratio of additional crop value to fertilizer cost was 11 to 1.

One other advantage of providing adequate levels of fertilizer for increased food grain production is that this program would also increase the quantity and quality of straw and stover normally used as feed for domestic animals. The application of fertilizers to forage crops also offers excellent opportunities for increasing the quantity and quality of animal feed. So, one of the most effective ways to increase world food production would be to invest in strategically located fertilizer plants.

When developing a short-term agronomic program, one should review local experimental data and make a brief survey of the production practices of a few leading farmers for indications as to the major factors limiting yields in a given area. Likewise, a survey should be made for possible improved varieties which have been developed or tested in other countries. Dwarf wheats from Mexico and stiff-strawed rice varieties from Taiwan and the International Rice Research Institute in the Philippines are good examples of superior germ plasm which has a high yield potential, and which appears to have unusually widespread adaptability.

In order to develop first approximations which can have immediate application, simple preliminary trials should be conducted on a broad spectrum of the variable being studied. All other variables should be at an optimum based on current information. These preliminary trials should be simple but should use good experimental field techniques and sound statistical design. After preliminary trials, consideration should be given to more critical and detailed experiments involving interacting effects of various production factors. The following types of trials should receive consideration:

*Variety Trials*—Comparisons for adaptability should be made on a wide range of improved high yielding varieties from other countries or areas with the best local varieties. This should be done under the best known levels of fertilization and methods of irrigation, cultural, and plant protection.

*Rate and Method of Fertilization*—Nitrogen is the most commonly deficient nutrient and the one to which crops usually respond most readily. It should, therefore, receive the most emphasis in an applied research and demonstration program. The rates of application tested should be as much as 1.5 times the expected need to define the optimum point in the response curve.

Clearly phosphorus and potassium are the next most commonly deficient nutrients. Soil tests should be used to determine the extent and degree of deficiencies of nutrients. Potassium deficiencies even though not apparent at first may become more apparent after years of intensive cropping. Zinc, iron, sulfur, manganese, and other trace elements are rarely deficient in annual food crops and their deficiency

can usually be observed and identified by the various abnormal appearances of above ground plant parts.

*Date and Method of Seeding Trials*—Well-fertilized, high-yielding varieties often react differently than local varieties. Dwarf varieties of wheat introduced to India have earlier and more rapid seedling and tiller development and appear to be favored by somewhat later planting. Also, dwarf wheats should not be planted as deep as is often done with primitive tools such as the wooden plow.

*Frequency and Time of Irrigation*—Water management may be a critical factor in achieving the maximum potential from well-fertilized, high yielding varieties. For example, in India introduced dwarf wheats which have rapid seedling and tiller development appeared to require earlier irrigation for proper tiller development than the indigenous varieties. Also, short, stiff-strawed varieties of various crops can be irrigated longer so full grain development can occur without the probability of lodging.

*Plant Protection Trials Involving Insect, Disease, and Weed Control*—The nature of plant protection trials will depend upon the problems revealed by review of existing local data and practices. Disease and insect control often take on new dimensions with the use of high levels of fertilizers and greater plant population. Also, the losses due to poor or inadequate plant protection become more significant due to the increased yields. Cultural and physical methods of pest control offer a cheap and often effective means of control. This is especially important in countries where chemicals have not been tested or are not available to supplement other control methods. Cultural methods which may give effective control for some species include time of planting, crop rotation, proper tillage, approved water management, and incorporation of crop residues. For example, delaying maize planting dates in areas of West Pakistan from the third week in July until the middle of August reduces stem borer infestation enough to allow for increase in yields of about 15 percent.[24] Similarly, by planting maize only during May rather than throughout the extended period April to September, Egyptian growers now control the European corn borer, the sugarcane borer, and the lined sugarcane borer when formerly three to four applications of insecticide were required. Maize is now planted so the most susceptible stages of the crop develop at the time of lowest pest populations. There is an annual saving of about 10 million dollars required for the program of insecticidal control, and yields have improved dramatically since the adoption of the program.

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[24] Gill, M. S., and Maan, M. A., Effect of sowing dates and manures on the yield of maize grain. West Pakistan Agr. Res. 1 : 163–169, 1963.

### *3.7.2 Long-Range Agronomic and Plant Protection Investigations*

The development of improved production practices is closely allied with that of breeding for improved crop varieties. In the breeding program, it is essential to develop and utilize the best production practices so that plant selection is made under conditions conducive to high yield potential. It is well known that the development of adapted high-yielding varieties provides greater yield potentials. High-yielding varieties also provide a mechanism for encouraging farmers to adopt improved production practices for any given crop. There is an obvious need for close cooperation and coordination among agronomists, pathologists, entomologists, agricultural engineers, and plant breeders.

For long-range research programs, emphasis should be given to more critical and detailed trials on the interactions of various production factors such as irrigation levels, fertilizers, varieties, and pest control. When diseases or insects are important, the magnitude of the interactions may become even greater. In India a slight delay in the seedling development of sorghum, caused either by a preemergence weed control chemical or a slight deficiency of nitrogen or phosphorus, may cause a several-fold increase in stem borer infestation. This is true because most of stem borer damage occurs during the seedling stage. Such problems as this, which will be discovered in short-term studies, should receive continuing attention.

Reconnaisance type surveys made at the beginning of short-term programs for intensification of plant production should be followed by more detailed surveys of the following: land use, water resources, salinity problems and drainage hazards; and pests such as insects, diseases, weeds, rodents, and birds that might affect production, harvest, or storage of crops. Crop intensification often results in an increase in problems of water supply, drainage, and salinity. Methods of coping with these problems usually require community or national action and therefore must be comprehensive.

In countries heavily dependent upon crops such as sugar, cocoa, rubber, banana, or coffee, the possibility of growing supplemental or alternative food crops should be investigated. In searching for such crops careful consideration should be given to crop adaptation, available resources, and hazards from pests. Emphasis should be given to well-adapted crops rather than attempt to grow all types of crops in order to be self-sufficient. This philosophy is deeply ingrained in traditional agriculture, particularly where the village system has prevailed. Improvements in transportation have decreased the need for "self-sufficiency" to the point that only those crops that are well-adapted to an area should be exploited.

Research on cropping sequences or rotations which will maintain or improve soil tilth while improving crop yields and equality are especially necessary.

The possibilities of pest control through the utilization of biological control agents should be studied intensively. Biotic control agents make up a major portion of the barriers to large increases in pest numbers. Use of both indigenous and exotic species of parasites and predators is an extremely useful method of pest control. Classic examples are the Vedalia beetle for control of cottony cushion scale and *Chrysolina* sp. for control of Klamath weed. Where effective, such methods provide long-lasting control without some of the adverse side effects often associated with pesticide use.

Most of the new hybirds or dwarf varieties of cereals have a shorter growing season than the indigenous varieties. This opens up new vistas for multiple cropping. Also, with the development of tools for more rapid harvest and land preparation, the time between crops can be greatly reduced. This allows for further possibilities of multiple cropping. The possibility of keeping the land occupied continuously by growing summer annuals, such as soybean, in sequence with winter annuals, such as wheat, should receive intensive study. Methods for intensifying crop yields on a per year basis by adopting multiple cropping techniques should be feasible in many areas.

## *3.8.0 Dissemination of Information in the Developing Countries*

### *3.8.1 Organization*

Every developing country has an extension or similar organization to disseminate information through meetings, demonstrations, field days, publications, and visual aids. In many cases they may serve regulatory and service functions as well as educational functions. The pattern varies widely but generally involves a pyramidal organization as one branch of the Ministry of Agriculture, and an effort is made to have it cover the country. Most frequently the link between extension, research and education, and the legal bases for the extension organization are poorly defined or nonexistent.

The above "deficiencies" are frequently cited as reasons for failure to obtain more effective dissemination of information and the more rapid adoption of recommended practices by farmers. Many attempts have been made during the past 20 years, through technical assistance programs, to create or to improve existing organizational structures of extension-information services. For the most part these efforts have failed to produce substantial organizational changes or to improve the effectiveness of extension programs. We believe, however, that these objectives will be more readily achieved by focusing on the function

of extension rather than on organizations per se. Efforts to change organizational patterns are likely to be unsuccessful in most countries.

Emphasis should be on the substance of the extension program. Efforts should be concentrated on identification of programs which have promise of showing substantial improvements in production. The traditional linking of extension with ministries of agriculture, or equivalent units of government, is so strongly entrenched that it is usually futile to undertake to transfer extension functions from such ministries. A close relationship with colleges of agriculture is a more desirable arrangement. If the substance of extension is emphasized and if all resources which can contribute to achievement of program objectives are utilized, a closer linkage with the colleges of agriculture is more likely to emerge than if the problem is approached through organization.

The keys to organization are effective leadership, competent technical and administrative personnel, and flexibility to permit concentration of effort where the greatest response can be expected.

### *3.8.2 Personnel*

Competent personnel is the key to effective extension work. The level of preparation of the extension agents who have direct contact with the farmer is far too low. In most developing countries this point usually is not recognized fully. In attemping to provide general coverage of the rural sector with an extension force, there is a strong tendency to sacrifice quality for quantity. Moreover, this approach has been supported by manpower studies that tend to define the need for personnel in terms of a ratio of extension agents to farmers.

The extension agent often lacks technical education and experience in practical agriculture. A sound technical education is the base upon which the development of extension personnel should rest. Beyond the sound educational base, extension training can be broadened and updated on an inservice basis supplemented by short courses. Inservice training programs should emphasize subject matter as well as methodolgy. Failure to emphasize subject matter in extension training programs has resulted in a waste of effort in many programs.

The usual sharp differentiation between the educational requirements for extension workers and those for research or teaching personnel should be discouraged. Terminal programs at the certificate and diploma levels, in schools of agriculture from which extension personnel are usually drawn, should give way to a vertically integrated system of agricultural education from which students can drop out at several levels to begin work, but which they can reenter to obtain the higher levels of education required for more responsible positions.

### *3.8.3 Extension Programs*

The extension program consists of essentially two elements. First, there are the substantive elements or the specific changes, innovations or practices of the proposed program. Second, there are the methodological elements for achieving the substantive elements.

From a substantive standpoint, the program must fulfill the following conditions:

1. It must be based upon sound experimentation and be fully proven by practical demonstration.
2. It must offer a clear advantage to the user—it must be profitable.
3. The advantages must be translatable in terms clear to the producer.
4. Such factors as availability of new inputs which are required to make information useful and applicable must also be considered. The availability of credit, if needed, must be assured.
5. The application must be reasonably within the reach of the population for which it is intended.
6. The economic factors affecting the profitability of innovations must be thoroughly understood. The test of effectiveness of these factors should be profitability to the producer as well as benefit to the national interest. For many developing countries this means returns to labor. Unless a new system of production practices clearly results in a greater return to the farmer's labor it is unlikely to be adopted. Only when capital inputs make up an important part of the total package of production inputs do returns to capital become meaningful.
7. Most important of the many economic factors to be considered are markets for commodities and fair prices to the farmer for his produce. The assurance of a cash market at a reasonable price is probably the greatest incentive for the farmer. If off-the-farm inputs are to be used, the assurance of a cash market for his produce is essential.

From the methodological standpoint, the program must be adapted to the capabilities of the field extension and supervisory staff and to the farmer group to which it is addressed. Full support of local leadership must be assured and the program must be defined in dynamic, imaginative, and sufficiently flexible terms so as to stimulate and challenge the local leadership, the farmer, and the extension staff. The field demonstration on farmers' fields, carried out by the farmers with the assistance of the extension staff, is the most effective extension technique. With the limitations of extension capabilities in most situations, it will usually be advantageous to be highly restrictive and to direct the entire effort toward the better farmers and those so situated geographically that maximum response can be expected. This is important not only because it is a more efficient allocation of limited resources, but also because at all times extension is on trial *vis-a-vis* the usual conservatism and skepticism of the farmer population. Con-

263-888 O—67——17

sequently, the test of usefulness of improved practices should be made on the best possible terms. The scope of the program must be limited to the resources available for its implementation. A limited scale program directed by competent personnel and executed by a well-supervised corps of field agents will be more productive than a program of broader scope carried out with inadequate personnel and resources. Every effort must be made to make every contact with the farmer and every demonstration successful. Single failures can negate numerous successes.

The scope of the program must be realistic not only in terms of magnitude with respect to geographic area or number of farmers, but also in terms of the complexity and range of the new practices which are being introduced at any one time. The program, however, should be so self-contained that no essential element is left out. For example, corn production improvement should include better soil preparation, use of better seeds, greater plant density, use of fertilizers, pest control, drying and storage, and marketing. This approach is likely to be more productive than one which is focused on certain improvements by generic types across the board—soil preparation, fertilizer use, or improved seeds.

*3.8.4 Relation to Research*

Effective and lasting results from extension programs must rest upon a continuing research program. Changing methods of production create new problems which in turn must be solved. This means that extension and research must work closely together. The traditional separation in the developing countries of agricultural research and extension, and of both from the universities, is a serious impediment, not only to the process of extension and application of research results but also in achieving better orientation of research to the solution of practical problems. A continuing effort should be exerted by United States agencies and institutions working in the developing countries to coordinate education, research, and extension activities. The mechanism for accomplishing this should be developed locally rather than be transplanted from one or another of the developed countries.

## *3.9.0 Education*

Education will play a key role in the world's progress toward an adequate food supply. Two separate and distinct aspects must be involved. One will involve changes in political and economic attitudes to ensure that policy decisions are compatible with and lend support to the objective: Agricultural progress.

There must be a complete realization that outside support can provide only short-term assistance; the final responsibility for continued progress is either population control or increased agricultural pro-

duction. This must be the responsibility of the individual governments.

Surveys within the United States show that the average salary level for agricultural scientists is lower than that for any other branch of science (Table 3–12).

TABLE 3–12.—*Salaries of scientists in the United States, 1966* [1]

| Scientific field | Lowest quartile | Median | Highest quartile |
|---|---|---|---|
| Chemistry | 9,400 | 12,000 | 15,100 |
| Earth sciences | 9,300 | 11,400 | 14,300 |
| Meteorology | 9,800 | 11,700 | 14,300 |
| Physics | 9,500 | 12,500 | 16,200 |
| Mathematics | 9,300 | 12,000 | 15,600 |
| Agricultural sciences | 8,200 | 10,000 | 12,500 |
| Biological sciences | 9,400 | 12,000 | 16,000 |
| Psychology | 9,300 | 11,500 | 14,200 |
| Statistics | 10,200 | 12,800 | 16,000 |
| Economics | 10,100 | 13,100 | 17,600 |
| Sociology | 9,200 | 11,300 | 14,500 |
| Anthropology | 9,200 | 11,500 | 15,000 |
| Linguistics | 8,200 | 10,000 | 13,000 |
| Others | 9,100 | 12,000 | 15,600 |

[1] National Register of Scientific and Technical Personnel, 1966.

The median salary of $10,000 was $2,000 less than the median for all scientists who responded to the inquiry for the National Science Foundation's National Register of Scientific and Technical Personnel. It was $3,100, $2,800, and $2,500 less than that reported for economists, statisticians, and physicists, respectively.[25] This disparity is even greater in the developing countries, so much so in fact, that few scientists are attracted to agriculture as a career. As long as this condition prevails the development and maintenance of the necessary corps of trained personnel will pose a very serious barrier to continued progress.

The second aspect of education involves the development of scientific competence in all subject matter areas necessary for a progressive agriculture. On a short-term basis such competence may be provided through assistance programs but these should be replaced by local competence as rapidly as it can be developed.

### *3.9.1 Role of Universities of the United States*

The role of our universities clearly involves both the dissemination of knowledge and the accumulation of new knowledge. Modern demands on agricultural faculties of our universities are creating serious difficulties in the accumulation of new knowledge. National and international educational programs have expanded greatly in recent years with no corresponding expansion in faculties. The universities are

[25] National Science Foundation News Release 66–167, Dec. 28, 1966.

supplying personnel for many of these programs and these increased obligations have reduced the emphasis on local research. Such a situation may be tolerated for a short period but our own interests, as well as those of the developing countries, preclude this imbalance as a continuing policy.

Clearly, the most effective assistance which our universities can render in fulfilling the educational needs of the developing countries is to provide training at a level that these countries cannot provide for themselves. To an increasing extent this will involve training at the graduate level. It must be recognized, however, that graduate programs designed for students of the United States may be poorly suited to the needs of foreign students.

### *3.9.2 Support Needed by the Universities*

The supply of agricultural scientists is inadequate to satisfy the needs of the United States and assistance programs in the developing countries. It must be recognized that the agricultural sciences have received neither the monetary rewards nor the public acclaim accorded the space program or molecular biology. As a result of these factors, plus the long-continued emphasis on "burdensome surpluses," the agricultural sciences have not attracted their fair share of new students and promising young scientists. This situation must be remedied if an adequate supply of competent manpower is to be available for foreign assistance programs.

As a consequence of the lack of public interest in, and support for, agriculture neither faculties nor facilities are adequate for any major expansion in foreign assistance programs. Facilities for research and teaching can be expanded more rapidly than faculties.

The ever-increasing demands on agricultural faculties resulting from State, Federal and international programs place a serious strain on an effective teaching and research program. New programs have been accompanied by new funds but funding has usually been inadequate for the support of additional personnel. This situation cannot continue without serious impairment of either teaching or research responsibilities. As the problems of world food production are national and international in scope, it seems appropriate that funding to cover the increasing international responsibilities asked of our universities should be federal in origin. The long-term character of the problem must be recognized and assurance given of support for some specified time-period which will permit permanent staff additions.

### *3.9.3 Support for Foreign Trainees*

Long-term improvements in agricultural production in the developing countries cannot be achieved without an increase in adequately trained local personnel. In the past much of this training, at both the baccalaureate and graduate levels, has been provided within the de-

veloped countries. Modifications of this system appear desirable. As rapidly as local facilities become available, training through the baccalaureate level should be provided within the country of geographical area. This will ensure a greater familiarity with local agricultural practices and an increased awareness of local problems.

Graduate training of foreign students in our universities has not been an unqualified success. The academic training is adequate but thesis problems are geared to our level of technology. In many cases foreign students appear to have difficulty, after returning home, in relating their classroom and research experience to action directed at the solution of local problems. This situation undoubtedly arises as a result of two limitations. First, the influence of instructors on foreign students in a classroom is relatively limited. Second, consultation with the student is largely geared to a consideration of plans and progress on the assigned research problem. Little opportunity is available for consideration of problems of importance to agriculture in the student's home country. This is inevitable as the advisor's time is limited and he cannot be expected to have the detailed knowledge of world agricultural and economic problems that would be required for meaningful discussions of specific research needs.

The adoption of a policy used successfully by the Rockefeller Foundation for many years could serve to increase the effectiveness of graduate training of foreign students. Under this system carefully screened candidates are provided fellowships to our universities for a period of 1 year, with the possibility of an extension for a second year. The appointment can be terminated at the end of the first year, for academic or other reasons, with no loss of face. If progress is satisfactory, the trainee may be permitted to complete the M.S. degree. Then he must return home and engage in agricultural research. His availability, as a candidate for further graduate training, will depend on his scholastic record and on the effectiveness of his research activities at his home station.

An additional approach would involve sending interested graduate students from the United States to foreign research centers or universities for completion of research studies. This procedure is now being used to a limted extent—by Illinois in Sierre Leone and by Cornell in the Philippines. An expansion of this program would: (1) broaden the training of students in the United States; (2) further the research activities of the country involved; (3) serve to stimulate interest in developing countries and overseas assignments; and (4) demonstrate the techniques and dedication required for effective research, possibly the most important of all.

# CHAPTER 4

# INTENSIFICATION OF ANIMAL PRODUCTION

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## Contents

| | | Page |
|---|---|---|
| 4.1.0 | Summary | 243 |
| 4.2.0 | Introduction | 246 |
| 4.3.0 | The Role of Animals in World Food Production | 248 |
| 4.3.1 | Utilization of World Grazing Lands | 248 |
| 4.3.2 | Utilization of Wastes and By-Products | 248 |
| 4.3.3 | Production of Animal Protein from Urea | 249 |
| 4.3.4 | Use of Cereals as Supplements to Forages in Modern Livestock Feeding Systems | 249 |
| 4.3.5 | Potential for Improvement in the Efficiency of Converting Plant to Animal Proteins | 250 |
| 4.4.0 | Inventory of World Livestock Resources and Potential for Development | 251 |
| 4.4.1 | World Livestock Numbers | 251 |
| 4.4.2 | Trends in Livestock Production | 255 |
| 4.4.3 | Estimates of World Animal Protein Production | 255 |
| 4.4.4 | Potential and Prospects for Increasing Production | 255 |
| 4.4.5 | Animal Production in Latin America | 258 |
| 4.4.6 | Animal Production in Near East | 261 |
| 4.4.7 | Animal Production in Far East | 263 |
| 4.4.7.1 | Prospects for Increasing Animal Production in India | 263 |
| 4.4.8 | Animal Production in Africa | 266 |
| 4.4.9 | Animal Production in the Developed Countries of Europe, North America, and Oceania | 267 |
| 4.4.10 | Animal Production in the United States | 267 |
| 4.5.0 | The Role of Draft and Fiber Producing Animals in Food Production | 268 |
| 4.6.0 | Contribution of Wild Animals | 268 |
| 4.6.1 | Potential in Africa | 269 |
| 4.6.2 | Potential in Other Areas | 270 |
| 4.6.3 | Control of Diseases in Wild Animals | 270 |
| 4.6.4 | Domestication of Wild Animals | 270 |
| 4.6.5 | Needs for Wild Animal Conservation Programs | 271 |



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Page

4.7.0 Animal Diseases ..... 271
4.7.1 World Livestock Disease Picture ..... 271
4.7.2 Tropical Animal Diseases ..... 271
4.7.3 Magnitude of Losses and Approaches for Control of Livestock Diseases ..... 275
4.7.4 Priorities for Latin America ..... 275
4.7.5 Priorities for Africa ..... 276
4.7.6 Priorities for Asia ..... 277
4.8.0 Animal Production Problems ..... 278
4.8.1 Animal Nutrition ..... 279
4.8.1.1 Feed Preservation and Storage ..... 279
4.8.1.2 Pasture and Range Management and Forage Production ..... 280
4.8.1.3 Tropical Range Management and Forage Research Needed ..... 280
4.8.1.4 Use of Supplements to Grazing ..... 281
4.8.1.5 Utilization of Wastes, By-Products, and Synthetic Materials ..... 281
4.8.1.6 Use of Urea in Ruminant Nutrition ..... 283
4.8.1.7 Use of Non-Conventional Foods as Animal Feeds ..... 283
4.8.2 Water for Livestock ..... 284
4.8.3 Animal Breeding for Tropical Conditions ..... 284
4.8.4 Animal Reproduction ..... 285
4.8.5 Marketing, Processing, Distribution ..... 286
4.8.6 Transportation, Manufactured Inputs, and Livestock Services ..... 286
4.8.7 Incentives, Government Policy, and Land Tenure ..... 286
4.8.8 Custom, Tradition, Social, Political, and Cultural Factors ..... 286
4.9.0 Research and Education ..... 287
4.9.1 Education ..... 288
4.9.2 Needs in Research ..... 289
4.9.3 Extension Programs in Animal Science ..... 290
4.9.4 Role of the Private Sector in Livestock Development ..... 290
4.9.5 Regulatory Programs ..... 290
4.9.6 United States Education in the Animal Sciences for Students from Developing Countries ..... 291
4.9.7 Education of United States Animal Scientists for International Service ..... 291
4.9.8 University Commitment to International Livestock Development ..... 291
4.10.0 Conclusion and Recommendations ..... 292

# 4.0 INCREASING WORLD SUPPLIES OF FOODS OF ANIMAL ORIGIN

## 4.1.0 Summary

One of the most complex aspects of the world food problem is the provision of sufficient quantities of proteins of adequate nutritional quality to foster good health and prevent protein malnutrition. Man traditionally has balanced his diet consisting largely of plant materials with foods of animal origin which contain essential amino acids, as well as fats, minerals, and vitamins. In the opinion of the Subpanel, as well as other knowledgeable experts, providing adequate quantities of animal products is one of the most effective ways to improve world protein nutrition.

There is no shortage of animal protein in the world as a whole; however, supplies available in the developing countries amount to only 9 grams per person per day compared to 44 grams or more in the developed countries. The FAO short-term target for animal protein supplies for the developing countries is 15 grams and the long-term target is 21 grams per person per day. These targets could be realized if maximum use were made of all available resources.

The unique and important contribution that animals can make to the world food supply is often underestimated or overlooked by world food planners, presumably because of the belief that increases in animal production can be made only by diverting to animals, foods that otherwise would be eaten by people. This approach ignores the fact that livestock consume great quantities of food such as forages, wastes, by-products, and even urea that cannot be eaten by man. Whether or not grains are fed to livestock generally is a question of economics. When it is profitable to do so, livestock producers feed grains; when it is not, they utilize other feedstuffs.

There are over 3 billion livestock in the world and an equal number of domesticated fowl. Although 60 percent of these animals are in the developing countries, these countries produce only 20 to 30 percent of the world's meat, milk, and eggs. This low productivity is due largely to a failure to utilize scientific principles of disease control and animal husbandry in production processes.

According to FAO data, world production of meat, milk, and eggs has increased during the decade 1953 to 1963. Even in the developing countries, animal protein production has kept pace with or increased

more rapidly than population increases. For purposes of the report, future world production of animal protein has been estimated, using as a guide our subjective evaluation of the various regions' resources and potential for animal production, as well as the rate of increase from 1953 to 1963. Predictions also assume that efforts will be made to maximize production of plant foods for human use. If reasonable progress is made in improving production, per capita supplies of animal protein are expected to increase until about 1990. After that, if population increases continue, the per capita supply almost certainly will decline.

It was not possible to quantify adequately the contribution that wild animals now make to the world food supply. In Africa, which is richly endowed with wild animal species, they contribute a great deal to human diets and the potential for increases are great. Under certain natural conditions, wild animals produce more meat than livestock species. A great deal of research on wild animal biology and diseases is needed. Domestication of new species better adapted to tropical conditions than existing livestock should be attempted.

Animal diseases constitute one of the most important limitations to animal production in the developing countries. Diseases capable of debilitating or destroying large livestock populations still exist. The most important epizootic diseases of livestock are rinderpest, contagious bovine pleuropneumonia, hemorrhagic septicemia, foot and mouth disease, African horse sickness, African swine fever, hog cholera, Newcastle disease, fowl plague, trypanosomiasis, East Coast fever, and piroplasmosis. It will be impossible to develop productive livestock industries until these diseases are brought under some measure of control. Numerous parasitic, infectious, nutritional, toxic, metabolic, and organic diseases also cause losses by killing animals or reducing their productivity. The incidence and prevalence of diseases and their morbidity and mortality are very high in the developing countries.

Animal diseases cause significant wastage of animal protein. Based on FAO estimates, a 50 percent reduction of losses from animal diseases in the developing countries, a realistic goal, could result in an increase in animal protein of 25 percent. Prospects for controlling the major livestock diseases are good, providing a nation desires to do so and is willing to implement long-term programs to accomplish this objective. This report recommends that international agencies take the lead by developing a world plan for the control of the major epizootic diseases so that all nations may contribute to this objective.

In adequate livestock nutrition is a very important cause of low animal production in the developing countries. Adequate quantities of essential nutrients must be provided during all seasons of the year for efficient livestock production. Improved systems of harvesting, preserving, and storing feedstuffs must be developed to sustain animals

during dormant seasons caused by cold weather, drought, and other environmental conditions. Substantial proportions of the agricultural land of Asia, Africa, and Latin America are grazing lands. The productivity of these lands could be increased manyfold through the use of improved pasture and range management techniques. Although there is a vast fund of knowledge about forages and range management in temperate regions, very little is known about tropical forages and range management.

Animals can use a wide variety of agricultural and industrial wastes and by-products. Unfortunately, many of these feedstuffs now are being wasted. Residues from the production of food grains, such as corn, wheat, rice, sorghums, oats, and barley make useful feeds. Vegetable wastes, sugar beet by-products, cottonseed meal, gin wastes, extracted sugar cane, spent brewery grains, and molasses are suitable for animal feed. Animal by-products, such as meat scraps, fat, tankage, bone meal, and even certain animal manures, serve as sources of nutrients. Oilseeds, such as peanuts, sesame, safflower, soybeans, and their products, as well as palm and coconut meals are highly nutritious and often are wasted or used as fertilizer in the developing countries. Residues from fruit processing industries are important sources of nutrients. Ruminants can utilize urea to partially replace dietary protein because microorganisms in the rumen convert it to protein. Wider use of this chemical could reduce strikingly the use of plant proteins for animal feeds.

There is need for greater use of new tropical breeds of livestock and for development of additional breeds and strains that are resistant to the climate and diseases of the tropics.

Adequate marketing, processing, distribution, and transportation systems, and the availability of manufactured inputs and livestock services are essential to a productive livestock industry. Adequate incentives, government policy, and land tenure systems favorable to livestick production are needed. An understanding of traditions and social, political, and cultural factors that inhibit progress in the development of the livestock industries also are necessary before realistic plans can be instituted.

There is a critical shortage of manpower in the developing countries trained and experienced in the sciences and technologies underlying animal production. Existing schools in these countries offering training at the professional level in veterinary medicine and in animal husbandry must be strengthened. Subprofessional education to provide manpower for extension and regulatory animal science programs and commercial enterprises should be expanded. Vocational training in animal husbandry should be expanded to promote widespread understanding of scientific livestock production among individuals who manage and service livestock operations.

Knowledge of the biology and diseases of animals in the tropics and of husbandry practices under tropical conditions is grossly inadequate. A great deal of research on animal diseases and parasites, feeds and forages, animal nutrition, physiology of animals, animal breeding, including the development of heat and disease resistant strains of livestock, and husbandry practices will be required to bring tropical animal production up to modern standards. International centers should be established to develop this information for both the humid and dry tropics. Another center devoted to research on epizootic animal diseases of the tropics is needed. National centers also are needed to adapt this knowledge to local conditions.

The developing countries must be assisted in developing livestock extension and regulatory programs. In addition to advancing their own commercial interests, private enterprises can be highly effective in livestock extension programs.

Education of students from developing countries in the animal sciences in the United States should be made relevant to problems that students will encounter when they return to their countries. Programs are needed to provide education for United States students who wish to enter careers in international livestock development. Following the acquisition of specific disciplinary skills and some knowledge of the processes of international development and the social, cultural, and political aspects of the region in which they will work, tutorial experience in a developing country with skilled and experienced livestock development experts should be provided. A university that wishes to engage in international livestock development programs through its School of Veterinary Medicine or Department of Animal Science must make long-term commitments to these programs so members of their faculties can develop careers in international livestock development.

### *4.2.0 Introduction*

The provision of adequate quantities of dietary proteins of proper nutritional quality is proving to be one of the more difficult aspects of the world food problem. Man has traditionally balanced his diet with proteins of animal origin; i.e., meat, milk, eggs, and fish, which have provided essential amino acids, as well as minerals, fats, and vitamins. Animal products also have contributed desirable flavor and structure to otherwise bland and formless diets. Provision of adequate quantities of animal products is generally conceded to be the ideal way to improve world protein nutrition.[1]

There is no shortage of animal protein in the world as a whole and the potential for expansion is great. Current supplies are adequate to

[1] Altschul, A. M. Edible seed protein concentrates: their role in control of malnutrition. Israel J. Med. Sci. 1: 471–479. 1965.

supply every person in the world with 20 grams per day; however, distribution is such that per capita consumption is 44 grams in the developed countries of North America, Europe, Australia, and New Zealand, and only 9 grams in the rest of the world and the developing countries. The FAO short-term targets for the developing countries are 15 grams per person, and the long-term targets are 21 grams. The important question is how to provide the needy countries with the necessary high quality protein in the most satisfactory and economical manner. Evidence collected in connection with this study suggests that increasing animal production is a highly satisfactory way to provide some of these needs.

The human organism does not distinguish between amino acids of plant, animal, bacterial, or synthetic origin so long as an adequate quantity of each essential amino acid is present. Meat, milk, eggs, and fish proteins are high quality because they contain a balance of the nine amino acids essential to man, while plant proteins lack one or more essential amino acids. For example, diets composed principally of corn, wheat, or rice are likely to be deficient in methionine, lysine, or tryptophan. Even oilseed proteins have relative deficiencies of certain amino acids; i.e., soybean protein is low in methionine; cottonseed in threonine and available lysine; and peanuts in methionine, lysine, and threonine. Diets composed mainly of cereal grains must be supplemented with foods containing the essential amino acids to meet human dietary requirements and avoid protein malnutrition. (For a discussion of nutrition, see Chapter 1.)

Meeting the world needs for quality proteins is complicated by the fact that human dietary habits are difficult to change. There is no doubt that human diets can be adequately supplemented with properly processed oilseed meals, microbial protein, and synthetics; however, strong preferences have developed for traditional foods. Consequently, people are extremely reluctant to accept what they consider to be aesthetically inferior substitutes. On the contrary, animal products are highly desired and are readily consumed by most people throughout the world; consequently, it is not realistic to ignore the potential for expanding the production of animal products to meet some of the world needs for high quality proteins. In the long-run, it may be far easier to increase animal production in certain areas than to alter food preference patterns developed over many centuries.

The objective of this report is to evaluate the potential of animals to contribute to world food supplies in the context of world resources and total nutritional needs. The report examines the reasons animal production in the developing countries is inadequate to meet the needs of these countries and outlines steps required to increase animal production throughout the world.

### *4.3.0 The Role of Animals in World Food Production*

Those concerned with planning for world food needs are often skeptical of the contribution that animals can make toward increasing world food supplies, arguing that increased animal production can be achieved only by diverting for animal use food that otherwise would be consumed directly by people. Their thesis is that it is wasteful to feed animals because the yield in energy from the animal products is only 10 to 30 percent as much as the energy fed; hence, it would be better to let people consume the food directly.

This concept applies only if the entire diet of the animal is composed of foods eaten by people. Livestock thrive on many feeds, forages, wastes, by-products, and even chemicals that are not suitable for human food. They have evolved over the centuries as highly developed scavengers, utilizing all manner of plant, animal, and human wastes whether they obtain them directly from the countryside or in highly developed livestock operations in which by-products, wastes, and forages are processed and fed to them. Whether or not grains suitable for human use are fed to livestock is mainly a question of the supply and demand for other uses and their cost. When grains are readily available at a low price, they are fed, sometimes in abundance; when they are not available at a low price, animals are provided other feedstuffs, which generally cannot be used directly as human food. Productive livestock systems can be developed whether or not large quantities of cereals are fed.

#### *4.3.1 Utilization of World Grazing Lands*

Over 60 percent of the world's agricultural land is non-arable and suited only for grazing. Animals are the only practical means of utilizing this resource for human food production. The productivity of these lands could be improved greatly if modern forage and range management techniques were utilized. Even land classified as arable will, under certain conditions, produce a more valuable human food resource through the production of certain high yielding forages, such as alfalfa or Sudangrass, for use as livestock feeds rather than when it is used to produce cereal grains for consumption by people. The application of modern range management techniques also promises to convert some of the lands of the world currently considered to be waste lands into valuable producers of forages.

#### *4.3.2 Utilization of Wastes and By-Products*

Animals utilize a wide variety of wastes and by-products of agricultural and industrial operations as food. Almost every food crop or food product has some utilizable waste or by-product associated with it. Most of these valuable products currently are wasted in developing countries where animal proteins are badly needed.

The important food grains, such as corn, wheat, rice, sorghum, and oats, have large plant residues and mill wastes that are extremely valuable sources of energy and protein, as are sugar beet pulp, bagasse, molasses, and spent brewers' grains. The animal industry generates a host of products that can be salvaged as animal feeds, such as meat scraps, tankage, bone meal, blood meal, animal fats, and even animal manures. Oilseed by-products, only part of which can be used in human diets, such as soybean, peanuts, safflower, copra, palm nut, cottonseed, and coconut meals, are valuable animal feedstuffs. Even fruit residues can be efficiently utilized by various classes of livestock.

### *4.3.3 Production of Animal Protein from Urea*

The polygastric ruminants such as cattle, sheep, and goats, unlike people and monogastric animals, can utilize non-protein nitrogen in the form of urea as a source of dietary nitrogen because microorganisms in their rumens convert these substances to proteins. Dairy cows have been fed urea, ammonium salts, potato starch, cellulose, and sucrose, and produced up to 4,325 kg. of milk containing 164 kg. of protein in a year without any other source of protein.[2] A beef calf weighing 290 pounds gained an average of 1 pound per day until she weighed 930 pounds, and produced a calf with urea as the sole source of protein.[3] Lambs fed urea have gained 0.21 pounds per day as compared to controls fed soybean protein, which gained 0.26 pounds per day. Urea is used extensively in the developed countries for dairy and beef feeding and also is fed to sheep. Much more would be used if abundant supplies of feed grains were not available at low prices. Urea can make a significant contribution to ruminant diets in developing countries having a shortage of protein feedstuffs.

### *4.3.4 Use of Cereals as Supplements to Forages in Modern Livestock Feeding Systems*

The rate of efficiency by which animals convert feed protein to food protein is meaningless except as it relates to diets composed entirely of foods that can be consumed by people. In practice, even in the United States where grains are available in quantity at low prices, livestock rations include a high proportion of forages and by-products not generally consumed by people. In the United States, 70 percent of an average dairy cow's protein intake is derived from forages, 60 percent of that of a beef steer, and 80–90 percent for sheep and beef brood stock. The use of small quantities of cereal grains as livestock feed in modern nations makes it possible to use, at low cost in terms of food that could be consumed by people, large quantities of forages and by-products that might not be used otherwise. An example of food grain

[2] Virtanen, A. I., Milk production of cows on protein-free feed. Science 153 (3744). 1603–1614. 30 Sept. 1966.

[3] Moore, L. A., Putnam, P. A., and Bayley, N. D., Unpublished data, Animal Husbandry Division, USDA, Beltsville, Maryland.

consumption in one segment of the United States livestock industry illustrates this point.

The input of protein from cereals and oilseeds and the output of milk protein of cattle under commercial conditions are given in Table 4–1. Total protein input has been corrected for proteins that are not considered appropriate food for people. About 96 percent of the protein from cereals and oilseeds was returned as milk protein. Had urea been used at recommended levels, the output of milk protein would have exceeded the input of oilseed and cereal proteins by 40 percent.

TABLE 4–1.—*Protein inputs from cereals and output of milk protein. (From a survey containing 1,500 cows producing 11,674 pounds of milk containing 3.69 percent fat on 46 Wisconsin dairy farms.*[1])

| Source of input | Crude protein pounds | |
|---|---|---|
| | Input | Output—milk |
| 3,173 pounds of grains and oilseed concentrates per year | 392 | 377 |

[1] Moore, L. A., Putnam, P. A., and Bayley, N. D. Unpublished Data. Animal Husbandry Division, USDA, Beltsville, Md.

It is evident that under certain circumstances the use of small quantities of cereal and oilseed proteins for animal feeds may result in the production of a more valuable food resource in the form of beef and milk proteins than the plant protein consumed.

### *4.3.5 Potential for Improvement in the Efficiency of Converting Plant to Animal Proteins*

The efficieny of converting crude feed protein to food protein utilizing husbandry and feeding practices currently used in the United States is 3:1 for milk, 4:1 for broilers, and 5:1 for eggs. The rate of efficiency for 450 kg. cow producing 13,500 kg. of 4 percent fat milk is estimated to be less than 2:1, while that of a 1.8 kg. hen producing 365 eggs per year is about 3:1 when fed according to National Academy of Sciences, National Research Council standards.[4] These data show that protein conversion efficiency rates are not fixed and are capable of being improved by scientific methods. A conversion ratio of 2:1 is very favorable indeed when one considers that the exchange is made between vegetable protein of low value for milk protein of very high biological value.

The efficiency by which animals convert total feed consumed to food is being constantly improved. Broilers are capable under carefully controlled conditions of converting 2.0 pounds of feed into 1.0 pounds of

[4] Byerly, T. C. The role of livestock in food production. J. Animal Sci. 25: 552–566. 1966.

broiler (live weight). Swine can produce a pound of live weight from 3.0 pounds of feed. The net loss of total nutrients with conversion ratios of this nature is small indeed if part of the diet consists of feeds that cannot be consumed by people.

## *4.4.0 Inventory of World Livestock Resources and Potential for Development*

### *4.4.1 World Livestock Numbers*

The world has about one billion each of cattle and sheep, over a half billion pigs, about one-third billion goats, 100 million buffalo, and more than 130 million horses, mules, asses, and camels. Distributions of livestock by areas is shown in Table 4–3. Cattle are the most important producers of animal protein, followed by pigs and poultry. Sheep, goats, and other animals are important in some areas and are found in almost all countries.

Approximately 60 percent of the world's livestock are raised in developing countries; however, these countries produce only 20 percent to 30 percent of the world's meat, milk, and eggs. Livestock in these countries produce at a fraction of the level attained in developed countries. The striking difference in productivity of cattle in developed and developing nations for 1962 through 1964 is shown in Table 4–2.

TABLE 4–2.—*Beef and veal and milk production per year per head of all cattle by regions* [1]

| Region | Cattle (million) | Beef and veal (kilograms) | Milk (kilograms) |
|---|---|---|---|
| North America | 114.7 | 74.8 | 570.7 |
| Europe | 117.9 | 62.9 | 1,134.2 |
| Oceania | 25.6 | 49.6 | 485.6 |
| Latin America | 213.4 | 27.5 | 102.7 |
| Near East | 32.9 | 20.2 | 201.6 |
| Africa | 112.5 | 13.9 | 87.1 |
| Far East | 235.7 | 4.5 | 64.1 |

[1] From Food and Agriculture Organization of the United Nations. Production Yearbook, Vol. 16, 1962, Vol. 17, 1963, and Vol. 18, 1964.

The low productivity of livestock in developing countries can be attributed to a number of factors, some of which have religious and cultural roots. The main reason that livestock are unproductive is the failure to use scientific principles of disease control and animal husbandry. If modern principles of genetics, nutrition, range and forage management, animal husbandry, and disease control were adapted to local conditions and applied, and if farmers were appropriately supported by suppliers and processors, animal production in these countries could be increased greatly without wastefully competing with people for food.

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TABLE 4-3.—*Average livestock numbers by regions* [1]

[In million of animals]

| Region | Cattle | | Pigs | | Sheep | | Goats | | Buffaloes | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1952-54 | 1962-64 | 1952-54 | 1962-64 | 1952-54 | 1962-64 | 1952-54 | 1962-64 | 1952-54 | 1962-64 |
| World | 798.7 | 982.0 | 336.5 | 546.4 | 823.0 | 1,005.4 | 300.4 | 354.9 | 74.0 | 104.2 |
| World [2] | 715.0 | 852.7 | 235.4 | 307.2 | 719.3 | 807.9 | 258.1 | 294.6 | 69.4 | 82.2 |
| Europe | 104.7 | 117.9 | 90.3 | 112.6 | 127.3 | 133.7 | 22.9 | 14.6 | .6 | .5 |
| North America | 101.0 | 114.7 | 60.7 | 62.5 | 33.0 | 30.6 | 2.7 | 3.8 | | |
| Latin America | 169.3 | 213.4 | 54.5 | 84.3 | 128.0 | 129.3 | 31.2 | 39.1 | | |
| Near East | 26.7 | 32.9 | .1 | .1 | 106.7 | 122.0 | 48.7 | 55.0 | 3.1 | 3.8 |
| Far East | 201.3 | 235.7 | 23.7 | 39.9 | 48.3 | 54.4 | 69.4 | 82.9 | 65.3 | 78.5 |
| Africa | 91.0 | 112.5 | 4.2 | 5.3 | 117.0 | 127.3 | 83.0 | 99.0 | .4 | |
| Oceania | 21.0 | 25.6 | 1.9 | 2.5 | 159.0 | 210.6 | .2 | .2 | | |
| United States [3] | 92.8 | 103.5 | 53.1 | 57.3 | 31.8 | 29.7 | 2.4 | 3.8 | | |
| U.S.S.R. [4] | 59.5 | 84.8 | 34.4 | 59.2 | 97.7 | 137.0 | 20.0 | 6.5 | | |
| Mainland China [4, 5] | | 44.5 | | 180.0 | | 59.0 | | 7.5 | | 21.0 |

| Region | Horses | | Mules | | Asses | | Camels | | Livestock units [6] | | Percent increase | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1952–54 | 1962–64 | 1952–54 | 1962–64 | 1952–54 | 1962–64 | 1952–54 | 1962–64 | 1952–54 | 1962–64 | 1952–54 | 1962–64 |
| World | 75.4 | 63.9 | | 15.5 | | 41.4 | | 11.4 | 1,023.6 | 1,263.5 | 23.4 | |
| World [2] | 55.0 | 47.3 | 13.3 | 13.8 | 26.1 | 29.6 | 9.7 | 11.1 | 886.1 | 1,033.6 | 16.6 | |
| Europe | 16.1 | 10.6 | 2.1 | 1.9 | 2.9 | 2.6 | | | 138.0 | 146.8 | 6.4 | |
| North America | 4.9 | 3.6 | 1.8 | 1.0 | | | | | 103.2 | 112.3 | 8.8 | |
| Latin America | 23.4 | 22.7 | 6.8 | 7.9 | 6.7 | 7.8 | | | 197.8 | 241.3 | 22.0 | |
| Near East | 2.3 | 2.7 | .8 | 1.1 | 6.7 | 8.2 | 3.8 | 4.2 | 52.7 | 62.8 | 19.2 | |
| Far East | 4.2 | 3.7 | .2 | .1 | 2.0 | 2.0 | 1.2 | 1.5 | 250.2 | 295.8 | 18.2 | |
| Africa | 3.0 | 3.3 | 1.6 | 1.8 | 7.8 | 9.0 | 4.7 | 5.4 | 110.0 | 131.9 | 19.9 | |
| Oceania | 1.1 | .7 | | | | | | | 34.2 | 42.8 | 25.1 | |
| United States [3] | | | | | | | | | 88.3 | 97.6 | 10.5 | |
| U.S.S.R. [4] | 15.4 | 9.0 | | | | | | | 82.5 | 107.3 | 30.1 | |
| Mainland China [4, 5] | | [7] 20.0 | | | | | | | | 122.2 | | |

[1] Data were obtained from FAO Production Yearbooks from 1953 though 1965. Some data were incomplete and some averages involved approximations.

[2] Totals given are the sum of the regions and exclude the U.S.S.R. and Mainland China.

[3] Included in North America.

[4] Not included in regional totals.

[5] From FAO/WHO Animal Health Yearbook 1965.

[6] Conversion factors used: Camels 1.1; buffaloes, horses, and mules 1.0; cattle and asses 0.8; sheep and goats 0.1.

[7] All equidae.

The thesis that low productivity of animals in developing countries is attributable to failure to utilize modern principles of disease control and animal husbandry is well supported by the existence of many highly productive livestock units in these countries that have succeeded because modern methods have been adopted. For example, livestock operations in the so-called White Highlands of Kenya developed during the Colonial era are highly productive and efficient. Many hundreds of herds and flocks of beef and dairy cattle and sheep equal or superior to the livestock of developed countries exist in this area today. One of the world's great large Holstein-Freisian herds is located on the equator near Naivaska, Kenya. Similar examples are present in Rhodesia.

The Republic of South Africa has developed an amazingly efficient and productive livestock industry even though the South Africans are confronted with most of the animal diseases and many of the adverse climatic factors present in the developing nations of Africa. A sizable portion of Australia lies in the tropics. The Australians have developed some excellent livestock operations in these areas despite adverse tropical conditions. During the last two decades, milk production in Japan has been increased 400 percent as a result of adopting modern disease control and husbandry practices on a wide scale. Examples of highly successful individual livestock operations could be cited in most of the developing countries. There is absolutely no doubt that we know the principles required to improve world livestock production and that these principles have been well tested under practical conditions.

One of the encouraging stories in livestock development is the recent emergence of a significant poultry industry in Mexico. In 1954 there was no such thing as a commercial egg producing operation in that country. Today between 15 million and 18 million highly productive hens are maintained under excellent conditions of management—a significant development indeed. In 1958 a commercial broiler (poultry meat) industry was begun. Last year Mexico poultrymen marketed over 25 million broilers. Similar developments are occurring in swine production in Mexico. Rather than decreasing the availability of grains for human food in Mexico, the development of the poultry and swine industries stimulated the production of more grains, particularly the grain sorghums which are better adapted to many areas in Mexico than are food grain crops. Developments in the poultry and swine industry are the direct result of the establishment of effective disease control and husbandry practices, and in the latter case, a commercial feed industry utilizing locally grown feedstuffs. Outstanding individual poultry units are to be found in such widely separated places as Java, Peru, Venezuela, Nigeria, and Pakistan. Improvement in poultry production is more easily achieved than in other livestock

production because poultry science is more readily transferable to non-temperate areas of the world.

The foregoing examples amply demonstrate the soundness of the thesis that world livestock production can be readily improved by adapting the principles of veterinary science and animal husbandry to livestock production problems in developing countries.

### *4.4.2 Trends in Livestock Production*

According to FAO data, world production of meat, milk, and eggs has increased during the 1953–1963 decade (Tables 4–4, 4–5, and 4–6) even in the developing countries, where with few exceptions it has increased more rapidly than population increases. All classes of livestock, except horses, increased in number during this period; more significantly, production of animal products increased more rapidly than livestock numbers. If these increases are real and not due to errors in data collection, they constitute encouraging evidence that results are being obtained from programs designed to improve the productivity of the world's livestock.

### *4.4.3 Estimates of World Animal Protein Production*

Realizing the shortcomings of available data, estimates of anticipated production of animal protein are given in Tables 4–10 and 4–12. The estimates are based on changes that were reported for the 1953–1963 decade, an evaluation of resources and the potential for animal production in the various areas. Expected efforts to maximize production of foods that can be consumed directly by man are taken into account. A range of low, medium, and high estimates are given for each area and date. The low values are based on minimum expected increases in production while the high values are expected maximum increases. Medium figures are believed to be the most realistic considering the complex nature of the development process.

Average per capita production of animal protein over the world is expected to increase until about 1990. Then it is expected to decline even with the "low" population projections given in Table 4–11. The developing nations must stabilize their populations at a more rapid rate than is indicated in Table 4–11 if they wish to maintain or increase the amount of animal protein in their diets. Our estimates are intentionally conservative. Maximizing animal production, without reducing plant food crops consumed directly by man, could result in increased supplies of animal protein almost to the end of this century if populations increase as projected.

### *4.4.4 Potential and Prospects for Increasing Production*

The potential for increasing world livestock production is great. Most of the major limiting livestock diseases are amenable to control. The productivity of the world's grazing lands, which constitute about two-thirds of the agricultural land in the world, can be improved

TABLE 4-4.—*Average meat production from indigenous animals by regions* [1]

[In 1,000 metric tons]

| Region | Beef and veal | | Pork | | Mutton and lamb | | Beef, veal, pork, mutton, and lamb | | Percent increase | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1952-54 | 1962-64 | 1952-54 | 1962-64 | 1952-54 | 1962-64 | 1952-54 | 1962-64 | 1952-54 | 1962-64 |
| World | 20,857 | 31,500 | 17,743 | 29,500 | 4,017 | 6,000 | 42,617 | 67,000 | 57.2 | |
| World [2] | 19,874 | 26,561 | 13,300 | 18,280 | 3,543 | 4,563 | 36,717 | 49,403 | 34.6 | |
| Europe | 5,107 | 7,417 | 6,170 | 9,473 | 823 | 990 | 12,100 | 17,880 | 47.8 | |
| North America | 6,447 | 8,687 | 5,220 | 6,027 | 333 | 360 | 12,000 | 15,073 | 25.6 | |
| Latin America | 4,840 | 5,880 | 1,037 | 1,237 | 400 | 420 | 6,277 | 7,537 | 20.1 | |
| Near East | 410 | 667 | | | 380 | 643 | 790 | 1,310 | 65.8 | |
| Far East | 850 | 1,070 | 600 | 1,220 | 495 | 547 | 1,945 | 2,837 | 45.9 | |
| Africa | 1,340 | 1,570 | 143 | 160 | 395 | 523 | 1,878 | 2,253 | 20.0 | |
| Oceania | 880 | 1,270 | 130 | 163 | 717 | 1,080 | 1,727 | 2,513 | 45.5 | |
| United States [3] | 5,959 | 8,034 | 4,772 | 5,564 | 319 | 347 | 11,060 | 13,945 | 26.1 | |
| U.S.S.R. [4] | | | | | | | | | | |
| Mainland China [4] | 2 | | 72 | | | | 74 | | | |

[1] Data were obtained from FAO Production Yearbooks from 1953 through 1965. Some data were incomplete and some averages involved approximations.

[2] Totals given are the sum of the regions and exclude the U.S.S.R. and Mainland China.

[3] Included in North America.

[4] Not included in regional totals.

TABLE 4–5.—*Average milk production by regions* [1]

[In 1,000 metric tons]

| Region | Cow | | Goat | | Sheep | | Buffalo | | Total | | Percent increase | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1952–54 | 1962–64 | 1952–54 | 1962–64 | 1952–54 | 1962–64 | 1952–54 | 1962–64 | 1952–54 | 1962–64 | 1952–54 | 1962–64 |
| World | | 323,333 | | 8,233 | | 6,867 | 15,600 | 17,434 | | 355,833 | | |
| World [2] | 220,633 | 265,099 | 8,566 | 8,067 | 5,567 | 5,800 | 13,500 | 17,434 | 248,233 | 293,100 | 18.1 | |
| Europe | 106,633 | 133,733 | 2,900 | 1,967 | 1,867 | 2,200 | 200 | 167 | 111,600 | 134,767 | 20.8 | |
| North America | 61,700 | 65,467 | | | | | | | 61,700 | 65,467 | 6.1 | |
| Latin America | 16,333 | 21,933 | 700 | 1,000 | | | | | 17,033 | 22,933 | 34.6 | |
| Near East | 4,900 | 6,633 | 1,933 | 1,700 | 2,967 | 2,900 | 1,133 | 1,400 | 10,900 | 12,633 | 15.9 | |
| Far East | 12,467 | 15,100 | 1,233 | 1,400 | | | 12,167 | 15,867 | 25,867 | 32,367 | 25.1 | |
| Africa | 8,167 | 9,800 | 1,800 | 2,000 | 733 | 700 | | | 10,700 | 12,500 | 16.8 | |
| Oceania | 10,433 | 12,433 | | | | | | | 10,433 | 12,433 | 19.2 | |
| United States [3] | 54,544 | 57,096 | | | | | | | 54,544 | 57,096 | 4.7 | |
| U.S.S.R. [4] | | | | | | | | | | 62,767 | | |
| Mainland China [4] | | | | | | | | | | | | |

[1] Data were obtained from FAO Production Yearbooks from 1953 through 1965. Some data were incomplete and some averages involved approximations.

[2] Totals given are the sum of the regions and exclude the U.S.S.R. and Mainland China.

[3] Included in North America.

[4] Not included in regional totals.

through improved forage, water, and range management practices. Yields of both feed grains and forages can be increased to much higher levels. Providing adequate diets to livestock during all seasons will result in marked increases in production. Non-protein nitrogen can be used to a much greater degree in ruminant diets, thus releasing proteins for other uses. Much better utilization of wastes, by-products, and crop residues is possible. Shifts from animal to other sources of power will release resources to produce animal food. All of these increases can be realized by wider utilization of present technology and adaptation to the conditions in the developing countries.

Increases in animal production also will be made possible as a result of research presently in progress. Major advances in disease and parasite control can be expected through the development of new drugs, vaccines, and biological control measures. Marked improvements are expected to result from research on animal nutrition, with more efficient feeding practices constantly being developed. Progress in converting cellulose and even lignin products into animal feedstuffs is worthy of particular note. Research on breeding and selection for more efficient and productive animals will result in marked improvements in productivity of all classes of livestock. The development of new methods of food processing and preservation promises to contribute to efficient animal production. It is important, however, that fundamental research in animal production and veterinary medicine be continued and expanded in developed countries if these advances are to be achieved.

### *4.4.5 Animal Production in Latin America*

Latin America is endowed with an abundance of resources for livestock production. Its agricultural land area approximates that of the United States, although a much larger proportion, i.e., over 80 percent, is grazing land. There are more than twice as many livestock units (Table 4–3) in Latin America than in the United States and Canada. Livestock numbers increased rapidly from 1953 to 1963, although increases in production per animal did not keep pace with the increase in the United States and Canada (Table 4–4, 4–5, and 4–6). Only one-half as much meat, about one-third as much milk, and one-fourth as many eggs are produced in Latin America as in North America.

Animal protein supplies in Latin America have barely kept pace with population increases from 1953 to 1963 (Table 4–8). Slight decreases in production of animal protein per capita seem likely in the future based on current estimates of livestock production and population estimates. Either population control, improved animal production, or a combination of both could increase per capita animal protein supplies substantially over those shown in Tables 4–10 and 4–12 before the end of this century.

TABLE 4–6.—*Average egg production from hens by regions* [1]

| Regions | Millions of eggs | | Weight of eggs (1,000 metric tons) | | Percent increase in weight of eggs | |
|---|---|---|---|---|---|---|
| | 1952–54 | 1962–64 | 1952–54 | 1962–64 | 1952–54 | 1962–64 |
| World | | 258,867 | | 14,167 | | |
| World [2] | 182,357 | 212,616 | 9,770 | 11,851 | 21.3 | |
| Europe | 55,333 | 84,100 | 3,053 | 4,673 | 53.1 | |
| North America | 71,267 | 69,600 | 4,040 | 4,093 | 1.3 | |
| Latin America | 12,633 | 18,700 | 687 | 1,000 | 45.6 | |
| Near East | 6,067 | 5,633 | 303 | 277 | −8.6 | |
| Far East | 30,433 | 25,533 | 1,357 | 1,333 | −1.8 | |
| Africa | 3,767 | 5,800 | 183 | 290 | 58.5 | |
| Oceania | 2,867 | 3,250 | 147 | 185 | 25.9 | |
| United States [3] | 69,184 | 64,255 | 3,923 | 3,791 | −3.4 | |
| U.S.S.R. [4] | | 28,429 | | | | |
| Mainland China [4] | | | | | | |

[1] Data were obtained from FAO Production Yearbooks from 1953 through 1965. Some data were incomplete and some averages involved approximations.
[2] Totals given are the sum of the regions and exclude the U.S.S.R. and Mainland China.
[3] Included in North America.
[4] Not included in regional totals.

TABLE 4–7.—*Land use by regions* [1]

[In hectares]

| Region | Total | Arable | Grazing | Total agricultural | Agricultural land (1964) | |
|---|---|---|---|---|---|---|
| | | | | | Per person | Per livestock unit |
| | *Millions* | *Millions* | *Millions* | *Millions* | | |
| World | 13,570 | 1,457 | 2,633 | 4,090 | 1.2 | 3.3 |
| World [2] | 10,354 | 1,118 | 2,085 | 3,203 | 1.4 | 3.1 |
| Europe | 493 | 152 | 90 | 242 | .5 | 1.7 |
| North America | 2,152 | 227 | 277 | 504 | 2.4 | 4.4 |
| Latin America | 2,053 | 96 | 415 | 511 | 2.2 | 2.1 |
| Near East | 993 | 85 | 96 | 171 | 1.2 | 2.7 |
| Far East | 1,314 | 275 | 154 | 429 | .4 | 1.4 |
| Africa | 2,496 | 248 | 603 | 851 | 3.3 | 6.4 |
| Oceania | 853 | 35 | 460 | 495 | 28.9 | 11.3 |
| United States [3] | 936 | 185 | 256 | 441 | 2.3 | 4.4 |
| U.S.S.R. [4] | 2,240 | 230 | 370 | 600 | 2.6 | 5.6 |
| Mainland China [4] | 976 | 109 | 178 | 287 | .4 | 2.3 |

[1] Data were obtained from FAO Production Yearbook for 1965.
[2] Totals given are the sum of the regions and exclude the U.S.S.R. and Mainland China.
[3] Included in North America.
[4] Not included in regional totals.

TABLE 4–8.—*Changes in population and in estimated protein content of national average food supplies per capita*

| | People (millions) | | | | Total protein [1] (grams per day) | | | | Animal protein [1] (grams per day) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1952–54 | 1962–64 | Percent increase | | 1952–54 | 1962–64 | Percent increase | | 1952–54 | 1962–64 | Percent increase | |
| | | | 1952–54 | 1962–64 | | | 1952–54 | 1962–64 | | | 1952–54 | 1962–64 |
| World | 2,542.7 | 3,162.0 | 24.4 | | | | | | | | | |
| World [2] | 1,744.0 | 2,250.7 | 29.1 | | 65.7 | 69.2 | 5.3 | | 25.2 | 27.1 | 7.5 | |
| Europe | 401.8 | 436.6 | 8.7 | | 81.7 | 86.4 | 5.8 | | 37.6 | 43.7 | 16.2 | |
| North America | 175.2 | 208.4 | 18.9 | | 90.2 | 91.0 | .9 | | 60.7 | 63.7 | 4.9 | |
| Latin America | 173.1 | 229.0 | 32.3 | | 66.5 | 69.9 | 5.1 | | 25.7 | 25.6 | .4 | |
| Near East | 132.0 | 143.4 | 8.6 | | 84.1 | 97.1 | 5.5 | | 13.9 | 17.5 | 25.9 | |
| Far East | 686.1 | 968.7 | 41.2 | | 48.3 | 53.0 | 9.7 | | 7.5 | 8.6 | 14.7 | |
| Africa | 162.4 | 247.8 | 52.6 | | | [3] 48.7 | | | | [3] 11.6 | | |
| Oceania | 13.4 | 16.8 | 25.4 | | 93.9 | 94.0 | .1 | | 62.3 | 63.0 | 1.1 | |
| United States [4] | 160.3 | 189.4 | 18.2 | | 90.2 | 91.0 | .9 | | 61.0 | 64.4 | 5.6 | |

[1] Based on averages of countries with available data in FAO Production Yearbooks and weighted by population numbers.

[2] Totals given are the sum of the regions and exclude the U.S.S.R. and Mainland China.

[3] Not included in regional totals.

[4] Included in North America.

Livestock diseases greatly limit production, while livestock nutrition is generally inadequate, particularly in the tropics. The productivity of pastures could be improved through proper management practices. Improvements in marketing, processing, and distribution of animal products are needed especially. Much improvement is needed in the genetic potential of livestock, their ability to adapt to local environments, and in reproductive efficiency. Governmental agricultural and price policies and farmer incentives need attention, as do means of providing seeds, fertilizers, and tools at more reasonable prices. Serious shortages of trained manpower exist in all spheres of the animal sciences.

### *4.4.6 Animal Production in the Near East*

Approximately half of the agricultural land in the Near East is arable and half is grazing land. There is twice as much arable land per person as in Europe and three times as much as in the Far East. This region contains 2.7 hectares of agricultural land per livestock unit as compared to the world average of 3.1 (Table 4–9).

TABLE 4–9.—*Estimated number of people in millions* [1]

| Region | 1962–64 | 1970 | 1980 | 1990 | 2000 |
|---|---|---|---|---|---|
| World | 3,162 | 3,574 | 4,269 | 5,068 | 5,965 |
| World [2] | 2,251 | 2,544 | 3,097 | 3,750 | 4,506 |
| Europe | 437 | 454 | 479 | 504 | 527 |
| North America | 208 | 227 | 262 | 306 | 354 |
| Latin America | 229 | 282 | 374 | 488 | 624 |
| Near East | 143 | 166 | 206 | 251 | 301 |
| Far East | 969 | 1,105 | 1,375 | 1,680 | 2,022 |
| Africa | 248 | 291 | 378 | 494 | 646 |
| Oceania | 17 | 19 | 23 | 27 | 32 |
| United States [3] | 189 | 211 | 245 | 284 | 330 |

[1] Estimated populations were adapted to above regions and countries from intermediate projections.
[2] Totals given here are the sum of the regions and exclude the U.S.S.R. and Mainland China.
[3] Included in North America.

All species of farm animals are represented in the Near East, with sheep and goats having greater relative importance than in most other areas. Total livestock units have increased at a slightly greater rate during the 1953 to 1963 decade than in the world as a whole (Table 4–3).

Meat and milk production has grown more rapidly in the Near East in the last decade than in most other countries (Tables 4–4 and 4–5). Egg production has decreased (Table 4–6). Animal protein supplies per capita have increased more rapidly than population although the average per capita supply is only 17.5 grams per day.

Increases in available animal protein apparently will keep up with population growth through the year 2000 in the Near East (Tables 4–10 and 4–12). Animal production could be expanded significantly.

if both the science and technology of animal production are developed. Modern techniques for disease control, nutrition, breeding, forage production, processing, marketing, and distribution of animal products must be adapted to local needs. The spectacular advances made by Israel serve as an example of what can be done.

TABLE 4–10.—*Present and anticipated animal protein content of national average food supplies per person*

[Grams per day]

| Region and Range [1] | 1962–64 [2] | 1970 | 1980 | 1990 | 2000 |
|---|---|---|---|---|---|
| World: | | | | | |
| Low | | 15.7 | 17.3 | 16.0 | 15.1 |
| Medium | 19.6 | 16.8 | 19.8 | 20.2 | 19.8 |
| High | | 21.1 | 23.7 | 25.6 | 27.8 |
| World: [3] | | | | | |
| Low | | 22.1 | 20.2 | 18.3 | 16.8 |
| Medium | 23.5 | 23.6 | 23.2 | 23.2 | 22.3 |
| High | | 25.5 | 28.2 | 29.9 | 31.9 |
| Europe: | | | | | |
| Low | | 43.5 | 43.2 | 43.0 | 44.7 |
| Medium | 43.7 | 46.4 | 50.0 | 53.2 | 57.2 |
| High | | 49.4 | 56.8 | 63.4 | 69.7 |
| North America: | | | | | |
| Low | | 63.0 | 62.7 | 61.9 | 59.1 |
| Medium | 63.7 | 67.1 | 71.3 | 80.1 | 82.4 |
| High | | 75.7 | 91.9 | 99.5 | 104.8 |
| Latin America: | | | | | |
| Low | | 22.2 | 19.9 | 17.7 | 15.7 |
| Medium | 25.6 | 23.7 | 22.6 | 23.3 | 22.0 |
| High | | 25.2 | 29.9 | 38.6 | 49.0 |
| Near East: | | | | | |
| Low | | 16.7 | 15.9 | 15.0 | 14.2 |
| Medium | 17.5 | 17.8 | 18.0 | 18.2 | 18.1 |
| High | | 18.8 | 20.0 | 21.4 | 22.9 |
| Far East: | | | | | |
| Low | | 8.1 | 7.1 | 6.0 | 5.2 |
| Medium | 8.6 | 8.6 | 8.1 | 7.1 | 6.1 |
| High | | 9.1 | 9.1 | 8.0 | 7.0 |
| Africa: | | | | | |
| Low | | 10.6 | 9.7 | 8.6 | 7.4 |
| Medium | 11.6 | 11.3 | 10.9 | 11.3 | 10.4 |
| High | | 12.0 | 14.5 | 18.7 | 23.2 |
| Oceania: | | | | | |
| Low | | 63.5 | 64.0 | 58.8 | 57.9 |
| Medium | 63.0 | 71.3 | 81.9 | 84.5 | 83.7 |
| High | | 79.1 | 117.1 | 104.7 | 104.8 |
| United States: [4] | | | | | |
| Low | | 61.8 | 60.7 | 58.8 | 56.2 |
| Medium | 64.4 | 65.9 | 69.2 | 76.9 | 79.1 |
| High | | 74.0 | 88.6 | 97.9 | 102.7 |

[1] The low values for the range are based on expected minimum increases in production while the high are expected maximum increases and the medium are thought to be most likely.

[2] These averages are taken from Tables 4–4, 4–5, and 4–6 except that the averages for the sum of the regions include Africa.

[3] Averages given are the sum of the regions and exclude U.S.S.R. and Mainland China.

[4] Included in North America.

TABLE 4–11.—*Estimated number of people in millions using low projections* [1]

| Region | 1962–64 | 1970 | 1980 | 1990 | 2000 |
|---|---|---|---|---|---|
| World | 3,162 | 3,515 | 4,071 | 4,659 | 5,296 |
| World [2] | 2,251 | 2,532 | 2,994 | 3,493 | 4,046 |
| Europe | 437 | 450 | 467 | 482 | 491 |
| North America | 208 | 222 | 248 | 274 | 294 |
| Latin America | 229 | 278 | 352 | 429 | 514 |
| Near East | 143 | 164 | 198 | 234 | 274 |
| Far East | 969 | 1,108 | 1,340 | 1,587 | 1,866 |
| Africa | 248 | 291 | 367 | 462 | 579 |
| Oceania | 17 | 19 | 22 | 25 | 28 |
| United States [3] | 189 | 201 | 222 | 245 | 263 |

[1] Estimated populations were adapted to the above regions and countries from "low" projections furnished by Subpanel 13.
[2] Totals given here are the sum of the regions and exclude the U.S.S.R. and Mainland China.
[3] Included in North America.

### *4.4.7 Animal Production in the Far East*

The Far East, characterized by extremely dense human populations, supports more livestock units than any other region; e.g., nearly one-third of the livestock in the world. There is less agricultural land per person and per animal than in any other region (Table 4–7). Productivity of animals is low, but they provide much of the draft power essential for plant agriculture and exist mainly as scavengers.

Milk and meat production increased at a greater rate in the Far East than the world average from 1953 to 1963, but egg production decreased slightly (Tables 4–4, 4–5, and 4–6). Per capita animal protein supplies increased in spite of a marked growth in population but are lower than for any other region (Table 4–8). After 1970 supplies are expected to decrease even for low population projections (Table 4–10). Animal numbers would have to be increased several fold to improve supplies significantly in view of the present small production and large population.

Considerable improvement in animal production is possible in the Far East and will come as a result of instituting modern disease control and production practices, as well as needed marketing and processing systems, coupled with favorable governmental agricultural policies and farmer incentives.

*4.4.7.1 Prospects for Increasing Animal Production in India.* Increasing production of animal products in India is highly complex partly because of the Hindu doctrine of ahinsa which, in conjunction with legal constraints, restricts the slaughter of cattle. Cattle in India, however, make significant and multiple contributions to the economy of that country. Bullocks provide most of the draft power for agriculture. Cow dung is rural India's main cooking fuel, and cow manure is extremely important to Indian agriculture as an organic fertilizer.

TABLE 4-12.—*Anticipated animal protein content of national average food supplies per person based on "Low" population projections*

[Grams per day]

| Region and range [1] | 1962-64 [2] | 1970 | 1980 | 1990 | 2000 |
|---|---|---|---|---|---|
| World: | | | | | |
| Low | | 18.8 | 18.2 | 17.4 | 17.0 |
| Medium | 19.6 | 20.0 | 20.8 | 22.0 | 22.3 |
| High | | 21.5 | 24.9 | 27.8 | 31.3 |
| World: [3] | | | | | |
| Low | | 22.2 | 20.9 | 19.6 | 18.7 |
| Medium | 23.5 | 23.7 | 24.0 | 24.9 | 24.8 |
| High | | 25.6 | 29.2 | 32.1 | 35.5 |
| Europe: | | | | | |
| Low | | 43.9 | 44.3 | 44.9 | 48.0 |
| Medium | 43.7 | 46.9 | 51.3 | 55.6 | 61.4 |
| High | | 49.8 | 58.2 | 66.3 | 74.8 |
| North America: | | | | | |
| Low | | 64.4 | 66.2 | 69.1 | 71.2 |
| Medium | 63.7 | 68.6 | 75.3 | 89.5 | 99.2 |
| High | | 77.4 | 97.1 | 111.1 | 126.1 |
| Latin America: | | | | | |
| Low | | 22.6 | 21.2 | 20.1 | 19.0 |
| Medium | 25.6 | 24.0 | 24.0 | 26.5 | 26.7 |
| High | | 25.5 | 31.8 | 43.9 | 59.4 |
| Near East: | | | | | |
| Low | | 16.9 | 16.5 | 16.1 | 15.6 |
| Medium | 17.5 | 18.0 | 18.7 | 19.6 | 19.9 |
| High | | 19.0 | 20.8 | 23.0 | 25.1 |
| Far East: | | | | | |
| Low | | 8.0 | 7.3 | 6.4 | 5.7 |
| Medium | 8.6 | 8.6 | 8.3 | 7.6 | 6.7 |
| High | | 9.1 | 9.4 | 8.5 | 7.6 |
| Africa: | | | | | |
| Low | | 10.6 | 9.9 | 9.1 | 8.3 |
| Medium | 11.6 | 11.3 | 11.3 | 12.1 | 11.6 |
| High | | 12.0 | 15.0 | 20.0 | 25.9 |
| Oceania: | | | | | |
| Low | | 63.5 | 66.9 | 63.5 | 66.2 |
| Medium | 63.0 | 71.3 | 85.6 | 91.2 | 95.6 |
| High | | 79.1 | 122.4 | 113.0 | 119.8 |
| United States: [4] | | | | | |
| Low | | 64.9 | 67.0 | 68.2 | 70.5 |
| Medium | 64.4 | 69.2 | 76.4 | 89.1 | 99.2 |
| High | | 77.7 | 97.8 | 113.5 | 128.9 |

[1] The low values for the range are based on expected minimum increases in production, while the high are expected maximum increases and the medium are thought to be most likely.

[2] These averages are taken from Tables 4-4, 4-5, and 4-6, except that the averages for the sum of the regions include Africa.

[3] Averages given are from the sum of the regions and exclude U.S.S.R. and Mainland China.

[4] Included in North America.

Much of the animal protein consumed by the Indians comes from cattle, largely in the form of milk. Cattle in India are partly scavengers, obtaining most of their sustenance from roadsides, ditch banks, or crop residue wastes. The slaughter of some cattle occurs in India. Tens of millions of people including pagans, Christians, and Moslems, as well as some Hindus, eat beef. The cattle problem in India is highly complex, and drastic recommendations to alter the present systems

should not be implemented without thorough study of the consequences. Nevertheless, it is important to work diligently toward an appropriate solution of the cattle problem so that the majority of India's cattle may become truly productive.

In spite of the religious dimension of livestock production in India, It is neither necessary nor wise to discount animals as important contributors to India's needs for high quality protein foods. There is considerable potential for increasing milk production and a place for a well-managed poultry industry, as well as for sizeable numbers of sheep and goats. Development of a significant livestock industry depends in part on the success of India's program to reduce the number of cattle by 50 to 60 percent of her 175 million head that contribute very little to the nation's economy. Some success is being achieved although admittedly it is modest. Castration of scrub bulls is practiced, and schemes to reduce reproduction in non-productive females may be yielding results. Public support for laws permitting the slaughter of cattle is developing. Some knowledgeable Indians believe that the time is not too far distant when India's huge cattle herd will be brought into better balance with feed supplies.

A great deal of livestock feed currently is lost because a high proportion of the plant residues and by-products generated by India's agricultural industries is poorly utilized or wasted. Forage preservation and storage systems are badly needed. Large quantities of by-products such as mill wastes and oilseed meals are allowed to spoil, are destroyed by pests, or used as fertilizer. Although some of these products can be salvaged for human food, much is suitable only for animal use. If these products were used in conjunction with forages and urea, they would support a significant dairy industry. As agricultural practices are improved, the quantity of usable plant residues and by-products available for animal feeds will increase. The yield of forages from grazing lands in India also could be increased greatly if modern pasture and range management technology were employed.

With the development of improved feeding practices and effective control of the major epizootic cattle diseases, improved breeding practices for milking animals will yield results. In some areas in India, the productivity of dairy cattle has been increased by the introduction of high producing Holstein-Friesian, Jersey, Sindhi and Sahiwal germ plasm through artificial insemination. There is a significant potential for upgrading indigenous cattle by this means. A program to improve dairy cattle should be accompanied by more widespread breeding of the high quality strains of Indian draft animals to provide a continuous supply of bullocks for agricultural uses because those from high producing dairy cattle frequently are not suitable for draft purposes. The buffalo also offers potential for improving both meat and milk production.

A well-managed commercial poultry industry utilizing the most productive genetic lines, modern husbandry practices, and disease control techniques developed to utilize specific agricultural and industrial wastes and by-products will contribute significantly to the Indian food supply. Chickens can convert inedible oilseed meals and mill wastes, when combined with small quantities of grains, into nutritious protein which in many instances will exceed the nutritional value of the edible foods required in their diets. Some of the needed feed grains are available in India. The efficiency of poultry production systems might be increased if wastes were used to fertilize fish ponds as is done in parts of Southeast Asia and China. More efficient disease control will increase the productivity of the important small poultry flocks that scavenge for their nutrients.

Sheep and goat meat is acceptable to many Indians. The production of these species would be enhanced by improved pasture and range management techniques and other methods.

There is no question that animal protein production in India can be significantly increased. It will require considerable time. With the great need for high quality proteins, however, that nation cannot afford to neglect any reasonable means of increasing its supplies of these foods. An evaluation of the quantities of feedstuffs that are being and can be produced suggests that these feed and forage resources could sustain a sizable and productive livestock industry that need not be competitive with people for food.

### *4.4.8 Animal Production in Africa*

Africa has a greater potential for livestock production than most other areas of the world. Its agricultural land area exceeds that of other regions, and there is more acreage per person and per livestock unit than in all other regions except Oceania. There are 113 million cattle in Africa compared to 115 million in North America; 226 million sheep and goats compared to 34 million in North America; and a total of 131 million livestock units compared to North America's 112 million (Table 4–3). In spite of high livestock numbers, production of meat, milk and eggs is low and has increased at a slower rate from 1953 to 1963 than in the world as a whole (Tables 4–4, 4–5, 4–6). Animal protein supplies per capita are low, about 11.6 grams, and probably have not increased as rapidly as population in recent years. Supplies of animal protein per person are expected to decrease (Table 4–10) although they might remain fairly constant throught the year 2000 if the "low" projections for population increases prevail. Rapid improvement in animal production is feasible and could lead to increases in per capita animal protein supplies even if the population increases as expected.

Africa's vast livestock potential is ineffectively utilized. It could be developed substantially if animal production technology were

widely applied. Disease control must be given high priority because a greater variety of serious animal diseases exist on this continent than in any other region.

Wild game as a source of animal protein in Africa deserves much more consideration than it has received. There is evidence that wild ungulates, with their differential, non-duplicating preferred diets, more flexible water requirements, and disease tolerance, make more efficient use of the available forage and water than traditional livestock species.

### *4.4.9 Animal Production in the Developed Countries of Europe, North America, and Oceania*

The developed countries of the world are characterized by a highly productive agriculture and a plentiful supply of animal protein. In 1962 to 1964 these regions produced over 70 percent of the world's beef, veal, pork, mutton and lamb, but they have less than 30 percent of the people (Table 4–9). Production of animal products per animal unit is high in these regions (Tables 4–4, 4–5, and 4–6). From 1953 to 1963, production increased much faster in Europe and Oceania than in North America because of a greater demand for animal products in Europe.

Production of animal protein per capita is expected to increase in all of these regions through 1990 (Tables 4–10 and 4–12). Oceania and North America could produce large excesses for export if foreign demands and purchasing power provided the price incentives, and the balance of payments problem could be solved.

### *4.4.10 Animal Production in the United States*

Meat production increased steadily in the United States from 1953 to 1963 (Table 4–4) resulting in the highest meat consumption per capita in the history of the country. Poultry meat production increased more than 50 percent in this period. Expected increases in personal incomes, improved technology of production and distribution, and the capacity of the country to increase production of feed grains and forages indicate further increases in availability of meat and animal products.

Production per breeding unit has increased about 2 percent annually for the last 10 years. Further increases in efficiency of production through improved husbandry and feeding practices, more effective disease and parasite control, improved breeding stock, and more effective use of breeds and their crosses can be expected if market price incentives and research programs continue. Milk production has continued to rise in spite of marked reductions in dairy cows. Fewer hens are producing many more eggs. Meat animals with leaner, more desirable carcasses and heavier marketing weights are anticipated.

The potential exists for increased feed grain and forage production through improved management of existing land and water resources.

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Animal production lends itself to multiple use of land which is receiving increased attention.

Idle reserves of agricultural land can be used for increased production of feed grains, pasture and forage, as well as for other crops. Only Oceania and Africa have more agricultural land per person and per livestock unit than the United States (Table 4–7). Yields of feed grains and forages will rise and more pastures will be improved if economic incentives materialize. Gains through better range and pasture management should more than offset losses of land for other uses.

### *4.5.0 The Role of Draft and Fiber Producing Animals in Food Production*

Although draft animals have yielded much of their role in agriculture to the tractor in the developed countries, they still are very important sources of power in the developing countries and appear likely to remain so for a long time.[5] Lord Linlithgow, when Viceroy of India, observed that "the cow and the working bullock bear on their patient backs the whole structure of Indian agriculture." What was true in pre-partition India is still true in that country, Pakistan, and most of the countries of Asia, the Far East, Near East, Africa, and Latin America. The tractor is finding an increasingly important place in land clearing and leveling operations in many developing countries and is being used on individual farms in some areas. However, draft animals still provide most of the agricultural power. In most of these countries man is the chief competitor of the draft animal as a source of power on farms.

Most draft animals are eventually consumed for meat. Draft cattle and water buffalo also produce milk. Wool, mohair, and other animal fibers are important components of the economy in many regions and play a major role in clothing the inhabitants and providing a source of income from manufacturing and export. Most fiber-producing and draft animals are eventually consumed for meat.

### *4.6.0 Contribution of Wild Animals*

It is not possible to quantify the contribution that wild animals currently make to the world food supply. Many people throughout the world depend wholly or in part on wild animals for animal protein. Recent studies in Africa, Australia, Union of Soviet Socialist Republics, United States, and the United Kingdom indicate that in some areas the potential yield from wild animals is greater than if the same land were used for livestock production. In other areas, food yields increase when land is shared by domestic and wild species. It is practical

[5] Phillips, R. W., Animal agriculture in the emerging nations. In: Moseman, A. H. (ed.). Agricultural sciences for the developing nations. Amer. Ass. Advance. Sci. Publ. 76, 1964. 221 p., pp. 15–32.

and economically feasible to produce meat from wild species through game management and semidomestication. Research is needed to determine the optimum way to utilize wild animals for food production, whether or not additional meat producing species can be profitably domesticated, and how to develop suitable methods of harvesting, processing, and marketing wild animals. Special attention should be given to determining the potential of sea mammals to contribute to world protein supplies.

### *4.6.1 Potential in Africa*

In Africa, which is richly endowed with great numbers of many species of animals, wild animals long have constituted an important source of food. In recent years, there has been a tendency to reduce or eliminate the vast herds of wild animals in many areas to permit the development of traditional temperate-zone livestock farming, mainly with cattle and sheep. In Rhodesia hundreds of thousands of wild animals have been killed to reduce the tsetse fly danger to livestock, and in East Africa there is a slow erosion of vast herds of plains animals as livestock operations encroach on their habitat and poachers take their toll. Game animals, adapted to local conditions, survive in areas in which livestock cannot because of disease or environmental factors. But more importantly, in certain well-defined circumstances, wild game produces more meat per acre than livestock on the same land. The evidence comes from studies conducted on unimproved land under somewhat primitive management systems, comparing indigenous domestic animals of low productivity with well-adapted wild species. The point is illustrated in the following example from a study in Rhodesia.[6]

An area of 50 square miles was studied which contained 16 species of grazing and browsing animals, with a population density of 76 animals and a standing crop of 19,000 pounds per square mile. The minimum annual crop was calculated, harvested by shooting, and sold through commercial channels. The annual meat yield was estimated at 118,000 pounds with a value of 5,500 Rhodesian pounds. The same area, if developed for use by cattle, with fencing, road, and water improvements, might have produced an estimated 95,000 pounds of meat annually, with a net profit of 506 Rhodesian pounds compared to a net profit of 3,200 Rhodesian pounds for the game animal enterprise.

A combination of grazing and browsing mammals under certain circumstances makes better use of arid, semiarid, mountainous, and other marginal lands than would existing breeds of livestock. More meat is produced per unit of land, and in general the habitat is maintained in better condition at a lower cost than under present primitive

[6] Dasmam, R. F., and Mossman, A. S., The economic value of Rhodesian game. Rhodesian Farmer 30: 17–20. 1960.

systems of livestock production. Unfortunately, data are not available to adequately compare game and livestock management systems.

### *4.6.2 Potential in Other Areas*

In the American tropics, there are habitats similar to those in Africa, but the number of wild species of grazing and browsing animals is small. Native animals probably cannot equal domestic livestock in meat production. Since available evidence suggests that the same ecological niches exist in tropical America as in tropical Africa, the introduction of various African mammals to be used in various combinations with existing breeds of domestic stock might lead to increased meat production from lands not suited to intensive development as pastures for livestock. Unfortunately, this possibility is complicated by the fact that African wild animals serve as reservoirs for a great number of dangerous diseases and parasites not found presently in North and South America. Means must be developed to obtain parent stock that is disease and parasite free before African animals can be used in Latin America.

The potential for exploitation of wild grazing and browsing animals in Southeast Asia is significant. Studies should be carried out in India, Indonesia, and other areas of tropical Asia, where wild game still exists in reasonable abundance, to determine their potential for meat production.

### *4.6.3 Control of Diseases in Wild Animals*

Although very little is known about diseases of wildlife and their control, it is clear that different species of game serve as reservoirs of many important livestock diseases and parasites, including rinderpest, hemoprotozoal infections, and foot and mouth disease. Livestock, on the other hand, are the source of many diseases that affect wild animals. Unfortunately, little correlation exists between disease programs in wild animal and livestock species. To attain maximum utilization of all types of animals, wild and domestic, research on disease management and control must be carried out simultaneously.

### *4.6.4 Domestication of Wild Animals*

The possibility of domesticating wild animal species should be investigated, especially to determine if certain wild species would be more useful than existing livestock for meat production, particularly in the tropical regions. Studies conducted to date suggest that many wild species are more heat tolerant, drought resistant, and resistant to diseases than are livestock. Some species are capable of utilizing plant forages that are of little use to livestock. Studies on the African eland and several species of small plains antelopes in Africa offer encouragement for rapid domestication of highly useful wild species.

### *4.6.5 Needs for Wild Animal Conservation Programs*

Millions of dollars are spent annually to ensure effective utilization and preservation of wildlife species. In most of the developing countries wildlife conservation receives very little support. Programs to preserve wildlife species and better utilize some of them as food for people should be supported. There is a special need to expand research on all aspects of the biology and diseases of wild animals.

## *4.7.0 Animal Diseases*

### *4.7.1 World Livestock Disease Picture*

Animal diseases (Table 4–13) constitute one of the most important limitations to the development of more productive livestock industries. Epizootic diseases capable of killing or debilitating large populations of animals are largely uncontrolled in developing countries. The most important epizootic diseases of livestock are rinderpest, contagious bovine pleuropneumonia, hemorrhagic septicemia, foot and mouth disease, African horse sickness, African swine fever, hog cholera, Newcastle disease, fowl plague, trypanosomiasis, East Coast fever, and piroplasmosis. These diseases limit livestock production in susceptible species wherever they occur. It is impossible to develop a fully productive livestock industry in areas where epizootic livestock diseases have not been brought under some measure of control.

The greatest total loss results not from the spectacular epizootic diseases, but from the many parasitic, infectious, nutritional, toxic, metabolic, and organic diseases that affect livestock throughout the world and especially in developing countries where little attention has been given to animal health. They include hundreds of diseases and infestations such as brucellosis, tuberculosis, anaplasmosis, mastitis, vibriosis, lumpy skin disease, bluetongue, parasitic infestations that occur commonly throughout the world, as well as diseases more limited in their distribution such as Ondiri disease, Nairobe sheep disease and Rift Valley fever.

Accurate data are not available on the incidence or prevalence of various livestock diseases in developing countries, but there is no doubt that it is great. Efficient livestock production cannot exist under these circumstances.

### *4.7.2 Tropical Animal Diseases*

Because most developing countries are in the tropics or subtropics, most of the livestock disease problems of these countries are significantly different from those of developed countries located in temperate climates. Although many principles of medical science and disease control developed for temperate regions apply to tropical problems, there is a critical deficiency in knowledge of tropical veterinary medicine. Work initiated and developed by some of the countries formerly

TABLE 4–13.—*Some of the world's major animal diseases*

| Disease | Cause | Animals affected | Susceptibility of man | Principal reservoirs | Vectors | Distribution | Prevalence | Control measures |
|---|---|---|---|---|---|---|---|---|
| Hog cholera | Virus | Swine | Not affected | Affected animals | None | Worldwide | Enzootic or epizootic. | Effective vaccines. |
| Fowl plague | do | Poultry | do | Affected birds | do | Worldwide except United States and Australia. | do | |
| Foot and mouth disease. | do | Ruminants, swine. | Rare, if at all | Cattle, swine, wild ruminants. | do | Worldwide except North America, Central America, Australia, New Zealand. | do | Vaccines (7 types) immunity short duration. |
| Rinderpest | do | Ruminants, particularly cattle and buffalo. | Not affected | Ruminants, particularly wildlife. | do | Africa, Asia | Epizootic | Vaccine provides solid lifetime immunity. |
| Contagious Bovine pleuropneumonia. | Bacteria mycoplasma. | Cattle and buffalo. | do | Cattle | do | Africa, Asia, Spain, Portugal. | Enzootic or epizootic. | Vaccine, immunity variable. Restricted movement from infected areas. |
| Newcastle disease. | Virus | Poultry | Rare (Conjunctivitis). | Affected animals | do | Worldwide | do | Attenuated and killed vaccines. |
| African swine fever. | do | Swine | Not affected | African wild porcine species. | do | Africa, Spain, Portugal. | Epizootic | No vaccine available. |
| African horsesickness. | do | Equines | do | None | Culicoides | Africa, Asia Spain. | Enzootic or epizootic. | Effective polyvalent vaccine. |
| Trypanosomiasis (Nagana). | Hemoprotozoa | Bovines, swine | Not affected by bovine or swine forms. | All domestic animals and many game animals. | Tsetse fly | Africa, south of the Sahara. | Epizootic in 4 million sq. mi. of Central Africa. | Control of Tsetse fly. Chemotherapy. |
| Trypanosomiasis (Surra). | do | Horses, dogs cattle, cats, buffalo, elephants, camels. | Not affected by by this species. | Affected species | Tabanids, possibly ticks. | Asia, Sudan, Ethiopia. | Enzootic | Control of vectors, chemotherapy. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Trypanosomiasis (Mal de caderas). | do | Horses, mules, donkeys. | do | Wide variety domestic and wild animals. | Biting flies, vampire bats. | South America, Panama. | do | Chemotherapy. |
| Trypanosomiasis (Chagas' disease). | do | Dogs, cats, pigs | Common in man | Wild animals; armadillos, opossums. | Reeuduvid bugs. | Mexico, Central and South America. | Prevalent | Chemotherapy in some stages. |
| Hemorrhagic septicemia. | Bacteria (Pasteurella) | Cattle; buffalo | Not affected by this species. | Affected species | | South and Southeast Asia, Africa. | Enzootic or epizootic. | Effective vaccine. |
| Rabies | Virus | All mammals | Affected | Affected animals apparently asymptomatic in some wild mammals and bats. | | Worldwide except British Isles, Australia, New Zealand. | Prevalent in Asia, Africa, South America; prevalent in wildlife in North America; prevalent in bats in Latin America. | Several vaccines effective. |
| Piroplasmosis (babesiasis). | Hemoprotozoa | Practically all mammals with specific *Babesia* spp. | Not affected | Affected species | Ticks (Ixodidae). | Practically worldwide; *B. Bovis* eradicated from North America. | Prevalent in Africa, Asia, Latin America. | Chemotherapy somewhat effective; regular dipping against ticks. |
| Anaplasmosis | do | Cattle; sheep; swine. | do | Wild animals | Ticks; biting flies. | Worldwide | Prevalent | Control ticks; immunizing agent shows promise. |
| East coast fever (Theileriasis). | do | Cattle | do | African buffalo | Ticks | East and central Africa. | Enzootic or epizootic. | Control ticks. |
| Equine encephalitides. | 5 distinct viruses. | Horses; mules; donkeys. | Man affected by all types. | Birds and swine; rodents(?). | Arthropods | North and South America, Russia, Middle East; Jap. B Japan and eastern Asia, Indonesia. | Sporadic or epizootic during height of insect activity. | Vaccine effective in equines. |

TABLE 4–13.—*Some of the world's major animal diseases*—Continued

| Disease | Cause | Animals affected | Susceptibility of man | Principal reservoirs | Vectors | Distribution | Prevalence | Control measures |
|---|---|---|---|---|---|---|---|---|
| Rift Valley fever | Virus | Sheep and cattle | Man affected | Affected animals, possibly old world monkeys. | Mostly mosquitoes. | East and South Africa. | Sporadic outbreaks. | Vaccine available. |
| Anthrax | Bacteria | Principally ruminant, but all mammals. | Man affected usually by malignant pustular form. | Affected animals and spores. | Occasionally biting flies. | Worldwide | Sporadic epizootics. | Effective vaccine available. |
| Brucellosis | Bacteria *B. abortus B. melitensis B. suis.* | Cattle, sheep, goats, swine. | Man infected by 3 forms. | Infected animals | | do | Variable from less than 1 percent in developed countries to as much as 40 percent in others. | Calfhood vaccination; slaughter of reactors. |
| Streptothricosis | Fungus | Cattle | Man not affected | Cattle | Possibly ticks. | Chiefly west and central Africa. | Widespread in areas mentioned. | No effective control or treatment. |
| Echinococcosis (hydatidosis). | Helminthic parasite. | Adult tapeworm in dogs. | Cysticercus stage in man, sheep, cattle, and swine in hydatid cysts. | Hydatid stage in man. | | Latin America, Africa, Asia; rare elsewhere. | Common in parts of Latin America, Africa, and Asia. | Antihelminthic treatment of dogs; preventing dogs access to offal. |
| Salmonellosis | Bacteria | All mammals and poultry. | Man highly susceptible to many species. | All animals and fresh animal products, including eggs. | | Worldwide | Sporadic epidemics in man; common in animals. | Antibiotic and chemotherapeutic treatment; sanitation. |

having colonies located in the tropics must be continued and expanded. Progress in controlling animal diseases in the tropics will be inhibited as long as the present critical deficiency in knowledge of tropical animal biology and diseases exists. Research centers must be established in the tropics to study and develop techniques for effective control of indigenous animal diseases.

### *4.7.3 Magnitude of Losses and Approaches for Control of Livestock Diseases*

A preliminary estimate of the losses caused by animal diseases in the world was made by the FAO in 1962. Losses from animal diseases in countries in which veterinary activities had been in progress for many years ranged between 15 percent and 20 percent of total annual production. In countries in which veterinary activities are less intensive and more recently established, losses ranged commonly between 30 percent and 40 percent. There was no estimate of the loss in countries without animal health programs, which include many developing countries, but it was assumed that they were much greater. Based upon these estimates, which admittedly are conservative, a 50 percent reduction in losses from animal diseases, a realistic goal, would increase the supplies of animal protein in areas of greatest need by 25 percent.[7]

No doubt great progress could be made toward the control of the world's major epizootic diseases if the efforts of all countries were carefully coordinated on a worldwide control program. Reasonably effective tools are available to control many of the major epizootic livestock diseases. Control measures for others undoubtedly will be developed.

The first step should be to develop an acceptable worldwide control plan. This plan should be administered by a United Nations organization or an international agency and be sponsored by an international veterinary medical association such as the International Veterinary Congress. The objectives would be to outline the steps required to bring the major epizootic livestock diseases under practical control, coordinate the activities of many cooperating agencies to maximize their effectiveness, and demonstrate to any non-participating nation how they could assist in the international disease control effort.

### *4.7.4 Priorities for Latin America*

Foot and Mouth Disease (FMD), a highly contagious viral infection of cloven-footed animals, is estimated to reduce cattle production in South America by 25 percent annually. The disease restricts exports of animal products because international marketing sanctions are imposed against animal food products from affected countries. There is little doubt that FMD in Latin America could be brought under

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[7] Pritchard, W. R., Increasing protein foods through improving animal health. Nat. Acad. Sci. Proc. 56(2) : 360–369. Aug. 1966.

practical control, provided the countries involved truly desire to work together to control it and adequate resources are made available for the job.

It is essential that FMD control in South America be based upon a well-conceived and coordinated continent-wide plan of action which has the support of agricultural and political leaders of all countries. Sporadic and piecemeal efforts by individual countries have been and will continue to be wasteful and have little hope of success. Epidemiological studies should be conducted during the initial stages of the program. The first stage of control must involve a massive vaccination program. Only after the incidence of FMD is drastically reduced will eradication be economically or medically feasible. Eradication programs cannot be instituted without intensive educational programs and marked reduction in the incidence of the disease brought about by vaccination and other control measures. The Pan American Foot and Mouth Disease Reserch Center in Rio de Janeiro should be adequately supported and research on improved means to control FMD expanded.

*Rabies* reportedly kills more than one million cattle in Latin America each year. It is the most serious disease of livestock in many areas. Research is critically needed on the role of bats as reservoirs and vectors of rabies, on bat control, and on improved rabies vaccines. Massive livestock immunization programs will be required until progress is made in reducing reservoirs of infection.

*Reproductive diseases* reduce the reproductive efficiency of livestock in Latin America. The incidence of brucellosis, vibriosis, trichomoniasis, and others is high. For example, prevalence rates of 40 percent have been recorded for brucellosis. A high incidence of infection also occurs in people having contact with animals. Control and eradication programs should be instituted by governmental disease control agencies.

*External and internal parasites* directly cause extensive losses in livestock, and some also serve as vectors of diseases. In addition to most of the parasites of livestock present in temperate climates, many additional tropical infestations occur which limit livestock production. The blood protozoan parasites and the tick *Dermatobia hominis* are especially significant. More effective means of controlling parasites and tropical diseases are vitally needed.

### *4.7.5 Priorities for Africa*

*Rinderpest*, an acute contagious, highly fatal, virual disease of cattle, has swept through Africa on numerous occasions, sometimes nearly decimating the animal population. An inexpensive and highly effective vaccine is available. In 1961, Joint Rinderpest Project 15 was launched by the Inter-African Bureau of Animal Health under the auspices of the Committee for Technical Cooperation South of the Sahara

(C.C.T.A.) now under the Organization for African Unity, the European Economic Community, and the U.S. Agency for International Development.

Phase I of the campaign began in 1961 in West Africa, covering areas from Senegal to Chad. In three successive phases, it will cover all of the countries of West Africa south of the Sahara and north of the Congo. To date, the campaign has been very successful with nearly 85 percent of the cattle vaccinated in areas covered, but it must be continued and extended to the Sudan, Ethiopia, and Somalia before permanent control can be expected. Project 15 is a model for future disease control collaboration in Africa and demonstrates how major problems can be solved on an international basis.

*Contagious Bovine Pleuropneumonia* (CBPP) is probably as serious and widespread in Africa as rinderpest once was, but it is more insidious and far less amenable to control. Project 16, initiated in East Africa by the C.C.T.A., with AID and United Kingdom support, is intended to develop a more effective immunizing agent, improve diagnostic techniques, and define the epizootiology of the disease. This long-range study should receive continuing support and control measures instituted and vigorously pursued at the appropriate time.

*Trypanosomiasis* (*Nagana*) is endemic in a 4.5 million square mile area of Central Africa in which the tsetse fly occurs. Eradication of the tsetse fly probably would enable Africa to stock an additional 125 million cattle. Elimination of the tsetse fly must be accompanied by developments in other aspects of tropical science, or primitive methods of cultivation and overgrazing could destroy the land within a few decades. Research on tsetse fly control and on trypanosomiasis must be expanded.

*Other tropical diseases*, such as East Coast fever and other hemoprotozoal and tropical diseases, many of which are transmitted by arthropod vectors, severely limit livestock production in tropical Africa. There is a critical need to expand research on problems of tropical animal diseases and to develop the science and technology necessary for their control. An international tropical animal diseases research center (manned by the world's most competent veterinary scientists) should be established at an early date to develop this needed body of knowledge.

### *4.7.6 Priorities for Asia*

*Hemorrhagic Septicemia* of cattle and water buffalo is the most serious livestock disease in Asia. Some years it destroys a million draft animals. An effective vaccine is available, but mechanisms to use it effectively must be established.

*Hog cholera* is enzootic in many parts of Asia and causes serious losses. The consequences are serious because pork is regarded as par-

ticularly desirable by a large part of the population of Southeast Asia and the Far East. Native Southeast Asian and Chinese swine are adapted to the environment and are extremely prolific. Because little land is available to divert to pasture and because cereal grains are not available for animal feeding, these native swine, notoriously capable of existing as scavengers, can provide a substantial part of the human protein requirements. To take full advantage of their productivity, they must be protected from hog cholera. Although an effective vaccine is available, problems resulting from inadequate means to administer it and poor quality vaccines commonly occur. More effective veterinary services must be developed.

*Foot and Mouth Disease* (FMD) is a serious and complicated disease problem from the Mediterranean to China. In addition to the conventional A, O, and C types occuring in Europe, Asia is also afflicted with Asian Type 1 and SAT 1. The urgency for controlling this disease lies primarily in the Middle East because the disease has been more severe in this area than in Southeast Asia or India. The new FMD virus types also threaten Europe through Turkey and Greece. It is in this area that a major control effort should be exerted immediately, and as resources become available, control can be pushed eastward toward India. The countries of the Middle East require immediate assistance in mass preparation and use of vaccines.

*Rinderpest* has again appeared in peninsular India, which had a low incidence of the disease for several years. Outbreaks also have occurred in Laos, Vietnam, and Saudi Arabia. The latter threatens the nomadic herds and flocks of the Middle East and could extend eastward to Pakistan. Assistance is needed in the production and distribution of vaccines. Some areas also need help in using these products.

*Sheep pox* occurs commonly in the arid pastoral areas of Asia. Death rates vary from 5 to 50 percent and are generally less among haired sheep. Many areas need vaccination programs well coordinated with nomadic movements.

### *4.8.0 Animal Production Problems*

Livestock in nations needing the food produce at a much lower level than that achieved in developed countries. The high level of animal production in developed countries has resulted from the exploitation of science and technology to increase the productivity and efficiency of the livestock industries. In developing countries, on the other hand, modern principles of animal husbandry have not been fully utilized, and in some, animal agriculture is practiced much as it has been for centuries.

A vast and increasing fund of knowledge exists on nutrition, genetics, physiology, pathology, and farm management that is applicable to improved livestock production. Any nation that desires to

improve its animal protein production can do so if it is willing to apply present knowledge and to engage in research where adequate knowledge is not available. Livestock production can be increased without wasteful competition between man and animals for the same food supplies.

The production of some classes of livestock can be improved with less effort than others. Poultry are rather easily improved because poultry science and technology are readily transferable from temperate to tropical countries, provided protection from adverse environmental factors is furnished by proper housing. It is much easier to establish a highly productive beef cattle operation in the tropics than an equally productive dairy cattle unit because adverse environmental, nutritional, and disease factors affect milk production more than beef production. Milk marketing, processing, and distribution problems also can be highly complex. It is beyond the scope of this report to list in detail the conditions under which different kinds of livestock production would be most desirable for a particular situation. It is our objective mainly to explore the principles involved and to pin-point some of the problems relating to the development of an efficient livestock industry.

### *4.8.1 Animal Nutrition*

Inadequate nutrition is one of the most important causes of low productivity of livestock in the developing countries. Animals, like man, have nutritional requirements which must be fulfilled. The needs for proteins, fats, and vitamins for livestock, as well as man, vary with age, sex, rate of growth, work performance, and productivity. For livestock, the needs also are determined by milk and eggs produced, disease, climate, and other stresses. Animals are highly adaptive and survive in nearly any environment, but at the survival level of nutrition, productivity is low. In primitive systems of husbandry, changes in season and weather cause changes in feed supplies which in turn cause nutritional levels to fluctuate from adequate to inadequate. Malnutrition, because of deficiencies of minerals, proteins, or total calories, also is common. Native vegetation without improvement or proper management and without some supplementation of required nutrients can not sustain a productive livestock industry. The provision of adequate quantities of essential nutrients during all seasons of the year is essential to efficient livestock production.

*4.8.1.1 Feed Preservation and Storage.* Few areas of the world are endowed with the climate, soil, and rainfall to support year-round plant production. Consequently, improved systems of harvesting, preserving, and storing of plant materials are needed to provide food for animals during seasons of limited plant growth. This is basic to improvement in livestock production. Livestock producers in developed

countries use hay, silage, crop residues, by-products, cereal grains, and root crops to sustain animals when fresh vegetation is unavailable. Feed preservation systems are almost nonexistent in developing countries and large quantities of animal feeds are either used inefficiently or are wasted because they cannot be stored for future use.

*4.8.1.2 Pasture and Range Management and Forage Production.* Substantial portions of the agricultural land in Asia, Africa, and Latin America are grazing lands (Table 4–7). They vary greatly in topography, altitude, soil type, natural fertility, type of vegetation, available water or rainfall, and climate. Many are desert, semi-desert, or subject to seasonal drought or flooding. Some are covered with trees or brush of little or no value, but which reduce or prevent efficient animal use, while some are covered with excellent natural vegetation. All types of grazing land can be improved and managed for increased production. A highly developed science and technology of range management has brought manyfold increases in the productivity of grazing lands in developed countries. The development of new and improved forages, better use of present forages, proper fertilization, water management, and weed and pest control increase the productivity of grazing lands and should be used more extensively in developing countries.

Large quantities of native vegetation are not used at present. Fertilization and reseeding of large land areas are now feasible with aircraft, and techniques for destroying brush and trees in areas suitable for grazing are available. There is a strong possibility that the estimates of land suitable for grazing in Latin America, Asia, and Africa may be too small due to the limitations of earlier surveys and to new technologies now used for improving land and crops. Rough areas unsuitable for cropping but previously limited by unsuitable or inadequate vegetation can be made more productive. Improvements in transportation and in processing and distributing livestock products could bring new areas into livestock production.

*4.8.1.3 Tropical Range Management and Forage Research Needed.* The range and pasture management technology of developed countries to a large extent is transferrable to temperate regions of developing countries. Although the principles apply to tropical regions, little of the technology is transferrable to these areas. Very little is known about many of the tropical grasses and legumes especially about their potential as forage crops. Research is vitally needed on these forages, their productivity, chemical and nutritional composition, and agronomic and cultural practices under various tropical conditions. The payoff in increased food production may be great if the few research programs underway in the tropics are an accurate indication of the potential for improvement. For example, research in tropical Australia has revealed that by seeding a new improved tropical legume, Towns-

ville lucerne, and applying 100 pounds of molybdenum superphosphate per acre, beef production per acre per year in one area has been increased from 20 to 270 pounds.[8] Thus, a 13-fold increase in productivity resulted from the adoption of simple tropical range management techniques developed through research.

In recent years considerable progress has been made in the development of tropical legumes which when mixed with improved tropical forage grasses increase their carrying capacity 50 to 100 percent. Production can be further increased with fertilizers. With these improved pastures properly managed, the tendency for humus to disappear in a few years is markedly reduced and the soils remain productive for long periods of time. Hence, utilization of these tropical soils for livestock production not only results in the production of a valuable food resource but also preserves the soil in striking contrast to the destruction that follows currently practiced cultivation techniques.

*4.8.1.4 Use of Supplements to Grazing.* Natural forages, though present in adequate quantity, may be deficient in one or more essential nutrients. In the wet tropics, native forages often are low in proteins, while under certain climatic conditions the protein content may be adequate, but energy low. Deficiencies in phosphorus occur widely among forages throughout the world, while deficiencies in molybdenum, zinc, copper, cobalt, iron or iodine are common. Such deficiencies must be identified and corrected if full utilization of feeds and forages is to be expected. Feeding animals bone meal, monosodium or disodium phosphate, and trace mineralized salt are supplementation techniques that are effective in correcting certain deficiency conditions.

Deficient pastures can be supplemented with preserved forages, as well as by-products such as oilseed meals, mill wastes, bagasse, urea, molasses, and crop residues. This is often done in developed countries but may not be too feasible in developed areas.

*4.8.1.5 Utilization of Wastes, By-Products, and Synthetic Materials.* Animals can use a wide variety of wastes and by-products of agricultural and industrial operations for food. Unfortunately, many potentially valuable by-products currently are wasted, exported, or used as fertilizer in developing countries because of the lack of a commercial feed industry to process and distribute them to livestock producers. This is particularly true in Asia where animal protein supplies are in very short supply.

The important food grains, such as corn and sorghums, have large plant residues which in developed countries constitute an important part of the animal food supply, particularly when preserved in the form of silage. However, when corn is harvested as grain, the cob and

[8] The Cunningham and Townsville Laboratories, C.S.I.R.O., Melbourne, Australia, pp. 34–35, 1965.

the stalk can provide the basis for an effective cattle ration, provided that adequate protein or nitrogen, vitamin, and mineral supplementation is provided. The straw of wheat, oats, or barley; the hulls of oats or cottonseed; the stalk from which broccolli has been harvested; the wastes from vegetable and fruit processing; the pulp from sugar beets; the extracted sugar cane; the spent grains from the brewery; and many other plant materials are suitable for animal feed.

The animal industry has a host of secondary products which can be returned to the animal feed industry for recycling in animal diets. Prior to the availability of soy protein for animal use, meat scraps and tankage were essential by-products for meeting animal protein needs, particularly those of swine and poultry. Bone meal was the primary source of calcium and phosphorus. Animal fats were formerly converted to lard or margarine or soap, but they now frequently serve as a source of energy in poultry or other animal rations. Although complicated by potential disease and parasite problems, animal manure and bedding may be salvaged to meet certain nutritional needs. As chemical fertilizers have become readily available, there is less dependence upon animal manure for the maintenance of soil fertility, and in many instances, the disposal of manure has become a practical problem. From a technical standpoint, it is possible to use animal feces as a nutrient for yeasts and bacteria used to synthesize protein for food for animals or man.

Many areas in Latin America, Asia, and Africa are, or could be, sugar producers. Few crops equal the energy yield per acre of sugar cane. Cattle can effectively utilize cane after extraction as well as the sugar and mollases. Cattle production is more likely to be limited by lack of energy than by restricted protein in many tropical areas. Indeed, the availability of cotton seed or coconut meal, and especially when urea is used as a substitute for proteins, make it relatively easy to establish a cattle operation in connection with a sugar plantation.

Cotton is produced in quantity in many of the protein-deficient countries. This crop yields cottonseed hulls, cottonseed meal, and cotton gin trash that can be used in cattle feeding. In some developing countries, cottonseed meal is used for fertilizer or is of such poor quality that it is not acceptable to man or animals. Serious study should be given to purchasing fertilizer for crop production so the protein-rich meal could be used for human and animal feeds.

Oil production from peanuts, sesame, safflower, soybeans, and other crops has increased rapidly, and meals from these and copra and palm nuts are available in many developing countries. In some, modern solvent extraction plants have been built and high quality oilseed meals either are being or could be produced. Some of the extraction facilities are old and inefficient.The meals are of poor quality, and in some cases, are burned rather than used as human or animal food or fertil-

izer. Waste of these potentially valuable feeds must be eliminated. In many instances, it may be best to use them for food for people, while in others, they may be best fed to animals. Some of these materials presently are wasted because local livestock producers are unaware of their value as animal feeds or they are improperly handled or stored and are wasted or become toxic.

Brewery grains can be effectively utilized by cattle, swine, or poultry. However, in too many instances, the by-products of the brewing industry are used inefficiently or wasted.

Fruits are produced commercially in many tropical and semi-tropical areas where fruit processing is carried out, there are valuable pulp residues which, in some countries, have led to the establishment of extensive cattle feeding operations adjacent to the processing facilities. This is especially true in citrus and pineapple producing areas. Coffee, coconuts, grapes, and various nuts all have residues suitable for animal use. Improved methods of processing are leading to entirely new fruit and vegetable products and many major food processing plants are being established in developing countries. Even when whole fruit is marketed; e.g., bananas and citrus, large volumes of non-marketable fruit often are available. Both of these crops can be fed to animals, particularly ruminants. As this occurs, attention should be given to the use of wastes or by-products for animal feeds.

*4.8.1.6 Use of Urea in Ruminant Nutrition.* Non-protein nitrogren compounds such as urea can be directly utilized by ruminant animals in meeting their protein requirements. Feed grade urea, in appropriate amounts, can be converted by the rumen microflora to amino acids, which are then utilized by the animal in the synthesis of meat and milk protein. In all of the major livestock areas of the world, urea is used to supplement plant proteins such as soybean and cottonseed meal, and at current prices it is replacing more expensive feed proteins. New technologies require new educational programs, and urea must be used with care. Properly used, it is recognized as one of the nutritional break-throughs of this century. In some tropical areas, beef and milk production have been significantly increased by the use of urea combined with native silages and molasses.

*4.8.1.7 Use of Non-Conventional Foods as Animal Feeds.* For centuries, man has used microorganisms to produce cheese, cabbage and other fermented vegetables, and a variety of fermented beverages, but interest in large-scale microbial production of proteins is of rather recent origin. At the present time, serious attention is being given to the commercial production of high protein foods from algae, yeast, bacteria, green leaves, grasses, and legumes. Current efforts to produce both edible fats from the catalytic oxidation of petroleum hydrocarbons, and proteins and amino acids by microorganisms adapted to a

263-888 O—67——20

petroleum medium are attracting considerable attention. Fish, long recognized for their excellent protein quality, are being harvested and processed in greatly increased volume for both human and animal use.

There are many technical problems to be solved before many of these products can compete economically with traditional plant and animal proteins as food for people. Man's food habits are not easily changed. The enrichment of rice, wheat, corn, or milk is largely a question of motivation and economies; however, man's preferences for specific foods such as white or yellow corn cannot be disregarded. Substituting wheat for rice is not acceptable to many who suffer from malnutrition or even starvation in certain parts of the world. The enrichment of grains with fish flour, chlorella, or bacterial protein certainly will meet with overwhelming resistance. Therefore, attention should be given to the use of some of the novel or unconventional sources of protein and energy as animal feeds so that man may benefit from increased protein production. All of these materials can be utilized by both monogastric and ruminant animals. In properly balanced diets fed to productive animals under optimum conditions, very little will be lost by feeding these products to animals rather than directly to people.

### *4.8.2 Water for Livestock*

The chief limiting factor in livestock production in certain areas is the lack of adequate quantities of water during dry periods. In many instances, the mortality of cattle in drought periods results largely from lack of water, rather than lack of forage. For example, on a 3 million acre ranch in tropical Australia, approximately one-third of the cattle have traditionally died during each severe drought. While there was sufficient water in the pastures, too many cattle gathered at a few watering areas, resulting in the destruction of vegetation for several miles from watering facilities. Cattle and calves died when forced to travel 5 miles out and 5 miles back each day to obtain both feed and water. After additional well-spaced watering areas were provided, this problem was nearly eliminated.

### *4.8.3 Animal Breeding for Tropical Conditions*

Livestock developed in temperate climates, where adequate feed and shelter generally are available, are highly demanding in terms of environmental requirements and do not thrive under the adverse tropical and subtropical climatic and disease conditions prevalent in most developing countries. Consequently, livestock in these countries cannot be improved solely by importing highly productive animals from the temperate zone.

The indigenous breeds of livestock in Asia, Africa, and to a lesser extent, tropical Latin America have evolved with an ability to survive under the conditions present in these areas. Having been exposed to heat, diseases, parasites, and low levels of nutrition for centuries,

only those capable of adapting to these factors have survived. Both domestic livestock and indigenous animals possess desirable genetic characteristics: productivity on the one hand, and resistance to environmental factors on the other. Animal breeders in developing countries should carefully blend temperature zone and indigenous breeds to capture the foregoing characteristics and select for high productivity, as well as resistance, in order to develop desirable strains and breeds for these areas. The success in the tropics of newly created breeds of cattle, such as the Santa Gertrudis, Brahman, Boran, Nandi, and others, attest to the soundness of this course of action.

Indigenous breeds and strains of livestock also can be improved by selection based upon production testing such as resulted in the development of the Sindi and Sahiwal breeds. This method of livestock improvement, however, is wastefully slow when compared to crossbreeding which can incorporate into indigenous livestock desirable traits already well-established in improved breeds. These principles apply to all classes of livestock.

In the long run, it might be advantageous to introduce modern breeds of poultry and swine in developing countries as "production packages," i.e., the improved breed or strain along with a complete balanced diet and husbandry practices which provide protection from adverse environmental factors, including diseases. The poultry industry throughout the world has developed on this basis in the last decade. Modern genetic lines of poultry are highly superior to indigenous breeds. It now is possible to protect them from most environmental factors at low costs so that any nation capable of providing adequate feed for poultry can develop an industry nearly equal to the most productive in the world. The same principles may apply to commercial swine production although too little is known about indigenous breeds to evaluate their potential.

### *4.8.4 Animal Reproduction*

As emphasized in previous sections, animal diseases, including diseases of the reproductive system, may prevent the establishment of pregnancy, may terminate pregnancy, or may result in early death of the newborn. All of these situations may reduce the prolificacy of domesticated or wild animals. The efficiency of the reproductive process of any species may be influenced by many factors other than disease.

In the United States it is expected that approximately 70 to 80 percent of healthy cows will become pregnant when inseminated with high quality semen or mated with a fertile bull. Under normal range conditions a herd of beef cattle should produce from 80–90 calves per 100 breeding females per year. In many areas of the world reproductive rates of 40 calves per 100 cows are common, and the number of calves raised is even less. The reasons are many, but investigation

often shows that lowered fertility is due to a lack of understanding of even the most basic principles of the reproductive process. Females may not have an opportunity to mate because of a lack of proper numbers of males, or the use of males which are only partially fertile or even sterile. When artificial insemination is used, failure may result from poor quality semen or insemination of the female at the improper stage of the reproductive cycle. The same principles are involved in swine and in sheep. There is little doubt that the use of fertile sires in accordance with improved breeding management practices, improvements in managing females of breeding age in relation to the reproductive characteristics of the species, and an understanding of the normal reproductive processes could, in many cases, double or even triple the present reproductive rate.

*4.8.5 Marketing, Processing, Distribution*

Meat, milk and eggs are highly perishable and require complex marketing, processing, and distribution systems to span the gap from farm to consumer. In most developing countries these systems are poorly developed or non-existent; consequently, animal products are not well-utilized and a great deal of wastage occurs. Efficient marketing, processing and distribution systems are needed. The nature of the systems required depends pretty much upon the state of development of the economies of these nations.

*4.8.6 Transportation, Manufactured Inputs, and Livestock Services*

An efficient and productive livestock industry, like other segments of agriculture, requires adequate transportation from farm to market, an adequate supply of manufactured inputs (insecticides, fertilizers, farm machinery, feed supplements), and livestock services (marketing information, insemination services and veterinary services).

*4.8.7 Incentives, Government Policy, and Land Tenure*

Livestock raising must yield a profit to the producer before a livestock industry will evolve. Government policy in relation to prices paid and prices received is a major determinant as to whether or not a livestock industry can be profitably established. Land tenure systems influence the quality and scope of livestock enterprises. Laws do not always favor rational utilization of a nation's total agricultural resources, including forages and feeds. For example, many livestock men in certain Latin American countries do not adopt improved management practices because in doing so they run the risk of having their farms confiscated by land reform programs. This is a senseless waste because production could be greatly increased on their holdings.

*4.8.8 Custom, Tradition, Social, Political, and Cultural Factors*

Technical innovations in the livestock industry will not be readily

adopted when contrary to custom, tradition, and political, social, and religious beliefs. Some cultural patterns can be changed, but others are so firmly entrenched that the probability of change is remote. It is essential that the nature of traditional and cultural practices be understood in order to develop rational systems to overcome them.

A good example of this point is the practice of overstocking grazing lands throughout much of Asia and Africa, which results in significant lowering of production and a great deal of damage to grazing lands. Tradition, prestige, dowry for the bride, and a measure of a man's worth are cited as the reason more livestock are kept than the land will support. Tradition undoubtedly grew out of experience over the centuries that during extended periods of drought or epizootic diseases, herds with large numbers of animals were more likely to survive and thus the large herdsman was able to rebuild his herd while those with few animals might lose them all. Present technology no longer makes this practice necessary. However, the advantage of carrying fewer animals must be demonstrated before the practice of maintaining large herds will be changed.

It once was believed that nomadic pastoralists would not accept a sedentary system of livestock husbandry. It has become apparent during the last few years, however, that many such peoples will willingly choose a sedentary life if adequate supplies of water, forage, and markets become available.

### *4.9.0 Research and Education*

There is a critical shortage of manpower trained and experienced in the sciences and technologies underlying animal production in the developing countries. Very little knowledge of animal production exists which is relevant to conditions found within these countries, most of which are located in the tropics or subtropics. There are too few skilled extensionists, and few effective mechanisms of extending new knowledge to animal producers. Regulatory agencies often are inadequately staffed and incapable of meeting national needs. Most important, the scientific resources of most developing countries are not organized in effective institutional structures; hence, most of these countries lack support from a highly integrated institutionalized science that characteristizes agriculture in most developed countries. It is essential that such national institutional structures be developed. Continued growth of any agricultural industry requires a sustained flow of new inputs which cannot be achieved by a series of infusions or transfers of segments of science from abroad. The development of effective indigenous institutions would be fostered by close association with counterpart American institutions that would help guide their development and supply some of the skilled individuals required. Strengthening research and educational institutions in the developed

countries would increase their capabilities for contributing to the development of science and technology in developing countries.

*4.9.1 Education*

Manpower shortages exist in most developing countries at all levels of competence. There are approximately 164,000 veterinarians in the world,[9] excluding Mainland China, with only about 17,000 located in these nations of greatest need. Even fewer individuals specifically trained in nutrition, genetics, physiology, and livestock management, the scientific components of animal husbandry, are available in these countries. In most developing countries, veterinarians not only supply the skills for animal disease control, but also those for animal husbandry. Education programs should be strengthened to increase the effectiveness of professionals both in veterinary medicine and animal husbandry.

There is a particular need throughout developing countries to strengthen professional education in animal husbandry. There is no doubt that the veterinarian must continue to receive a great deal of education in animal husbandry to meet his professional obligation of promoting animal health and productivity as well as preventing and curing disease. On the other hand, there is a critical need for training individuals in animal husbandry with a thorough understanding of the complex interrelationships of animals, plants, soils and environment as well as a broad knowledge of agriculture including economics and management. It would appear appropriate for colleges of agriculture and colleges of veterinary medicine in most developing countries to cooperate in developing curricula to fulfill this need and to provide the education required. Because veterinary medical schools over most of the world have assumed the obligation for animal husbandry, they have a special obligation to society to see that this branch of animal science is developed to meet world needs for livestock development.

A great number of schools attempting to provide training at the professional level in veterinary medicine and animal husbandry have been established in developing countries. It would be far better to assign available resources to fewer institutions to develop a few high quality centers of education. Regional compacts to provide education in the animal sciences should be explored by countries that cannot support teaching programs adequately in all these subjects. Professional education programs in most developing countries should provide students with practical experience with animals because most students who attend these schools have not had significant animal experience prior to entry.

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[9] Steele, J. H., World need for veterinary training. Amer. Rev. World Health 14 : 18–24. 1966.

Technically oriented education in the animal sciences should be expanded to provide much of the manpower needed to implement extension and regulatory programs, as well as to supply animal science know-how to commercial enterprises. One or two year programs of study beyond secondary school, combining formal programs of study in the animal sciences with practical experience in various facets of animal production, fit the need for training of highly valuable sub-professionals. Individuals trained in these programs serve a variety of needs such as assistants to veterinarians, livestock development officers, extension specialists, inspectors, inseminators, meat packing house or dairy plant operators, and animal nutritionists with commercial firms. Approximately 5 to 10 times as many sub-professionals are needed as professionals.

Vocational and technical training in animal husbandry at the secondary school level is one of the most effective ways of developing widespread understanding of scientific livestock production by the individuals that manage and service farm livestock enterprises. These programs can be combined with traditional secondary education as in high school vocational agricultural programs in the United States or can be provided by schools devoted entirely to vocational agricultural education, as is done in many countries. The program should combine formal and practical offerings in the spectrum of animal science disciplines most needed in a particular country.

### *4.9.2 Needs in Research*

Knowledge of biology, ecology and diseases of animals in the tropics and husbandry practices under tropical conditions is meager. A great deal of research on animal diseases and parasites, feeds and forages, animal nutrition, physiology of animals, breeds and breeding, including the development of heat and disease resistant strains of livestock and husbandry practices will be required to bring tropical animal production up to acceptable standards. It would appear to be unduly wasteful to create modern research laboratories with equipment, including the latest in computers, animal environmental chambers, isolation units costing many millions of dollars, as well as a large multidisciplinary research staff, modern libraries, and supporting facilities at many locations. A more reasonable and economical initial approach would be to establish two or three international animal science centers to serve both the humid and dry tropics. These centers should be closely coordinated with tropical agricultural research programs. Close association with a tropical forage research program would be desirable. They would conduct research on all aspects of tropical animal science, including diseases, and focus particularly on important problems limiting livestock production in the tropics. As described elsewhere in this report, another center devoted entirely to research on the epizootic

tropical diseases of livestock should be established, preferably in tropical Africa.

National programs of research in animal husbandry and veterinary medicine should be established to respond to local research needs and to adapt the principles of animal science developed at international research centers and elsewhere to local problems. These programs should be closely related to educational institutions, extension programs and national regulatory agencies.

### *4.9.3 Extension Programs in Animal Science*

Effective programs of extending innovations to producers in all aspects of animal science are desperately needed in developing countries. Extension programs of organizations supplying supervised or directed credit such as the World Bank and commerical concerns such as feed manufacturers and distributors, milk processors, pharmaceutical manufacturers, and packing plants are important and effective and should be encouraged and assisted in every possible way.

### *4.9.4 Role of the Private Sector in Livestock Development*

Governments should encourage more participation of the private sector in the promotion of livestock improvement programs. Livestock producer's associations, veterinary medical associations, breed improvement associations, professional organizations and others should be stimulated to expand and accelerate extension programs. Active livestock organizations exist in Mexico, Argentina, Colombia, Peru, and are present in most developing countries. In Ecuador, the Holstein-Friesian Association has done a remarkable job of introducing the concept of cattle improvement to dairymen and is now expanding its efforts to other breeds. It also is sponsoring improved health, feeding, and management methods for its membership. The success of this organization results from enlightened leadership which works closely with government officials to improve milk quality and solve distribution problems. Also more favorable milk prices have been negatiated by this association. Such organizations can do much to resolve the problems of the livestock industries.

### *4.9.5 Regulatory Programs*

Regulatory services to control contagious diseases and enforce quality standards are essential to a profitable and productive livestock industry. Their main functions are to operate diagnostic laboratories, eradicate disease, operate quarantine programs upon which disease prevention schemes are based, and enforce quality standards. In many developing countries, these agencies must also produce vaccines when they are not otherwise available. They also enforce quality standards for drugs and vaccines used for livestock and attest to the quality and wholesomeness of animal products moving to consumers. These programs should be staffed by highly competent individuals dedicated to

the advancement of the animal industries. Regulatory programs should be closely coordinated with educational research and extension programs.

*4.9.6 United States Education in the Animal Sciences for Students from Developing Countries*

Generally, it is advisable for students from developing countries to obtain education through the B.S. or D.V.M. degrees, or their equivalents in indigenous or accessible regional institutions. Graduate study in the United States should be made as relevant as possible to local problems confronting students when they return. Every effort should be made to provide the student with the principles of the discipline he is studying, some of the techniques used in that discipline, and experience in the solution of problems similar to those he will encounter in his native environment. Ideally, the graduate student from the developing countries studying in the United States should return to his home country to conduct his thesis research under the direction of a skilled professor from the United States institution in which he studied. The international service faculty concept being developed in the United States today will make this possible.

*4.9.7 Education of United States Animal Scientists for International Service*

Educational programs should be developed to better prepare United States students for careers in international livestock development. They should develop skills in an animal science discipline at the B.S., M.S., D.V.M., Ph. D., or post-doctoral level. Their education should contain courses on international development and studies in the area in which they wish to work, e.g., Latin America, Africa, or Asia. Finally, they should spend one to three years with senior people working in the discipline in a developing country. Again, the international service faculty concept will make programs of this nature possible.

*4.9.8 University Commitment to International Livestock Development*

Livestock development programs are inherently of long duration. Few programs can hope to yield significant results in less than five to ten years. Long-term commitment of the university as represented by its school of veterinary medicine or department of animal husbandry is necessary. Individuals working in the program will be more effective if they can devote their lifetimes to the acquisition of the skills and experience relevant to international livestock development programs. The international service faculty concept will make it possible for the university and members of its faculty to make long-term commitments to international livestock development programs.

### *4.10.0 Conclusion and Recommendations*

Prospects for expanding world animal protein production are good. Latin America, Africa, and the Near East can support major expansion of their livestock industries without wastefully competing for food that might be consumed directly by people. Southeast Asia, too, could significantly expand animal production. The problem in India and Pakistan is more complex. Pakistan can expand its cattle industry significantly by adopting modern animal science technology. It is doubtful, however, that per capita supplies of animal protein can be increased significantly in view of rapid population increase. India has a special problem because of Hindu religious beliefs relating to cattle. Reduction of the number of non-productive cattle would be helpful. The expansion of efficient commercial dairies, poultry production units, as well as swine farms mainly utilizing wastes and by-products not now utilized, appears to be the best way to increase necessary animal proteins. There is little hope, however, that the dietary need of Indians for high quality proteins will be met solely by animal products. Alternative plant or marine sources must be exploited.

Increases in world production of animal protein could, under favorable circumstances, equal or slightly exceed population increases at least until 1990. It might be possible to accelerate estimated increases in animal production by maximizing efforts to control animal diseases and utilizing science and technology in production processes; however, we do not consider this to be a likely prospect.

To achieve high levels of production in the livestock industries of developing countries, an indigenous base of science and technology must be established that will furnish the sustained flow of innovations required to make continued development possible. Institutions that will provide appropriate education at all needed levels, create and extend new knowledge, and regulate livestock activities must be established and made to function effectively. These will take a great deal of time and effort; however, there is no doubt about the nature of the job that must be done.

*The following recommendations are made:*

1. The unique contribution that animals make to the world food supply should be taken into account in the development of world food plans and action programs to reduce the world food deficit.

2. Major efforts should be made immediately to control the world's major epizootic diseases of livestock. A coordinated worldwide plan of action is needed, with the necessary research emphasized and supported to ensure the success of control programs. An International Center for Tropical Veterinary Research should be developed in the tropics to devise effective control measures for the major tropical animal diseases.

3. Programs to increase animal production, based upon long-range plans conceived after careful evaluation of each nation's total agricultural resources, and designed to exploit unique attributes of animals to contribute to that nation's food supply, should be instituted. Programs to develop optimum genetic stocks of livestock for local conditions; measures to increase forage production and improve range and water management; steps to improve livestock nutrition and utilize local feeds and feedstuffs, particularly wastes and by-products; means to improve animal husbandry and the industries and services that support livestock production, as well as disease control programs, should be included.

4. Special efforts should be made to develop the educational, research, extension, and regulatory institutions which will provide the continuing mechanisms whereby a nation will utilize science and technology to increase animal production. Manpower needs in animal husbandry and veterinary medicine are particularly acute. Marked expansion of training programs at the professional, subprofessional, and vocational levels are needed.

5. International Centers for Animal Science should be established in the tropics at a very early date to develop a body of knowledge of tropical animal science and husbandry practices for both the humid and dry tropics. These centers would conduct research on animal nutrition and feeding, animal breeding, environmental physiology, animal husbandry, and animal diseases, except for the epizootic animal diseases. They should be located in close proximity to and cooperate with tropical agricultural research centers.

# CHAPTER 5

# INCREASING HIGH QUALITY PROTEIN

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## Contents

| | | Page |
|---|---|---|
| 5.1.0 | Summary | 299 |
| 5.1.1 | The General Protein Problem and the Statistical Paradox | 299 |
| 5.1.2 | The Complexity of the Problem | 299 |
| 5.1.3 | Protein Needs of Grain and Non-Grain Regions | 300 |
| 5.1.4 | Time, Scale, and Priorities | 300 |
| 5.1.5 | What the U.S. Government Should Do | 300 |
| 5.2.0 | Introduction | 301 |
| 5.2.1 | General | 301 |
| 5.2.2 | The Complexity of the Problem | 302 |
| 5.2.3 | Types of Crises | 303 |
| 5.2.4 | The Time Factor | 304 |
| 5.2.5 | Scale of Effort | 304 |
| 5.2.6 | Implications of the Time-Scale Pressure | 305 |
| 5.2.7 | Varying Circumstances | 305 |
| 5.2.8 | Government Mechanisms | 307 |
| 5.3.0 | A Condensed and Different Look at the Calorie and Protein in the Diets of the World | 307 |
| 5.3.1 | Diets With Animal Protein | 308 |
| 5.3.2 | Cereal Diets | 309 |
| 5.3.3 | Fat, Sugar, or Tuber Diets | 309 |
| 5.4.0 | Is There a Protein Deficiency? | 310 |
| 5.4.1 | The Effect of Protein Malnutrition in Young Children and Pregnant and Nursing Women | 312 |
| 5.4.1.1 | The Pre-School Child | 312 |
| 5.4.1.2 | Pregnant and Nursing Mothers | 312 |
| 5.4.2 | Malnutrition, Food Habits and Taboos: Implications of Programming | 313 |



PREVIOUS PAGE BLANK

Page

5.5.0 Nutritive Quality of Proteins ..... 314
5.6.0 Fortification of Cereal Grains ..... 316
5.6.1 Rationale of Cereal Fortification ..... 316
5.6.2 Is the Fortification of Cereal Grains Nutritionally Sound? ..... 316
5.6.3 With What Should Diets High in Non-Cereal Carbohydrates as the Main Calorie Source be Fortified? ..... 319
5.6.4 Specific Techniques of Cereal Fortification ..... 319
5.6.5 Planning a Cereal Fortification Program ..... 322
5.6.6 Fortification of Cereal Grains during Central Processing ..... 322
5.6.7 Possible Guidelines for Establishing Action Programs to Meet Protein Deficit ..... 325
5.6.8 Possible Method for Applying a Fortification Action Program ..... 328
5.7.0 The Improvement of Protein Quality of Cereals by Genetic Means ..... 329
5.8.0 Increasing Animal Protein Supplies ..... 330
5.8.1 Disadvantages of Animal Production ..... 331
5.8.2 Evaluation of Animal Production ..... 331
5.8.3 Efficiency of Conversion of Feed ..... 333
5.9.0 Oilseed Proteins ..... 335
5.9.1 Soybeans ..... 340
5.9.2 Cottonseeds ..... 342
5.9.3 Peanuts ..... 344
5.10.0 The Fishery Potential of the Ocean ..... 345
5.11.0 Protein from Inland Fisheries ..... 347
5.11.1 Usage of the Catch ..... 348
5.11.2 Amount and Origin of the Catch ..... 348
5.11.3 Types of Fish Cultures ..... 350
5.11.3.1 Fresh-Water Ponds ..... 350
5.11.3.2 Brackish Water Ponds ..... 351
5.11.3.3 Flowing Water Cultures ..... 352
5.11.3.4 Fish Culture in Rice Fields ..... 352
5.11.4 Projected Future Demand ..... 353
5.11.4.1 Sources of the Projected Catch ..... 353
5.11.4.2 Requirements for New Ponds ..... 354
5.11.4.3 Requirements for Fertilizer and Feed ..... 354
5.11.5 Time Goals for Expansion of Pond Areas ..... 355

Page
5.12.0 Fish Protein Concentrate (FPC) 355
5.12.1 The Potential FPC Resource 356
5.12.1.1 Introduction and Some Basic Assumptions 356
5.12.1.2 Definition of the "Mega Ration" 356
5.12.2 Preservation of Fish 358
5.12.3 FPC Manufacturing Methods 358
5.12.3.1 Chemical Methods 358
5.12.3.2 Biological Methods 359
5.12.3.3 Physical Methods 360
5.12.4 Costs of FPC Production 360
5.13.0 Single Cell Protein 361
5.13.1 Hydrocarbons and Carbohydrates as Substrates 361
5.13.1.1 Yields from Hydrocarbons and Carbohydrates 362
5.13.1.2 Cost Comparisons for Power, Oxygen and Substrates 362
5.13.2 Methane as a Substrate 364
5.13.3 Cellulose as Substrate 365
5.13.4 Fungi 365
5.13.5 Nutritive Value of Cells 366
5.13.6 Price Estimates 367
5.13.7 Potential Requirements for Development 367
5.14.0 Leaf Protein 368
5.15.0 Algae 370

# 5.0 INCREASING HIGH QUALITY PROTEIN

## *5.1.0 Summary*

la destinée des nations dépend de la manière dont elles se nourrissent . . .
—Brillat-Savarin.

### *5.1.1 The General Protein Problem and the Statistical Paradox*

Although statistical surveys, based on total food available per capita, suggest that there is no protein shortage, there is conclusive clinical evidence that large numbers of people suffer from protein malnutrition. There is evidence to indicate that most of the malnourished are not getting the amounts suggested by average figures. The reasons for this apparent discrepancy are due to the fact that, clinically, the "average" level and type of protein per capita determined from surveys is inadequate to meet the needs of three sensitive groups of any population: preschool children, pregnant women, and nursing mothers. Protein needs of children of weaning age are high and unless these needs are satisfied, physical development and growth are impaired, and mental retardation may be a damaging consequence. In general, surveys fail to consider segments of a population, variable in time, place, and number, which are under nutritional stress due to sickness, special poverty, or crop failure. In addition, another, and very important factor, is the wide disparity between data based on surveys of actual production and the quantity actually available to the population which may be reduced by various types of losses, by insects and rodents, poor transportation and other factors.

Each region of the world has available to it certain foodstuffs; the people who live in each region have specific food habits and taboos. Choice of a course of action for a target population is dependent on assessment of local production and distribution and pinpointing the requirements and the specific acceptability patterns of the population.

### *5.1.2 The Complexity of the Problem*

Supplying adequate nutrition to a developing area is not an isolated protein problem. It involves the control of the rate of growth of population, the creation of a food supply adequate in calories and essential nutrients including protein and, finally, technological, economic, social, and other factors involved in getting the needed foods and nutrients to the consumer. Hunger and malnutrition are symptoms of the lack of economic development. Therefore, atten-



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tion must be focused on total economic development polarized around agriculture and full use must be made of the resources of the private sector and government in the target areas and in developed nations.

### *5.1.3 Protein Needs of Grain and Non-Grain Regions*

Proper protein nutrition involves the provision of adequate calories and a proper amount of protein of suitable *quality*. The mass of the population in developing countries gets most of its protein and most of its calories from grain. Thus, for these people, the central protein problem is the *provision of more protein* by increase of agricultural production, by reduction of the present enormous waste, by better distribution, by *improvement of the nutritional quality* of the grain protein by genetic means, and by fortification with the essential amino acid, lysine (which is low in all major grains) or with protein concentrates from oil seeds and fish.

A minority of the people in developing countries obtain most of their calories from cassava and other starchy roots which are low in protein. In these non-grain regions, there is no alternative to providing adequate additional foodstuffs that are rich in good protein.

### *5.1.4 Time, Scale, and Priorities*

It is imperative for programs designed to alleviate protein deficiency to produce big results in a relatively short time. Since even the most vigorous efforts probably will fall short of the goal, work should be initiated promptly on any program which shows promise of possible significance. Nutritional programs, however, differ greatly in the speed with which they can be initiated and developed as well as in their ultimate impacts. Thus, what can be accomplished in a few years, apart from whatever agricultural, economic and social improvements may be feasible in a short time, is extremely limited. The present donations of grain and protein concentrate mixtures (weaning foods), of course, are having an immediate and important effect on protein nutrition. The special protein program which shows greatest potential for early results is central fortification of grain with lysine and/or oilseed protein concentrates. Immediate efforts to stimulate production and distribution by industry of protein food products to meet local taste will have the greatest long-term impact.

Eventually, all agricultural and nonagricultural methods of providing adequate protein and calories will be needed in order to fulfill the enormous needs of the increasing populations of the world. These, in general order of priority, time for implementation, and probable success, are described and evaluated in the report.

### *5.1.5 What the U.S. Government Should Do*

An assessment of the over-all protein needs of the developing areas of the world and a comparison of these with the resources of the United States quickly demonstrate that our abilities to feed these areas of the

world are limited and diminishing. Although some may say that the problems are those of the areas themselves, our role as a leader of the free world and the desire to assure survival of our own way of life, dictate that we must not only help but lead. Thus, whatever we do must stimulate greatly improved and expanded activity in the target countries themselves. Because the solution of the protein supply problem cannot be separated from the overall food supply and distribution problems, the following principles should guide actions by the United States government:

1. Help initiate and support a strong voluntary population control program in each country in which assistance is to be given.
2. Increase to the greatest possible extent available food supply by improving production, preservation, and distribution of food and by taking action to reduce losses due to spoilage, insect pests, and rodents.
3. Institute fortification of Food for Peace cereal grains with amino acids and/or protein concentrates.
4. Stimulate protein fortification of grains grown in developing countries.
5. Meet the emergency needs of post-weaning children by increasing the donations of protein concentrate mixtures.
6. Institute and support large-scale programs to improve the protein nutritional value of grains by plant breeding and by development of low-cost sources of threonine and tryptophan.
7. Stimulate and support industrial development and production of low-cost protein foods which utilize indigenous materials.
8. Stimulate introduction of cereal and high protein crops in cassava areas and other areas where the major source of calories is low in protein.
9. Stimulate local production and utilization of fish and their products.
10. Encourage and support research and development on processes leading to the production of protein from new sources such as single cell and leaf protein.
11. Encourage animal production in those areas where there are large quantities of inedible (by man himself) feed materials and lands which are unsuited for crops.

## *5.2.0 Introduction*

A man seldom thinks with more earnestness than he does of his dinner.

—Samuel Johnson.

### *5.2.1 General*

Pasteur, Koch and others in the latter half of the 19th century made research discoveries which led to the control of communicable diseases. The conquest of these diseases has enabled man to defer death and to reduce infant mortality and has transformed the traditional pattern of

high birth and death rates into one of high birth and low death rates. This change has created disturbing and disrupting paradoxes throughout the world. The increase in man's reproductive efficiency has transformed the kinetics of demography from simple arithmetic additions to complicated geometrical progressions. An accelerating rate of population increase has resulted in a progressive rise in the number of mouths to be fed which is not being matched by a comparable acceleration in the rate of food production.

It is now well accepted that a reduction in birth rate and an increase in food production must occur to avoid widespread starvation before the end of the century. The purpose of this report is to consider a special aspect of the world food problem—the needs for high quality protein [1] and the ways these needs can be met, for the short-term and for the long-term. This introductory statement will define the framework within which all protein products and alternative programs to alleviate malnutrition must be considered.

### *5.2.2 The Complexity of the Problem*

To make responsible and realistic decisions concerning protein products and malnutrition, it is imperative to know and to understand:

1. The characteristics of different protein products.
2. The relationship of a product or program to the specific problem being faced.
3. The *time* available to solve the specific problem.
4. The *scale* or magnitude of the need.
5. The special circumstances and needs of the target area and group.
6. The resources, human and material, presently or potentially available from outside the target area (largely from the United States and Western Europe).
7. The resources, human and material, presently or potentially available within the target area.

Each country or regional problem must, therefore, be discussed in context. Yet, it has been a recurrent experience that most discussions of products and projects, at length and in detail, at conferences and symposia attended by those with a general interest in protein nutrition are quite irrelevant when a specific situation in a specific country is considered.

The only practical objective for a program to improve protein nutrition is to get an adequate amount of high quality protein into the

[1] *A high quality protein,* is defined as one which supplies all the essential amino acids (lysine, histidine, tryptophan, methionine, threonine, leucine, isoleucine, valine, phenylalanine) in near-optimal proportions. The misleading term, *"animal protein,"* is often used to refer to such materials, because proteins from animal sources are usually complete, not because proteins with the full complement of amino acids are exclusively derived from animal sources.

maximum number of undernourished people within a *certain limited time*; projects aimed only at doing *some* good will not solve all of the problems. This objective cannot be achieved merely by devising food products. Many other aspects of the problem, solutions to which must be evaluated and pursued by other disciplines [2] are involved, ranging from intensification of agricultural production of crops and of industrial production of vitamins and amino acids through the entire chain of processing, storage, marketing, and consumer acceptability of foods. Failure of any link in the chain means failure of the entire system. Thus, apart from the fact that protein problems are varied in themselves, the steps needed for the successful attack in any one area are very complex. For the most part, after this acknowledgment, we shall take the work of other subpanels for granted and focus our discussion on problems associated with protein nutrition.

### *5.2.3 Types of Crises*

1. *Long-range*

The impetus to the present consideration of world food supply has been the sense of impending urgency caused mainly by the current, rapid expansion in population. Unabated, this could lead to the ultimate and most widely discussed crises, i.e., large shortages of calories and protein culminating in mass starvation. The sharp increase of urbanization in the developing countries has been noted by the United Nations which states that as early as 1950, one-third of the world's cities with populations exceeding 100,000, were in Asia. This trend toward urbanization is by no means at an end.[3]

2. *Immediate Problems*

> . . . and it shall come to pass that when they shall be hungry, they shall fret themselves, and curse their king and their God, and look upward.
>
> —Isaiah 8:21.

It is important to realize, however, that a more immediate problem than mass starvation, is the possibility of collapse of weak societies under the strain of local, even temporary, food shortages. The hypothesis that this will first strike cities, dependent on rural areas for food, is being borne out by experience in large cities of Asia where there are increasingly ominous rumblings. These disturbances, of course, are not attributable exclusively to protein shortage. Yet, protein shortage is a far more important element than popularly recognized.

Furthermore, so far as adequate protein nutrition is concerned, there now exist immense and critical problems. Large parts of the developing world already have a grave shortage of high quality protein for the young, manifested by high death rates among infants

[2] In this report, this refers to the expertise of the members of the other subpanels.

[3] Food and Agriculture Organization of the United Nations. Population and food supply. Freedom from Hunger Campaign, Basic Study No. 7, August 1962, pp. 19–21.

and pre-school children and, as recently recognized may cause other long-term adverse effects such as retarded mental development.[4]

*5.2.4 The Time Factor*

The various kinds of crises and the approaches to resolve them differ in many technical respects, especially in the pressure to achieve adequate results within a certain period. A protein program cannot be discussed meaningfully without consideration of the *time* in which it can be effective. This aspect is often wholly neglected in current thinking.

For instance, it can be calculated that proteins from microorganisms and algae could supplement conventional sources of protein. However, many intricate problems must be faced before such potential new proteins can be expected to have any appreciable impact on the world protein supply (see Section 5.13). There is no intention to belittle or to minimize the need to pursue worthwhile leads which are unlikely to produce quick pay-offs. It must be emphasized, however, that for some purposes *quick* results are *essential.* Saving time, even when it is expensive in money and involves waste, mistakes and duplication, may be more important than the more logical and economical alternatives dictated by scientific and technological potential alone.

*5.2.5 Scale of Effort*

Another basic factor is *scale.* For instance, milk is a desirable and demonstrated source of high quality protein. But, in terms of the sheer volume of protein need in the developing world, the amount of milk protein available is extremely small. Trials of many protein products should be encouraged, if practical, so the potentialities and limitations of each can be determined by experience. But, it is folly to repeat past errors and to ignore or underemphasize the importance of scale in selecting alternative programs.

Apart from increased production of cereal and certain American "giveaway projects" no program yet undertaken has supplied protein on a large scale to the segment of a population whose needs are the greatest. There has been progress in understanding and in the development of products, techniques and programs which, on the basis of pilot studies, offer possibilities for the future. There has never been a successful, massive attack on the ever-increasing world shortage of protein. Special protein foods have been produced in various parts of the world but the hard fact remains that, to date, these foods have been marketed to those in greatest need in miniscule amounts.

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[4] These are well documented in National Research Council. Food and Nutrition Board. Pre-school malnutrition—primary deterrent to human progress. Nat. Res. Council Publ. 1282, 1966, 355 p.; and in Chapter 1, of this report.

### *5.2.6 Implications of the Time-Scale Pressure*

There is a humanitarian need to produce significant results quickly, but the larger the goal and the shorter the time for achieving it, the more severe are the restrictions on how the job can be done, and the more limited are the choices among products and programs which offer hope for success.

Those protein programs which are intended to be successful in the very short run, must be designed to accept existing societal conditions. Agricultural, technological, economic, or social changes must be limited to those which are practical within the next few years and which make minimum demands on the present structure and fabric of the social order of those whom they are to aid. Rapid changes on a large scale in type of farming, in economic status, in food habits, in educational level, and in marketing mechanisms, are out of the question on this time-scale. For the future, however, the catalysis of such changes is an essential goal, for which preparation must begin now, since lead-time for fundamental alterations in structure of traditional cultures is almost incredibly long.

The short-term goal is *not* to achieve optimum protein nutrition; it is to get results where the danger is greatest, among young children in the cities. Unfortunately, the subsistence farmer will, in most cases, be largely (although not entirely) compelled to wait for general changes in rural structure and activity. By not recognizing the restrictions on what can be done on a large scale in a short time, one runs the risk of accomplishing nothing if one tries to design a program that will have an impact on the entire population.

The partial control of infectious diseases, which has triggered the increased growth of population and the threatening food crises, has occurred quickly and has affected a huge number of people. Malaria, for example, was largely eradicated in Ceylon and India by systematic spraying with DDT. These great and fast results were obtained (1) by action from the top; (2) by central decision and operation; (3) at low cost; and (4) without major changes in social structure. One program to improve protein nutrition, which has these characteristics potentially, is the central fortification of local food staples with amino acids or protein concentrates (which admittedly has difficulties, uncertainties and limitations not yet fully understood and resolved.) The exact substance and technique to be used for fortification will vary with the nature of the staple, how it is distributed and used, and many other factors.

### *5.2.7 Varying Circumstances*

There can be no universal or simplistic solution to problems of protein nutrition. The variations and complexities are many and pro-

found, and, consequently, every protein product and program must be discussed in relation to specific circumstances as well as in relation to time and scale if practical results are to be achieved.

Rice alone is the staple food of about half the entire human race.[5] More than two-thirds of the population of the world customarily depend on grains for caloric requirements.[6] The problem, then, is whether adding modest amounts of protein concentrate or amino acids to these grains can transform them into adequate sources of protein. For a small fraction of the world's population, calories are obtained mainly from starchy roots such as cassava which contain very little protein. Such staples must be supplemented with larger amounts of high quality protein to effect the needed change in nutrition.

Regions vary in other important ways, in their social and economic patterns, in the type of grain grown and the form in which it is eaten, in the protein supplements (fish, beans, or pulses) available locally, in the industrial and commercial possibilities, and in governmental facilities and effectiveness.

In the cities, traditions have been modified by urban life so that food habits are relatively easy to change. Almost anywhere in the world, the situation in cities is radically different from that in the country. City residents are on a money economy and they purchase their food; the poorest classes inevitably buy the cheapest source of calories. City residents are reached by commercial distribution and promotion and are more amenable to accepting alternatives in the food they eat.

There are important differences between types of farmers. Some live entirely on what they grow, so-called subsistence agriculture. Others produce cash crops and, being in a market economy, are able and expect to buy some of their food.

All told, to be successful, all protein programs must be accepted by the consumer and not require continuing government pressures on the consumers. In other words, protein programs must be *market-oriented*, i.e., eventually geared to the development of self-sustaining food producing, processing, and distributing businesses even if, in some links of the chain, government subsidies and regulations will be involved. Each program must be designed to fit the needs and possibilities of a particular market and must be based on adequate knowledge of the local socio-economic situation and its possibilities. Unavoidably, then, the discussions of special products and programs must be related to particular markets and will ultimately depend on the rate of economic development.

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[5] Food and Agriculture Organization of the United Nations. The state of food and agriculture 1966. Rome, 1966.

[6] Food and Agriculture Organization of the United Nations. Production yearbook 1962. Rome, 1962.

### *5.2.8 Government Mechanisms*

A final and important aspect of protein problems is the question of what the United States Government can and should do with its limited resources of money, materials, knowledge, and manpower.

Since American resources of all kinds are finite, American contributions can be effective only if they have multiplier effects. There is little point to initiating an American program which, even if successful at first, cannot be carried on, improved, and expanded within a country utilizing that country's own resources. A program which depends mainly upon materials and management from the United States for survival and expansion is a bad program. Even a program which can be expanded with local resources only slowly and on a small scale is unsatisfactory if quicker and larger-scale alternatives are feasible. Every protein proposal must be considered realistically from the point of view of its potential to become self-sustaining, particularly in terms of the development of local industry.

Because of the heterogeneity of problems in time and space and the variety of ways local raw materials can be used to obtain food, many different alternatives for protein projects must be considered. There must be top-level administrative decisions on the division of necessarily limited resources among different types and locations, the provision of resources essential for the success of each program, and the target time and relative emphasis for each priority.

Administrative organization and procedures must be provided which will insure that planning and policy, both here and abroad, be made quickly and concisely to encourage participation by target countries and by industry. The agencies responsible for the administration of these programs must be organized to provide accurate analyses of the problems involved in each area; to offer feasible and practical solutions, area by area; and to provide the necessary follow-up to insure that the effectiveness of each program is evaluated, whatever the time required for evaluation. Administrative mechanisms in the target countries are equally important for the success because a certain amount of cooperation is essential for any program.

## *5.3.0. A Condensed and Different Look at the Calorie and Protein in the Diets of the World*

Brevis esse labōro obscūrus fio
(In trying to become concise I become confused)

The diet of the world's population can be categorized generally on the source and calorie-protein ratio of food, and on the incidence of Kwashiorkor, a childhood disease caused by protein deficiency (see Table 5–1).

TABLE 5–1.—*The calorie-protein ratio of 3 general classes of diets* [1]

| Calorie protein ratio [2] | Main source of food | Characteristics of diet | Protein condition |
|---|---|---|---|
| Lowest | Varied and balanced | High in protein calories of animal origin. | Could be surfeit of protein. |
| Intermediate | Cereals | High in grain calories: | |
| | | Wheat | Could be adequate except for sensitive groups (i.e., preschool children). |
| | | Rice | Less adequate than wheat; some occurrence of Kwashiorkor. |
| | | Corn | Kwashiorkor prevalent. |
| Highest | Tubers and sugars | Low in grain calories, high in fats, tubers, or sugars. | Kwashiorkor widespread. |

[1] Based on isocaloric diets and assuming sufficient calories in each group.
[2] Legumes temper the protein condition somewhat and are used in intermediate and highest classes. However, in general, the protein situation of a population becomes worse as one moves from lowest to intermediate to highest.

There are three classes of diets: (1) those characteristic of North America, Oceania, most of Europe, and other developed areas that contain relatively large amounts of animal protein; (2) those diets in which most of the calories are derived from cereals; and (3) those diets in which most of the calories are derived from fats, sugars, or tubers or some combination of these foods. Several points are made about the present and prospective supply of proteins in each of these general classes of diets.

### *5.3.1 Diets With Animal Protein*

1. Only in populations with this class of diet is there no protein malnutrition at present.

2. Animal protein will disappear last from these societies so research on reducing the cost and improving the potentialities of animal production is still justified. It might be well to concentrate more on land areas and feedstuffs that cannot be used directly as sources of food for humans. With improvements in food science, ruminants are likely to offer the best potential because grazing animals can utilize land that may not be suitable for cultivated crops.

3. This type of society is accustomed to high esthetic levels and low monotony levels of food. Fortification of cereal grains probably will be less acceptable than new protein foods with the same quality as animal foods. Increased emphasis on new protein foods acceptable to the consumer is recommended. This means improvement in the level of food science and technology and more research on protein sources.

4. Since these societies are not in immediate danger, they can undertake more long-term research and will continue to be the exporters of protein, other foods, and technology.

*5.3.2 Cereal Diets*

1. The diets of people in some countries are based primarily on cereals. Such countries should be encouraged, first of all, to produce more cereal, to prevent losses and to emphasize the production of cereals of highest protein content and quality and second, to fortify cereals with amino acids or protein concentrates in ways least likely to change food habits. Whether fortification or improvement of protein quality by genetic means should take priority depends on specific regional situations. Either approach has the potential to eliminate problems of protein malnutrition.

2. These people strive for less monotony of diet. They would prefer animal protein but satisfying this preference may not be in accord with the most efficient use of land and agricultural inputs—i.e., to consume the plant materials directly. Great effort should be given to the development of low-cost protein from other sources, including plants and fish.

3. Legumes and pulses reduce the cost of protein (bypassing inefficient animal conversion) because they permit more calories from plants and can make a substantial protein contribution. Any method to improve usefulness of certain legumes and pulses such as beans, peas and, particularly, oilseeds by breeding or by simple processing should be pursued.

4. Low priority should be given to the improvement of animal component.

*5.3.3 Fat, Sugar, or Tuber Diets*

1. The people on these diets suffer from a low level of protein intake. The first priority should be to correct this by increasing the proportion of cereals, oilseed meals and fish in diets. This would mean discouraging any effort to increase tuber, sugar or fat calories unless concomitant provisions are made for increasing protein sources.

2. To substantially increase supplies of low cost protein for these societies will require more imagination and innovation than for the other diet classes. Simple solutions will fail. The need justifies intensive effort to develop cheap concentrates from oilseeds, from fish, from leaf, and by fermentation and to convert protein from these sources into acceptable foods. Since much additional research is needed, efforts to help these societies will be expensive.

3. Efforts to improve animal protein sources should be limited to obvious and simple procedures and should concentrate on the ruminant segment and possibly poultry production.

Several generalizations can be made about the calorie-protein ratio of the diet. (1) If the rate of increase in per capita income of a society is greater than the rate of increase in the cost of calories, a greater proportion of animal protein will be consumed. An outstanding example of this is postwar Japan where rises in per capita income have

been paralleled by increasing demand for animal protein. With the reverse situation, i.e., a decrease in per capita income, protein consumption diminishes. (2) If the cheaper source of calories is not adequate in a society, starvation conditions will result in the absence of external aid. (3) In certain societies, the rate of increase in per capita income still exceeds the increase in the cost of calories but this proportion may not be maintained. One consequence of an increase in cost of food and an increase in percentage of per capita income spent on food could be a shift from animal to plant protein or an increasing calorie-protein ratio.

### *5.4.0 Is There a Protein Deficiency?*

**Jamaica—"Sugar baby" disease**
**Cameroons—"Enfant Rouge"**
**Gold Coast of Africa—Kwashiorkor (Ga dialect)**
**Germany—Mehlnahrschaden**
**Mexico—"Culebrilla"**
**Central America—Polycarencil infantile**

Calculations of average protein consumption in many areas fail to reveal a great deficiency in the quantity of protein available. For example, it has been calculated that the per capita requirement in India is 48.3 grams daily,[7] but food balance data indicate that the average supply in India is 55.6 grams daily.[8] These data do not reflect the true situation since a major cause of morality among young children is protein malnutrition.[9] Some years ago, Lord Boyd Orr, the first Director-General of FAO, described this paradox simply and forcefully: "All I have learned about nutrition . . . is this: If people are hungry, they need food. If they are ill-nourished, they need good food." [10]

With specific reference to protein, the problem can be stated in five questions: (1) Of the protein produced, how much is actually consumed? (2) Of the protein available, how evenly is it distributed? (3) What is the quality of the protein? (4) How valid are the calculations of requirements for humans? (5) Has protein malnutrition been observed?

1. The losses of grains and food due to such things as rodents, insects, inadequate processing and microorganisms have been estimated and although the estimates vary widely, they are tremendous. These losses are known to be serious in the specific situations where measurements have been possible (see Chapter 10, Tables 10–1 & 10–2).

2. It is obvious that people at the lower end of the economic spectrum depend almost entirely on the cheapest source of calories. For

[7] Chapter 1, Table 12.

[8] U.S. Department of Agriculture. Economic Research Service. Foreign Regional Analysis Division. Food balances for 12 countries in the Far East and Oceania, 1959–1961. U.S. Dep. Agr. Econ. Res. Serv. ERS-Foreign 88, 14 p. Aug. 1964. Table 5.

[9] National Research Council. Food and Nutrition Board. Pre-school malnutrition—primary deterrent to human progress. Nat. Res. Council Publ. 1282, 1966. 355 p.

[10] Cited in: Calder, R. Common sense about a starving world. New York, MacMillan, 1962. 176 p.

example, in those countries in which cereals are the staple, the very poor will consume more than the average amount of grain whereas the most affluent will consume less (Table 5–2). Some individuals will,

TABLE 5–2.—*The per capita calorie supply by expenditure level in Maharashtra State, India, 1958* [1]

| Expenditure in rupees [2] (monthly) | 0–8 | 8–11 | 11–13 | 13–18 | 18–24 | 24–34 | >34 |
|---|---|---|---|---|---|---|---|
| Total calories (daily) | 1,120 | 1,560 | 1,850 | 2,190 | 2,440 | 2,530 | 3,340 |
| Calories derived from cereals | 940 | 1,300 | 1,510 | 1,740 | 1,860 | 1,800 | 2,150 |
| Percent cereal calories of the total | 84 | 83 | 81.6 | 79.5 | 75.3 | 71.2 | 64 |

[1] From: Sukhatme, P. V., The world's hunger and future needs in food supplies. Roy. Statist. Soc. J. Ser. A 124(4): 463–525. 1961.

[2] 1 rupee is equivalent to $0.13 U.S.

therefore, not only consume less than the average amount of protein available, but will also consume low quality protein because a greater proportion is derived from cereals.

3. The quality of protein is important because protein is the source of essential amino acids in the diet. From age 1 to 5, the daily protein requirement in terms of human or cow milk is reported to be 1.0–1.5 gm/kg of body weight.[11] If a 10-kg child consumes 100 gm of wheat containing 12 percent protein he will consume 12.0 gm of protein daily, apparently an adequate amount of protein. Wheat, however, is deficient in lysine. A hundred grams of wheat supplies only about 0.25 gm of lysine whereas a 10-kg child requires about one gram of lysine per day.[12] The energy requirements could be satisfied with 250–300 gm of wheat but the lysine intake would not be adequate.

4. The protein and amino acid requirements estimated by FAO are probably fairly accurate for healthy children. But the results of field tests suggest that the protein malnourished child or the child suffering from infection has a greater protein requirement to regain normal health.[13] Also, if an insufficient amount of food is consumed to satisfy energy requirements, part of ingested protein will be used for energy, reducing the amount available for tissue repair and synthesis.

5. Protein malnutrition can and indeed does exist in spite of calculated per capita consumption figures which indicate no deficiency. Kwashiorkor exists as a disease entity. As Calder has written: "It may be true that our knowledge of absolute protein requirements may be more debatable than our measurements of over-all calorie requirements, but some of us can put names and faces to satistics." [14] We must

[11] Food and Agriculture Organization of the United Nations. Human protein requirements and their fulfillment in practices, proceedings of a conference in Princeton, United States (1955). Rome, 1957. 193 p. Reference p. 99 and 105.

[12] Holt, L. E., and Snyderman, S. E., The amino acid requirements of infants. Amer. Med. Ass. J. 175(2): 100–103. Jan. 14, 1961.

[13] Scrimshaw, N. S., and Bressani, R., Vegetable protein mixtures for human consumption. Federation Proc. 20 (1) Part III, Suppl. 7:80–88. March 1961.

[14] National Research Council. Food and Nutrition Board. Pre-school malnutrition—primary deterrent to human progress. 1966. Reference on p. 253.

recognize that average global figures may underestimate the food problem and its acuteness in specific regions and that protein malnutrition cannot be considered in isolation. As Calloway and Spector have stated:

> To the general principles set forth—that on a fixed adequate protein intake, energy level is the deciding factor in nitrogen balance and that with a fixed adequate caloric intake, protein level is the determinant—may be added a corollary. That is, at each fixed inadequate protein intake there is an individual limiting energy level beyond which increasing calories without protein or protein without calories is without benefit.[15]

### *5.4.1 The Effect of Protein Malnutrition in Young Children and Pregnant and Nursing Women*

*5.4.1.1 The Pre-School Child.* Maurice Pate of UNICEF has pointed out that the death rate between ages 1 and 4 in developing countries averages 35 per 1,000 and, in developed countries, 1 per 1,000.[16] These startling differences are due, to a large measure, to malnutrition.

As stated in the general summary of the International Conference on the Prevention of Malnutrition in the Pre-School Child:

> Malnutrition in the pre-school child is one of the world's most serious health problems in developing areas. Not only is it killing and maiming the children of today, but also, through physical, mental and emotional damage, it will handicap the society of 1984, the next generation . . . of those it does not kill, pre-school malnutrition permanently impairs physical growth and probably causes irreversible mental and emotional damage . . .[17]

Scrimshaw and his associates at INCAP have shown that cited figures of protein requirements may be applied to the healthy child. However, in the case of the undernourished child, much of the time, more protein is required for repletion and associated good health. This is due to the high frequency of infection which depletes the child of protein through a decrease in appetite, a change in the food offered, decreased absorption and, invariably, an increased metabolic loss of nitrogen in the urine. Each period of depletion due to an infection is followed by a period two or three times longer in which there is need for additional protein to replete the subject.[18]

*5.4.1.2 Pregnant and Nursing Mothers.* The minimal requirements for protein during pregnancy and lactation have been reviewed by Hegsted[19] and Blaxter[20] who point out and quantify the increased

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[15] Calloway, D. H. and Spector, H., Nitrogen balance as related to caloric and protein intake in active young men. Amer. J. Clin. Nutr. 2(6): 405–412. Nov./Dec. 1954.

[16] Pate, M., The challenge of the pre-school child. Int. Congr. Nutr. Proc. 6: 465–467. 1964.

[17] National Research Council. Food and Nutrition Board. Pre-school child malnutrition—primary deterrent to human progress. Nat. Res. Council Pub. 1282, 1966. 355 p.

[18] Scrimshaw, N. S., Nutrition and infection. *In:* Brock, J. F. Recent advances in human nutrition. Boston, Little, Brown, 1961. 454 p. Pp. 375–388.

[19] Hegsted, D. M., Protein requirements. *In:* Munro, H. N., and Allison, J. B. (eds). Mammalian protein metabolism. Vol. II. New York, Academic Press, 1964. 642 pp. 135–171.

[20] Blaxter, K. L., Protein metabolism and requirements in pregnancy and lactation. Ibid, pp. 173–233.

needs of both mother and child. The ravages of poor protein nutrition of pregnant and nursing mothers have been vividly portrayed by Calder [21] and there is no doubt about the validity of the needs, the inadequacy of the supply of protein, and the dire consequences.

### *5.42 Malnutrition, Food Habits and Taboos: Implications of Programming*

. . . These are the beasts which ye shall eat among all the beasts that are on the earth . . . .

—Leviticus 11:2.

A successful attack on malnutrition is closely dependent on an understanding of the specific area, its people, and their social structure and culture.

Much of our present knowledge of food habits is derived from research conducted during the World War II [22] by nutritionists and social scientists who, for the first time, worked together to maintain and improve nutritional standards.

It is now obvious that a multidisciplinary effort will be required to solve many of the food problems of the developing world. The social scientist is a necessary member of the nutrition team to help understand food practices and outline a meaningful program that will least disturb existing mores while improving food intake.

Dietary habits are inculcated early in life. Food selection, in traditional cultures, expresses a society's philosophy of life. As Brillat-Savarin, the eminent French gastronome stated: "Dis-moi ce que eu manges, je te dirai ce que tu es".[23]

In the last decade, several companies have been active in various underdeveloped areas of the world and have utilized market research techniques to great advantage. The role of commercial ventures in changing food habits has been reviewed by Yudkin and McKenzie.[24] Meaningful recommendations for products, processes, or raw materials cannot be made from the isolation of an office or laboratory thousands of miles from the scene of action. Field investigations by knowledgeable people are needed, particularly before any plan is made to introduce unfamiliar food into the diet of a traditional society.

Many a scheme for solving a local nutritional problem has failed because proper attention was not given to existing habits and taboos. Dietary customs can be changed, but a change of this type requires time and a carefully prepared program of consumer education.[25]

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[21] Calder, R., Food supplementation for prevention of malnutrition in the preschool child. Nat. Res. Council Publ. 1282: 251–257. 1966.

[22] Burgess, A. (ed), Malnutrition and food habits, report of an international and interprofessional conference. New York, MacMillan, 1962. 210 p.

[23] Brillat-Savarin, J. A., Physiologie du goût. Paris, Just Tessiers, 1825.

[24] Yudkin, J., and McKenzie, J. C. (eds), Changing food habits. London, MacGibbon & Kee, 1964. 144 p.

[25] Blair, T. L. V., Continuity and change in African food habits. Food Technol. 20(6): 757–762. June 1966.

In summary, a remedy for malnutrition, which involves a change in food habits, is highly likely to be ineffective in the short run. Even a long-range plan must be selected with an unusual amount of common sense, depending on the local situation, and must be carefully targeted and programmed. Reactions and results should be studied and measured at each stage so that the lessons learned will not be forgotten, only to be relearned in some other scenario.

### *5.5.0 Nutritive Quality of Proteins*

Πρωτειος—pre-eminent

—*Mulder*, 1838.

The nutritive quality of a protein is dependent on its content of essential amino acids, i.e., those which cannot be synthesized by humans. If the exact requirements of humans for the essential amino acids were known at each stage of development and if these requirements were uninfluenced by other factors, it would be a simple matter to evaluate the nutritional quality of a protein from its amino acid composition.

The requirements, unfortunately, at different stages of development are not know accurately and these requirements are altered somewhat by the quantities of the other amino acids present. In addition, presence of an amino acid in a protein as determined chemically does not mean that it has nutritive value because some proteins cannot be digested after being eaten. For these reasons, the nutritive quality of a protein must be evaluated from rates of growth or retention of nitrogen in experimental animals. Data obtained for one animal species cannot be used as the absolute requirements for another species, but as Hegsted [26] has pointed out, there has been good agreement between the observed protein requirements for most animals and man.

The term "animal protein" is often used synonymously with "high quality protein". Animal protein should be used only as a designation of source of protein—the quality being dependent on the amino acid composition. Proteins from animal sources (milk, eggs, and meat) are high quality because they are composed of relatively large amounts of the essential amino acids. This aspect of quality is illustrated from a comparison of the relative amounts of essential amino acids in selected foods (Table 5–3). The amounts are compared, on a percentage basis, to those in egg which has an amino acid composition that is about the same as the composition required by man. (Egg is higher than necessary in methionine-cystine and is certainly higher in essential amino acid to nitrogen ratio.) Most proteins from animal sources contain excess amounts of lysine, trytophan, threonine, and methionine, of which one or more may be deficient in cereals and other vegetable products.

[26] Hegsted, D. M., Theoretical estimates of the protein requirements of children. Amer. Diet. Ass. J. 33: 225–232. 1957.

Munro [27] points out that, in order to maintain nitrogen equilibrium, about 4 percent of the total energy consumed by an adult must be in the form of protein containing a balanced mixture of amino acids. If there is less than 4 percent protein in the diet, sufficient food cannot be consumed to maintain nitrogen equilibrium because appetite (or lack thereof) will limit food intake. The protein content of foodstuffs that are important dietary staples in several areas of the world are given in Table 5–4.

TABLE 5–3.—*Percentage of ideal concentration of essential amino acids observed in typical proteins (using egg as 100 percent)* [1 2]

[Percentage concentration in whole egg protein]

| Foodstuffs | Histidine | Threonine | Valine | Leucine | Isoleucine | Lysine | Methionine | Phenylalanine | Tryptophan |
|---|---|---|---|---|---|---|---|---|---|
| Beef | 157 | 90 | 73 | 87 | 84 | 141 | 84 | 70 | 92 |
| Fish muscle | 124 | 96 | 86 | 106 | 105 | 148 | 100 | 79 | 109 |
| Soybean meal, low fat | 138 | 80 | 76 | 89 | 97 | 111 | 53 | 95 | 127 |
| Whole rice | 81 | 78 | 88 | 91 | 84 | 52 | 106 | 89 | 118 |
| Whole wheat | 100 | 67 | 62 | 78 | 64 | 44 | 78 | 91 | 109 |
| Cottonseed meal | 128 | 61 | 69 | 67 | 64 | 57 | 53 | 107 | 118 |
| Whole corn | 119 | 76 | 76 | 167 | 103 | 38 | 97 | 89 | 55 |
| Peanut flour | 100 | 57 | 66 | 79 | 66 | 57 | 25 | 88 | 72 |
| Dried roast beans | 104 | 79 | 78 | 78 | 89 | 106 | 62 | 89 | 73 |
| Sesame meal | 106 | 81 | 67 | 70 | 63 | 38 | 53 | 78 | 93 |

[1] Data mainly taken from Hopper, T. H., Amino acid composition of foodstuffs. *In:* Altschul, A. M. (ed). Processed plant protein foodstuffs New York, Academic Press, 1958. 955 p. pp. 877–891.

[2] Data mainly taken from Heinz (H.J.) Company. The Heinz handbook of nutrition: a comprehensive treatise on nutrition in health and disease. Rev., 2d ed. New York, McGraw-Hill, 1965. 462 p.

TABLE 5–4.—*Representative protein contents of various major foodstuffs* [1]

| Foodstuff | Protein content as— | |
|---|---|---|
| | Grams per 100 grams edible portion | Percentage of total energy content of food |
| Cassava flour | 1.5 | 1.8 |
| Plantains | 1.0 | 3.1 |
| Irish potatoes | 2.0 | 10.7 |
| Milk | 3.3 | 20.6 |
| Wheat flour (70 percent extract) | 10.0 | 11.4 |
| Fish, lean | 19.0 | 37.6 |
| Soybean seed | 35.0 | 36.6 |
| Rice, polished | 7.0 | 8.0 |
| Maize meal (86 percent extract) | 9.5 | 10.5 |

[1] Munro, H. N., An introduction to nutritional aspects of protein metabolism. *In:* Munro, H. N., and Allison, J. B. (eds). Mammalian protein metabolism. Vol. II. New York, Academic Press, 1964. 642 p. Reference p. 8.

[27] Munro, H. N., An introduction to nutritional aspects of protein metabolism. *In:* Munro, H. N., and Allison, J. B. (eds). Mammalian protein metabolism. Vol. II. New York, Academic Press, 1964. 642 p. Reference p. 8.

263–888 O—67——22

## *5.6.0 Fortification of Cereal Grains*

. . . Grain shall make the young men flourish . . .
—Zachariah 9:17.

Fortification of cereal grains or products is simply the addition of the limiting amino acid(s) or protein concentrate(s) to the grain to improve the quality of the protein, i.e. to increase its nutritive value and to increase the protein quantity (in the case of protein concentrate fortification).

### *5.6.1 Rationale of Cereal Fortification*

The fortification of cereal grains can be undertaken in many areas and, where feasible, it can have an impact in a short time on large numbers of people.

The basic rationale of cereal fortification is easily stated. Approximately half of man's total dietary protein comes from cereal grains.[28] Moreover, cereals contribute nearly 80 percent [29] of the calories in the less developed regions (see Table 5–5). The 9 gm. of animal protein consumed per capita daily in the less developed regions of the world is only one-fifth that in the more developed regions. Some 1.8 billion people of the world, which includes the bulk of the undernourished people of the world, depend mainly on cereal grains for both calories and proteins. Phillips has stated the general proposition that countries that are low in calorie supplies are also low in protein supplies.[30] Generally, if cereals, starchy roots, and sugar furnish more than two-thirds of the total calories, it is evidence of malnutrition in the population.[31]

According to the FAO estimate, about 20 percent of the people in the developing areas of the world are *undernourished* (inadequacy of the quantity of the diet, i.e., caloric intake; strictly appropriate to adults, not to children) whereas about 60 percent are *malnourished* (inadequacy of the quality of the diet).[32] Need one cite statistics further?

### *5.6.2 Is the Fortification of Cereal Grains Nutritionally Sound?*

The question to be answered is whether fortification of cereal grains will improve the nutritional value for humans. Innumerable investigators have demonstrated that a cereal diet fortified with limiting amino acids fed to laboratory animals increased rate of growth or

[28] Food and Agriculture Organization of the United Nations. The state of food and agriculture 1964. Rome, 1964. References p. 108 and p. 118.

[29] Food and Agriculture Organization of the United Nations. Third world food survey. Freedom from Hunger Campaign, Basic Study No. 11, 1963. 102 p. Reference p. 33.

[30] Phillips, R. W., Future programs for increasing food production with reference to the preschool child. Nat. Res. Council Publ. 1282, 1966. p. 306.

[31] Food and Agriculture Organization of the United Nations. Third world food survey. Freedom from Hunger Campaign, Basic Study No. 11, 1963. 102 p. Reference p. 49–50.

[32] Ibid, p. 51.

TABLE 5–5.—*Summary of average per capita caloric and protein supplies in selected areas* [1]

| Subregion and region | Population (millions in 1960) | Calories in diet (average) | Calories derived from cereals, starchy roots, and sugar as percentage of total calories | Total protein, grams per day | Animal protein, grams per day |
|---|---|---|---|---|---|
| Far East (region) (including China mainland) | 1,603 | 2,060 | 81 | 56 | 8 |
| South Asia | 534 | 1,970 | 78 | 50 | 7 |
| Southeastern Asia, mainland | 67 | 2,030 | 78 | 49 | 13 |
| Southeastern Asia, major islands | 120 | 2,070 | 81 | 45 | 7 |
| Near East (region) | 132 | 2,470 | 72 | 76 | 14 |
| Africa (region) | 215 | 2,360 | 74 | 61 | 11 |
| North Africa | 27 | 2,260 | 75 | 66 | 16 |
| West and Central Africa | 90 | 2,360 | 74 | 50 | 5 |
| Latin America (region) | 211 | 2,510 | 63 | 67 | 24 |
| Mexico and Central America | 60 | 2,370 | 65 | 63 | 19 |
| Mexico | ---------- | 2,440 | 65 | 68 | 20 |
| Central America | ---------- | 2,130 | 71 | 58 | 14 |
| Brazil | 70 | 2,650 | 64 | 67 | 19 |
| River Plate countries | 25 | 3,040 | 54 | 96 | 55 |
| Western Europe | 322 | 2,910 | 55 | 83 | 39 |
| North America (region) | 192 | 3,110 | 40 | 93 | 66 |
| Low calorie countries | 2,038 | 2,150 | 78 | 58 | 9 |
| High calorie countries | 856 | 3,050 | 57 | 90 | 44 |

[1] From data in Appendix Table 4, Food and Agriculture Organization of the United Nations. Third world food survey. Freedom from Hunger Campaign, Basic Study No. 11, 1963. 102 pp. References on pp. 88–93.

increased retention of nitrogen. Tests with rats have shown that protein of the common cereal grains can be made about equal to the quality of milk protein (casein) by fortification with lysine, threonine, and tryptophan.[33] Corn requires lysine and tryptophan (this was first shown by Mendel in 1915; footnote 42, page 321; the others, lysine and threonine. Fortification with lysine, the first limiting amino acid, gives a marked but not optimal response in each case.[34] [35]

The quality of protein may be determined experimentally with animals and is conveniently expressed as Protein Efficiency Ratio (PER).[36] The PER for rats is the ratio of the weight gained to the protein consumed by weanling rats maintained on a diet containing the test protein at a prescribed level for 28 days. Casein is used as a reference and its PER is arbitrarily set at 2.5. For any experiment, all the values are adjusted to this arbitrary value so results will be comparable from experiment to experiment.

[33] Howe, E. E., Jansen, G. R., and Gilfallan, E. W., Amino acid supplementation of cereal grains as related to the world food supply. Amer. J. Clin. Nutr. 16(3) : 315–320. Mar. 1965.

[34] Rosenberg, H. R., Amino acid supplementation of foods and feeds. *In: Albanese,* A. A. (ed). Protein and amino acid nutrition. Ed. 2. New York, Academic Press, 1959. pp. 381–417. Reference p. 405.

[35] Howe, E. E., and Gilfallan, E. W. Unpublished data.

[36] Chapman, D. G., Castillo, R., and Campbell, J. A., Evaluation of protein in foods. 1. A method for the determination of protein efficiency ratios. Can. J. Biochem. Physiol. 37(5) : 679–686. May 1959.

TABLE 5–6.—*The effect of limiting amino acids on nitrogen balance in children fed three cereal grains* [1]

| Protein source | Nitrogen | | |
|---|---|---|---|
| | Intake milligrams per kilogram per day | Absorbed percent of intake | Retained percent of intake |
| Skim milk | 454 | 79.5 | 18.6 |
| Corn masa | 461 | 74.8 | 2.3 |
| CM+lysine+tryptophan | 464 | 71.0 | 17.8 |
| Skim milk | 310 | 80.3 | 24.8 |
| Wheat flour | 328 | 85.4 | 8.2 |
| WF+lysine | 335 | 86.0 | 17.9 |
| Skim milk | 317 | 80.4 | 28.1 |
| Rice | 320 | 76.9 | 18.7 |
| R+lysine | 320 | 79.7 | 24.7 |

[1] Note: Protein fed at 2–3 gm./kg. body weight/day. From: Bressani, R., Improvement of nutritional status in developing countries by improved food production: cereals. Int. Congr. Nutr. Proc. 1966. (preprint).

The pioneering work of the Institute of Nutrition of Central America and Panama (INCAP), during the past 15 years, has demonstrated the potential efficacy of cereal fortification with amino acids or protein concentrates, or both.[37 38] The experiences at INCAP have shown that proteins from a cereal diet containing sufficient calories do not cure protein malnutrition in children, but that rice, wheat, or corn fortified with limiting amino acids is effective (Table 5–6). Barnes, et al.[39] have also reported that the nutritional quality of a wheat farina diet may be improved if fortified with lysine.

Acute protein malnutrition does occur in preschool children in areas in which the diet consists mainly of grains. Scrimshaw et al.[40] have shown that a diet consisting of a vegetable mixture with a PER of 1.8 (determined on rats) when consumed at 2 to 3 gm of protein per kg of body weight per day will initiate cure of kwashiorkor. Such a diet would also prevent kwashiorkor from occurring. Cereal proteins, as demonstrated by rat tests (Table 5–7), can be fortified with lysine with a resultant protein quality to equal or surpass the quality of the vegetable mixture used by Scrimshaw. Cereal and grains fortified with lysine would probably prevent kwashiorkor in a cereal grain-

[37] Scrimshaw, N. S., and others, Supplementation of cereal proteins with amino acids. 1. Effect of amino acid supplementation of corn-masa at high levels of protein intake on the nitrogen retention of young children. J. Nutr. 66(4) : 485–499. Dec. 10, 1958.

[38] Bressani, R., Improvement of nutritional status in developing countries by improved food production : cereals. Int. Congr. Nutr. Proc. 1966. (Preprint.)

[39] Barness, L. A., Kaye, R., and Valyasevi, A., Lysine and potassium supplementation of wheat protein. Amer. J. Clin. Nutr. 9 : 331–344. 1961.

[40] Scrimshaw, N. S., and others, all vegetable protein mixtures for human feeding. V. Clinical trials with INCAP mixtures 8 and 9 and with corn and beans. Amer. J. Clin. Nutr. 9 : 196–205. 1961.

TABLE 5–7.—*Daily intake of protein if a child consumes 100 calories per kilogram of body weight of the cereals fortified with lysine (quality of protein expressed as PER)* [1]

| Cereal grains | L-Lysine HCl added (percent) | Daily protein[2] intake (grams per kilogram) | PER of fortified grains | PER of original grains |
|---|---|---|---|---|
| Wheat | 0.1 | 3.0 | 1.7 | 1.3 |
| Corn | .1 | 2.4 | 2.0 | 1.5 |
| Rice | .05 | 1.8 | 2.3 | 1.5 |
| Sorghum | 0.2 | 2.3 | 2.2 | .7 |
| Millet | .3 | 2.5 | 2.1 | .7 |
| Barley | .05 | 3.4 | 1.9 | 1.6 |

[1] From E. E. Howe, personal communications.
[2] Of fortified cereal.

consuming area if the children were fed adequate amounts of the fortified grains. Because the intake of lysine is suboptimal in areas where the children are known to be malnourished, it is reasonable to assume that enrichment of wheat, with lysine, coupled with adequate calories and vitamin enrichment, would improve the nutritional status of babies and children. It certainly would not be deleterious to any segment of the population.

### *5.6.3 With What Should Diets High in Non-Cereal Carbohydrates As the Main Calorie Source Be Fortified?*

The pragmatic problem of whether to fortify diets high in carbohydrate with protein concentrates or amino acids (excluding questions of cost and availability) depends on whether the need in an area is for improved quality or simply for *more protein.* Diets in which cereal grains are the major source of calories may be fortified with amino acids or protein concentrates of either animal or vegetable origin with beneficial results. Where calories are derived mainly from sugar, cassava, or plantains, it is necessary to provide more *protein;* fortification with one, two or three amino acids will not suffice.

### *5.6.4 Specific Techniques of Cereal Fortification*

The exact technique of fortification depends on the grain (corn, rice, wheat, or others), on the state in which it passes through central facilities (whole grain or flour), and on the cost. It is self-evident that fortification generally will be limited (in the short-term) to grains which are centrally supplied or milled, i.e., to populations in urban areas on a money (rather than commodity-barter) economy. Cereals could also be fortified in local mills in rural areas if the program were given sufficient emphasis. Where cereals are marketed as whole grain, the choices are limited to materials that can be added in small quantities, i.e. amino acid(s) and vitamins, if desirable.

For flours it is possible to improve the *quality* of the protein by amino acid fortification or by addition of protein concentrates—such as oilseed meals or fish protein concentrate (FPC). The limiting factor in flour fortification is the amount of oilseed meal or FPC that can be added without imparting off-flavor, color, or odor or impairing the functional quality of the flour. Another factor that must be considered is cost.

Fortification with lysine will not provide optimal protein nutrition. For this to be achieved by amino acid fortification of cereals, the other limiting amino acids, threonine or tryptophan, would be required in order to make the cereal protein comparable in quality to milk protein.

The data in Table 5–8 show the amounts of amino acids needed to approximate the nutritional value of casein, the costs per pound of grain, and the equivalent amounts needed of fish protein concentrate and soybean protein as well as the respective costs of fortification for each method. Given the assumptions that have been made in Table 5–8, it can be seen that fortification with amino acids is cheaper than fortification with soybean meal or fish protein concentrate. Costs will vary depending upon the particular circumstances and conditions but it is interesting to note that to fortify rice and wheat would cost 30 percent more with FPC and 10 percent more with soybean meal than with amino acids.

TABLE 5–8.—*Comparison of cost*[1] *of fortification of cereal grains with amino acids, fish protein concentrate, and soybean protein. (This amount of fortification is required to make the protein quality of the cereals similar to milk protein, caesin.)*

| | Wheat | Corn | Rice, barley | Millet sorghum |
|---|---|---|---|---|
| Percentage of amino acid required | [2] LMH 0.3<br>[3] Thr 0.15 | [2] LMH 0.2<br>[4] Try 0.35 | [2] LMH 0.2<br>[3] Thr 0.1 | [2] LMH 0.45<br>[3] Thr 0.18 |
| Cost of amino acids per pound of grain..cents.. | 0.53 | 0.27 | 0.35 | 0.72 |
| Percentage FPC[5] required (9.7% LMH[2]) | 3.1 | 2.05 | 2.05 | 4.65 |
| Cost of concentrate.....cents.. | 0.77 | 0.51 | 0.51 | 1.16 |
| Value as energy source.....do.... | 0.09 | 0.06 | 0.06 | 0.14 |
| Net cost of amino acids in FPC[5].....do.... | 0.68 | 0.45 | 0.45 | 1.02 |
| Ratio of cost of FPC[5] cost of amino acids | 1.3 | 1.7 | 1.3 | 1.6 |
| Percentage of SBP[6] required (6.4 percent LMH[2]). | 4.7 | 3.1 | 3.1 | 7.0 |
| Cost of concentrate.....cents.. | 0.71 | 0.47 | 0.47 | 1.05 |
| Value as energy source.....do.... | 0.14 | 0.09 | 0.09 | 0.21 |
| Net cost of amino acids in SBP[6].....do.... | 0.57 | 0.38 | 0.38 | 0.84 |
| Ratio of cost of SBP[6] cost of amino acids | 1.1 | 1.4 | 1.1 | 1.2 |

[1] These calculations are based on estimated costs of L-lysine HC1, L-threonine, and L-tryptophan of $1, $1.50, and $2 per pound, respectively. The requirement of protein concentrate is calculated from its lysine content since each concentrate will supply an excess of threonine or tryptophan. The cost of FPC and SBM are assumed to be 25 and 15 cents per pound, respectively, and both are assumed to be 80 percent protein.

[2] LMH—L-Lysine Monohydrochloride.

[3] Thr—L-Threonine.

[4] Try—L-Tryptophan.

[5] FPC—Fish Protein Concentrate.

[6] SBP—Soybean Protein.

Only about 2 percent *soya flour* (44–50 percent protein) can be added to wheat flour without imparting undesirable flavors to the bread, but if *soy protein isolates* (~90 percent protein) are used, about 6 percent can be added.[41] About six times more protein can be added as soy protein isolate but there is a cost differential. The cost of protein in the finished product containing the soy protein isolate is about twice as great. (Soy flour, 52 percent protein, about 12¢/lb. of protein, vs. soy protein isolate, 90 percent protein, about 39¢/lb. protein.) It may be possible to utilize several protein sources in a complementary fashion. This concept was first advanced by Mendel.[42] Mendel worked with lactalbumin fortification of Zein.

The program of fortification has another and a pragmatic aspect in relation to the time and scale of effort and availability.

Table 5–9 presents data on the estimated amount of lysine and of FPC needed to fortify the 1965 shipments of Food for Peace wheat and 1966 shipments of wheat flour.

Two points stand out in respect to costs. First, the differences in initial capital expenditures required and the differences in costs of the product. Additional points are that lysine plants could be made available readily and soon, whereas a large scale FPC operation of this type would require several years. Costs are given for 6 percent FPC, but these are in part meaningless inasmuch as 6 percent cannot be added to whole formed grain (nor can 1 percent, in all probability) nor can 6 percent be added to flour without impairing the

TABLE 5–9.—*An example of comparative costs of fortification of Food for Peace wheat* [1] *and wheat flour* [2] *with lysine and fish protein concentrate (FPC)*

| | L-Lysine HCl [3] | FPC [4] |
|---|---|---|
| Amount required | 32,500,000 lb | 336,000,000. lb. |
| Cost | $32,500,000 | $84,000,000.[7] |
| Capital expenditure | $16,000,000 [5] | $51,000,000.[6] |
| Cost of 6 percent FPC | | $465,000,000 at 25 cents per pound. |
| Capital expenditure 6 percent FPC | | $260,000,000. |

[1] 1965 shipments of wheat $3 \times 10^{10}$ lb.

[2] 1966 shipments of wheat flour $1 \times 10^{9}$ lb.

[3] 0.1 percent L-lysine HCl required for wheat; 0.25 percent L-lysine HCl required for wheat flour. Cost of L-lysine HCl, $1 per pound.

[4] Calculated on basis of 9.7 percent L-lysine HCl in FPC.

[5] Based on cost of FPC, $0.25 per pound. Estimate of $1,000,000 capital expenditure of $1,000,000 kg. lysine HCl per year.

[6] Based on estimated cost.

[7] Based on the addition of 1 percent FPC in whole wheat and 2.5 percent in flour.

[41] Berk, Z., Personal Communication. (Paper to be published in Cereal Chem., 1967.)

[42] Mendel, L. B., Nutrition and growth. Amer. Med. Ass. J. LXIV(19): 1539–1547. May 8, 1915.

flavor or functional quality of the flour. Obviously, if one could do so, a 6 percent level would add much more protein.

### *5.6.5 Planning a Cereal Fortification Program*

In planning the fortification of cereals, one must realize that average consumption figures do not reflect accurately the food eaten by individuals day by day and meal by meal. For example, legumes may be eaten with cereals on one day and not on the next. Healthy children may be given pulses, whereas they may be the first food withdrawn from the sick child who needs them the most, and thus the diet undoubtedly will vary in protein adequacy from day to day and meal to meal. Therefore, the only practical short-range approach to fortification is to transform the major source of protein—the cereals—into the best possible source of protein. Ideally it would be desirable, if practical to do so, to transform by fortification cereal protein into the equivalent of animal protein.

Because the mother may not be aware that her child or family is malnourished, the provision of an adequate amount of protein in a cereal diet is highly desirable. Under such conditions, if the diet contains adequate calories it would also provide adequate protein.

The basic problems in fortification of cereals without changing form relate to:

1. Whether to fortify with vegetable protein or animal protein or a combination. With present technology, this is impossible except in the flour form.
2. The efficacy of amino acid or protein concentrate fortification has not been studied on a large-scale population basis.
3. Central fortification can be initiated immediately at central distribution or milling points or both but not when a farmer grows and mills his own grain, unless there would be a massive attempt at education or extension.

### *5.6.6 Fortification of Cereal Grains During Central Processing*

A step in the direction of central fortification has already been taken by the United States government in that all wheat flour shipped in the Foreign Donation Program is now fortified with calcium (Ca), iron (Fe), thiamine, riboflavin, and nicotinic acid. The way has been opened for vitamin A fortification using a dry preparation.

Thus central fortification offers an opportunity to fortify not only with an amino acid(s) but also with other nutrients such as vitamins and minerals. Further, the possibility of exacerbating a second limiting deficiency by correcting the first, as was the case in Brazil and in other countries recently, when improved protein nutrition precipitated cases of blindness due to Vitamin A deficiency, would be avoided. Table 5–10 is a tabulation of the nutrient content of the various cereals as

compared with the NRC, recommended daily allowances of age 1–3. The values are calculated for a child that consumes 350 gm of cereal grain per day.

From the data in Table 5–10, it is possible to calculate the quantity of each nutrient which must be added to each cereal to make it nutritionally adequate. These calculated values are shown in Table 5–11.

From the above, the cost of such fortification may be estimated as shown in Table 5–12.

TABLE 5–10.—*Nutrient content of various cereals*

| | Nutrients per 350 grams of cereal grain | | | | | | | Recommended dietary allowances (1–3 years of age) |
|---|---|---|---|---|---|---|---|---|
| | Whole wheat | Wheat flour | Rice | Corn | Millet | Sorghum | Barley | |
| Vitamin A micrograms | 0 | 0 | 0 | 1,800 | 0 | 0 | 0 | 2,000 |
| Vitamin D micrograms [1] | | | | | | | | 400 |
| Vitamin E micrograms | | | | 12 | | | | [2] 15 |
| Thiamine milligrams | 1.8 | .3 | .2 | 1.3 | 2.6 | 1.3 | .4 | .7 |
| Riboflavin milligrams | .4 | .2 | .1 | .4 | 1.3 | .5 | .2 | 1.0 |
| Nicotinamide milligrams | 15 | 3.5 | 6 | 7 | 8 | 14 | 11 | 8 |
| Vitamin $B_6$ milligrams | 3.5 | 1.7 | 1.4 | 1.7 | | | | [2] 1 |
| Vitamin $B_{12}$ milligrams | .3 | | | | | | | [2] 2.5 |
| Pantothenic acid milligrams | 5 | 3 | | | | | | [2] 5 |
| Folic acid micrograms | 140 | 28 | | 25 | | | 50 | [2] 50 |
| Ascorbic acid milligrams | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 35 |
| Calcium milligrams | 160 | 55 | 85 | 70 | 70 | 100 | 55 | 1,000 |
| Phosphorus milligrams | 1,240 | 330 | 330 | 900 | 1,100 | 1,000 | 660 | [2] 800 |
| Magnesium milligrams | 560 | 90 | | 420 | | | 600 | [2] 200 |
| Iron milligrams | 12 | 3 | 3 | 8 | 24 | 15 | 7 | 7 |
| Iodine micrograms | | | | | | | | [2] 80 |
| Copper milligrams | 2.8 | .7 | 1.7 | | | | | [2] 1.0 |
| Potassium milligrams | 1,300 | 330 | 320 | 1,000 | 1,500 | 1,200 | 560 | |

[1] No values found for cereal grains. In many cases sunlight is adequate.

[2] Values set by FDA for children 1 through 8 years of age. Cereal values from Watt, B. K., and Merrill A. L., composition of foods; raw, processed, prepared. U.S. Department of Agriculture, Agriculture Handbook 8, 190 pp. Rev. December 1963; and Heinz (H. J.) Co. The Heinz handbook of nutrition; a comprehensive treatise on nutrition in health and disease. Rev., 2d ed. New York, McGraw-Hill, 1965. 462 pp.

TABLE 5–11.—*Fortification required per kilogram of Cereal Grain*

| | Vitamin A (micrograms) | $B_1$ (milligrams) | $B_2$ (milligrams) | Nicotinic (milligrams) | $B_{12}$ (micrograms) | Ca (grams) | Fe (milligrams) | I (micrograms) | Lysine (grams) |
|---|---|---|---|---|---|---|---|---|---|
| Whole wheat | 6,000 | | 1.7 | | 7 | 2.4 | | 80 | 1.0 |
| Wheat flour | 6,000 | 1.4 | 2.4 | 14 | 7 | 2.7 | 11 | 80 | 2.5 |
| Rice | 6,000 | 1.3 | 2.6 | 7 | 7 | 2.7 | 12 | 80 | .5 |
| Corn | | | 1.8 | 3(?) | 7 | 2.7 | | 80 | 1.0 |
| Millett | 6,000 | | | | 7 | 2.7 | | 80 | 3.0 |
| Sorghum | 6,000 | | 1.4 | | 7 | 2.7 | | 80 | 2.0 |
| Barley | 6,000 | .8 | 2.4 | | 7 | 2.7 | | 80 | .5 |

*Note.*—Question mark is due to relative lack of $B_{12}$ in cereal grains.

TABLE 5–12.—*Cost of nutrient fortification of cereals*

| | Cost of fortification per kilogram of cereal grain (cents) | | | | | | | | | | Total | | Cost per child per year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Vitamin A | Thiamine | Riboflavin | Niacin | Vitamin $B_{12}$ | Ca [1] | Fe | I | Total (exclusive of lysine) | Lysine | Kilogram (cents) | Ton | |
| Whole wheat | 0.018 | ---------- | 0.0051 | ---------- | 0.02 | 0.02 | ---------- | 0.00002 | 0.0631 | 0.221 | 0.284 | $2.58 | $0.36 |
| Wheat flour | .018 | 0.0024 | .0072 | 0.0042 | .02 | .02 | 0.0044 | .00002 | .7742 | .555 | .629 | 5.61 | .80 |
| Rice | .018 | .0022 | .0078 | .0021 | .02 | .02 | .0048 | .00002 | .7749 | .11 | .185 | 1.69 | .24 |
| Corn | ---------- | ---------- | .0054 | .01 [2] | .02 | .02 | ---------- | .00002 | .0654 | .221 | .286 | 2.60 | .37 |
| Millet | .018 | ---------- | ---------- | ---------- | .02 | .02 | ---------- | .00002 | .0580 | .665 | .723 | 6.56 | .92 |
| Sorghum | .018 | ---------- | .0042 | ---------- | .02 | .02 | ---------- | .00002 | .0622 | .443 | .505 | 4.57 | .65 |
| Barley | .018 | .0014 | .0072 | ---------- | .02 | .02 | ---------- | .00002 | .0666 | .11 | .177 | 1.60 | .23 |

[1] Projected addition of calcium has been limited to 1.1 gm./kg. which is the quantity used at present in donations made by the United States government.

[2] Niacin added to supply full requirement since availability of that in corn is questionable.

Thus, each of the major cereals may be made adequate as the sole source of food for man at any stage of his development by proper fortification at costs of 23 to 92 cents per child per year. The cost per adult would be approximately twice this figure.

### *5.6.7 Possible Guidelines for Establishing Action Programs to Meet Protein Deficit*

Each region of the world has available to it specific foodstuffs; the people who live in the region have specific food habits. Table 5–13 outlines a possible procedure for assessing the nature of the nutritional problems existing in a specific locale. This table also outlines a possible method for choosing a course of action for a target population or a segment thereof. To help the reader, and by way of example, the tables consider options for supplementing the diet of the 1–5 year-old infant in a grain-consuming population such as India.

Three assumptions are made in developing the outline given in Table 5–13:

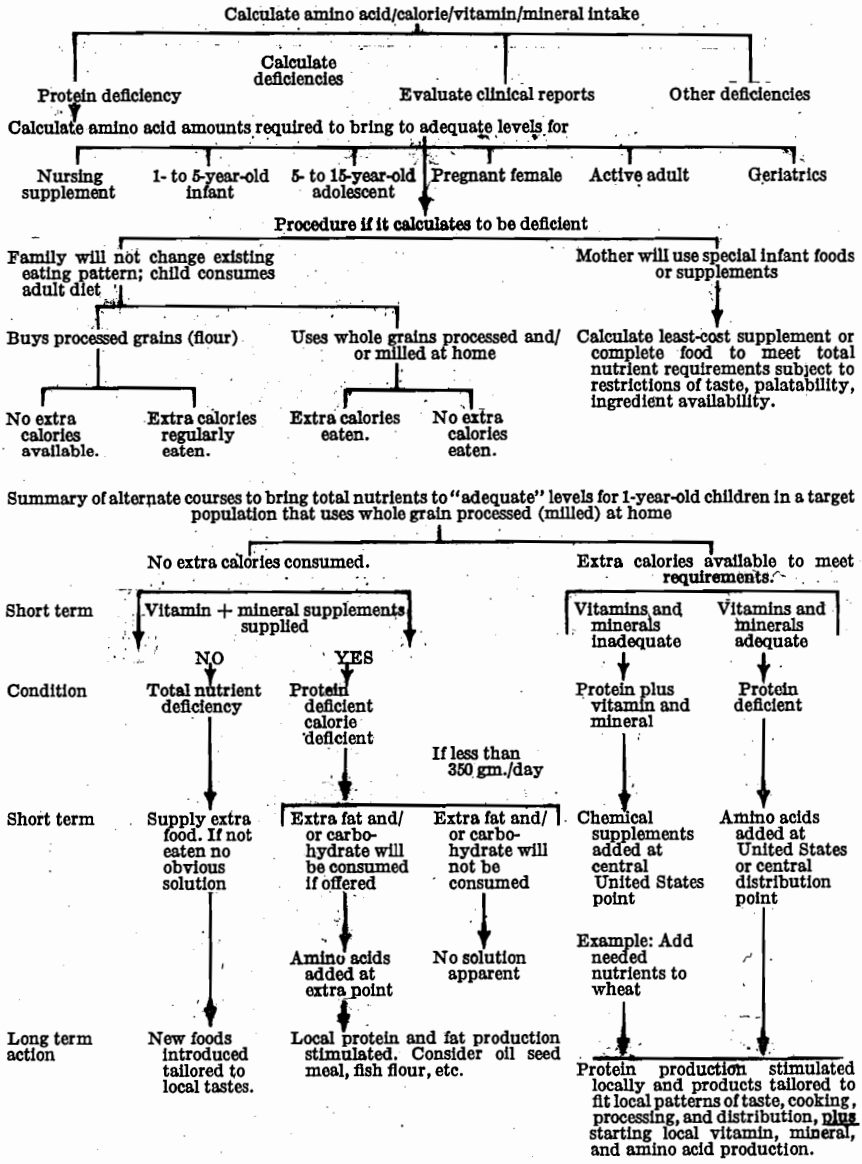
1. To meet a given specific crisis, any product available in the United States could be made available in the target area, subject only to food habits, taboos, processing and distribution restrictions. Obviously, if too many places are involved, the hard question of priority and total availability of United States production must be raised.
2. On a short-term crisis basis, the ingredient (or ingredients) required is of no consequence, as far as the individual consumer is concerned, because either the United States government or the local government will purchase the material required to supplement the dietary.
3. On a long-term basis, the questions of cost and ability of the local region to become self-sufficient in food production become paramount.

It is assumed further that a coordinated approach to a given area will be made such that, in meeting an immediate crisis, the foundation is laid for ongoing self-sufficiency.

The recommended courses of action are subject to the following uncertainties:

1. The lack of precise knowledge concerning the requirement of humans for each dietary ingredient at different age levels and different physiological states such as inanition, disease and pregnancy.
2. Knowledge concerning the availability, quality and acceptability of various protein sources for human beings is not well established. In fact, blanket recommendations cannot be made which ignore specific local conditions.

TABLE 5–13.—*What do people eat?*




3. There is not extensive experience of dealing with the twin problems of extrapolating animal data to humans and of extrapolating human data obtained in one region under one set of conditions to human beings in another region under another set of conditions.

However, the above are not considered as bars to effective action, since on a practical basis, there is enough experience extant to make

allowances for these uncertainties. Rather, these uncertainties suggest priorities for further study and experimentation which should be conducted once action programs are committed in a given area.

The following priorities seem to be the critical ones in establishing a long-range solution for a specific population which has a demonstrable protein deficit:

1. Local production of high-protein concentrates must be stimulated.
2. Families must be persuaded to accept special supplements or foods for infants and young children.
3. New processing and distributing techniques must be developed at the local level. This will make it possible to introduce specific protein supplements into the food chain needed to meet the *total* requirement of all age groups, particularly to meet the protein and energy needs of infants and children in the 1–5 year age bracket.

It must be recognized that a multipronged program is required to lead to any long-term solution of the world protein deficit. Further, priorities and continuing implementation must be planned so that adequate follow-through is provided. For example, agricultural economists should calculate carefully how much additional soybean meal (or other protein) supplied from United States production would be required to develop long-term acceptance of a product until local production can be brought on-stream. At the same time, one must ask how much local production of a specific foodstuff it will be possible to stimulate in order to place that foodstuff into the local food chain so that it may be utilizable and acceptable on the long term, to the local population. In addition, while the various nutritional alternatives receive prime attention, one should recognize in a specific situation that as much effort might well be expended in improving distribution or processing of materials already present as in importing materials from the United States. In any case, the consequences of catering to fixed food habits must be carefully assessed, because if people cannot be induced to change food patterns, the chances are reduced of finding a long-term solution to their basic problem. Whatever the approach, it must be an evolutionary one and one well thought out and studied by competent social scientists.

More and more, it is clear from this discussion that the immediate response to a specific problem is almost certain to require the full cooperation and enforcement of the local government in order to ensure that, despite local food customs, the acutely deficient portion of the population (most probably the young children) is reached. This problem is of the same order of complexity as the birth control program, but probably involves less social change to carry out effectively.

### *5.6.8 Possible Method for Applying a Fortification Action Program*

The examples that follow are based on linear-programming techniques commonly used in the feed industry and illustrates how one may apply these techniques for planning and assessing the food needs for a specific population, although for most countries, computer solution will not be required. Table 5–14 summarizes the nutrient contributions from principal foodstuffs available in overseas regions. A great deal of evidence exists which demonstrates that meeting a requirement for only one nutrient may exacerbate the requirements for all other nutrients. Therefore unless dietary levels for all nutrients are brought to adequate levels, it is possible that singly fortified diets may not have a very significant effect. Table 5–15 lists the amino acid, caloric, vitamin and mineral requirements for a 10 kg. infant. A specific assessment of food consumption must be made for a given population. Then the quantity of a given protein concentrate or amino acid

TABLE 5–14.—*Nutrient composition of ingredients (amount per 100 grams of each ingredient)*

| Components | Ingredients | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Wheat | Rice | Full fat soybeans | Soybean meal—50 percent | Soybean meal—44 percent | Torula yeast | Fish meal | Fish flour |
| Protein (grams) | 11.0 | 8.0 | 40.0 | 51.0 | 45.0 | 48.5 | 65.0 | 80.0 |
| Energy (Kcalories) | 344 | 364 | 331 | 228 | 228 | 273 | 375 | 375 |
| Fat (grams) | 1.8 | 1.7 | 20.5 | .5 | .5 | 2.5 | 7.0 | .5 |
| Fiber (grams) | 2.9 | 10.0 | 2.1 | 3.0 | 7.0 | 2.7 | 1.0 | 1.0 |
| Calcium (grams) | .05 | .05 | .16 | .2 | .25 | .5 | 4.5 | 5.5 |
| Phosphorus (grams of available) | .13 | .11 | .176 | .22 | .2 | 1.6 | 2.4 | 3.0 |
| Arginine (grams) | .51 | .6 | 2.48 | 3.1 | 2.8 | 2.6 | 2.57 | 3.16 |
| Glycine (grams) | .765 | .68 | 2.16 | 2.7 | 2.4 | 2.7 | 4.29 | 5.28 |
| Methionine (grams) | .13 | .14 | .6 | .75 | .68 | .8 | 1.90 | 2.34 |
| Methionine plus cystine (grams) | .323 | .23 | 1.192 | 1.49 | 1.34 | 1.4 | 2.07 | 3.28 |
| Lysine (grams) | .35 | .26 | 2.56 | 3.2 | 2.78 | 3.8 | 5.62 | 6.92 |
| Tryptophan (grams) | .153 | .10 | .52 | .65 | .58 | .5 | .48 | .59 |
| Leucine (grams) | .575 | .51 | ---------- | 3.78 | 3.4 | 3.5 | 4.16 | 5.0 |
| Isoleucine (grams) | .396 | .32 | ---------- | 2.80 | 2.4 | 2.9 | 2.81 | 3.46 |
| Phenylalanine (grams) | .468 | .31 | ---------- | 2.40 | 2.2 | 3.0 | 2.48 | 3.05 |
| P.A. plus Tyrosine (grams) | .82 | .91 | ---------- | 4.00 | 3.6 | 5.1 | 4.31 | 5.4 |
| Threonine (grams) | .259 | .26 | ---------- | 1.90 | 1.8 | 2.6 | 2.32 | 2.85 |
| Valine (grams) | .38 | .43 | ---------- | 2.70 | 2.2 | 2.9 | 3.42 | 4.2 |
| Histidine (grams) | .187 | .15 | ---------- | 1.22 | 1.1 | 1.4 | 1.43 | 1.76 |
| Vitamin A (I.U) | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- |
| Vitamin B (I.C.U) | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- |
| Thiamine (milligrams) | .55 | .07 | .80 | .60 | .6 | 9.17 | .066 | ---------- |
| Riboflavin (milligrams) | .04 | .10 | .211 | .264 | .264 | 4.4 | .551 | .678 |
| Pantothenic acid (milligrams) | .5 | .8 | 1.057 | 1.32 | 1.32 | 8.1 | .661 | .812 |
| Niacin (milligrams) | 2.4 | 3.4 | 1.67 | 2.09 | 2.64 | 49.5 | 6.61 | 8.12 |
| Vitamin $B_{12}$ (micrograms) | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | 6.61 | 8.1 |
| Ascorbic acid (milligrams) | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- |
| Choline (milligrams) | 35.0 | 99.0 | 211.5 | 264.0 | 264.0 | 286.0 | 286.0 | 143.0 |

TABLE 5–15.—*Daily nutrient requirements for 1-year-old infant weighing 10 kilograms, receiving amino acids to supply 2 grams per kilogram of body weight of protein per day and consuming 200 grams of food*

| Nutrient | Requirements as— | | Milligrams amino acid per gram nitrogen |
|---|---|---|---|
| | Amount per day | Amount per unit of food | |
| Calories | 1,200 calories | 6,000 calories per kilogram. | |
| Calcium | 1.0 g | 0.5 percent. | |
| Phosphorus | 0.5 g | 0.25 percent. | |
| Methionine | 0.34 g | 0.17 percent | 107 (FAO 144). |
| Methionine plus cystine | 0.64 g | 0.32 percent | 200 (FAO 270). |
| Lysine | 0.84 g | 0.42 percent | 270. |
| Tryptophan | 0.28 g | 0.14 percent | 90. |
| Leucine | 0.96 g | 0.48 percent | 306. |
| Isoleucine | 0.84 g | 0.42 percent | 270. |
| Phenylalanine | 0.56 g | 0.28 percent | 180. |
| Phenylalanine plus tyrosine | 1.12 g. | 0.56 percent | 360. |
| Threonine | 0.56 g | 0.28 percent | 180. |
| Valine | 0.84 g | 0.42 percent | 270. |
| Histidine | 0.36 g | 0.18 percent. | |
| Thiamine | 0.7 mg | 3.5 mg. per kg. | |
| Riboflavin | 1.0 mg | 5.0 mg. per kg. | |
| Niacin | 8.0 mg | 40.0 mg. per kg. | |
| Vitamin A | 2,000 I.U | 10,000 I.U. per kg. | |
| Vitamin D | 400 I.C.U | 2,000 I.U. per kg. | |
| Vitamin $B_{12}$ | 1 mcgm | 5.0 mcgm. | |
| Ascorbic acid | 35 mg | 175 mg. per kg. | |

that may be used without altering the processing or cooking or flavor characteristics of the foodstuffs may be determined.

## *5.7.0 The Improvement of Protein Quality of Cereals by Genetic Means*

. . . it is characteristic of science and progress that they continually open new fields to our vision . . .

—L. Pasteur.

The application of modern genetics could achieve the equivalent of fortification with amino acids thereby obviating the necessity of producing, purifying, mixing, and extra handling of the foodstuffs. Development of a cereal(s) with the desired amino acid balance, however, could well take an additional 5–10 years of concerted effort.

A superior variety of corn (opaque-2), which has about the same protein quality as animal protein,[43] [44] has been under investigation. The corn contains about 65 percent more lysine, more tryptophan, and a

[43] Mertz, E. T., Bates, L. S., and Nelson, O. E., Mutant gene that changes protein composition and increases lysine content of maize endosperm. Science 145 (3629): 279–280. July 17, 1964.

[44] Mertz, E. T., and others, Growth of rats fed on opaque-2 maize. Science 148 (3678): 1741–1742. June 25, 1965.

better amino acid balance than ordinary hybrid corn (see Chapter 3 report for a discussion of this development).

Young children fed this corn at 2 gms of protein per kg/day, retain similar amounts of nitrogen as children that are fed skim milk.[45]

These exciting findings point out the increased feasibility of attacking the problem of quality of proteins in cereals by manipulation of germ plasm. The work with corn should be extended to wheat and rice and other economically important grains. There has been little emphasis to date on selection of cereals for quality; instead, the demand has been for high yielding varieties. This fact, coupled with modern knowledge of nutritional requirements of animals and human beings should dictate an increased emphasis on breeding programs designed to select plants with proteins having an improved nutritional value. The ideal amount in any cereal would be that which would provide a balanced amino acid profile and an optimal protein: calorie ratio for a specific animal or human population.

Resistance to pests and drought and high yields per acre will have to be combined with the better protein quality for this advancement to have its greatest impact. In addition, color may be an important factor limiting its inclusion in some human foods.

Nevertheless, the potentialities of corn improved in protein quality by genetics are tremendous. The results with corn are indicative of the possibilities with other cereals. It could do away with all of the problems inherent in fortification with amino acids, i.e., such problems as mixing, extra cost and extra handling. It could affect markedly the requirements for soy protein and fish meal in swine and poultry feeds, thereby releasing more of these concentrates for human foods and it could markedly increase the contribution of protein in corn to the human diet.

In summary, the discovery of the opaque-2 variety is one of the exciting developments of the 1960's which should be pursued and expanded in research efforts, both at the basic genetic level and at the field trial state. The goal should be large-scale commercial plantings within five years and development of adapted varieties for countries where corn is a staple in the human diet.

### *5.8.0 Increasing Animal Protein Supplies*

. . . Who shall give us flesh to eat? . . .

—Numbers 11:4.

Proteins of animal origin are very desirable in the human diet because: (a) in general, they are adequate in amino acid content to meet the presently known human requirements and (b) they have

[45] Bressani, R., Improvement of nutritional status in developing countries by improved food production: cereals. Int. Congr. Nutr. Proc. 1966. (Preprint.)

pleasing flavor and texture. Animal proteins (including milk) do make very important contributions to our total protein supply, even though the amounts vary drastically from area to area.

Many facets of the problem must be considered in reaching a decision as to whether animal protein supplies (excluding fish which are considered in Sections 5.10, 5.11, and 5.12) should be increased in any given area. In considering this problem one must recognize: (1) *That some people do like foods, including milk and eggs, of animal origin.* In certain areas, religious or other patterns prevent the consumption of certain types of animal products, but in this paper, only those areas where products of animal origin may be consumed freely or with a minimum amount of restriction are being considered. (2) *That proteins from animal sources have better quality than individual vegetable proteins.* Meat, milk and eggs supply all the essential amino acids required by man in single, unaltered products. Meats also supply certain minerals and vitamins and are a particularly good source of vitamin $B_{12}$. (3) *That generally the consumption of animal products desired and purchased will increase as the economic level increases.* Arrayed against this, however, are some disadvantages of animal production.

### *5.8.1 Disadvantage of Animal Production*

1. Human food cannot be produced as efficiently through animal production as when grains are consumed by man himself.

2. Animals may be fed cereal grains and thus compete with man for food.

3. There is more risk in producing animal products than in producing plant products. After they have consumed a given amount of feed, animals may become victims of disease and parasites and may die before they can be transformed to edible products. Meat may be lost through spoilage after the animals have been slaughtered. More labor and cost are required to care for animals and to process and to produce animal products than are required for cereal grains.

4. Animal production may compete with other types of food production for land use. In some areas, however, beef cattle and sheep may be produced on lands that are not suitable for other kinds of agriculture. Poultry production is not only efficient in terms of utilization of feed but requires little land. There are also other areas where the land used for animal production might have alternate uses that are more profitable from the standpoint of both monetary return and total food production.

### *5.8.2 Evaluation of Animal Production*

Balancing the advantages against the disadvantages of producing animal foods for human beings indicates that the production of animal

263-888 O—67——23

foods cannot be justified on an economic basis except in special cases. It is now evident that people are going to eat, if at all possible, what they want to eat including animal products and that every available source of food will be needed to solve the world's food problem and to improve the quality of life. The needs and means of increasing animal production must be considered in terms of potential and future economic demand.

Certain factors must be evaluated in any area in which increased animal production is contemplated:

(1) When livestock populations are increased, there must be an effective demand for that type of product. If production exceeds demand, there will be a surplus and the price will be depressed to a point where there is no incentive to produce the animal products. But when the quantities produced are too low, prices will increase so much that the population cannot pay for the commodities that are produced. In each area, therefore, a careful study must be made so production can be balanced with effective demand.

(2) A study must be made of the potential of the land and the existing feedstuffs to satisfy the needs of the animals. The land can support only a limited number of animals. An optimum number of animals will yield the greatest production. Greater numbers of animals will have slower rates of growth and reproduction resulting in higher costs of production than if fewer animals were raised efficiently. It may be possible, therefore, to increase total production by raising fewer but better animals.

(3) Competition for land use must be considered. Often land used to produce feed for animals or pasture for animals might return a larger supply of food grain or more money if used for the direct production of crops. It is also true that certain types of land may be improved to develop pastures, improved for future grain crops and at the same time improved for the production of animals. There are types of land which are suited only for the production of animals, particularly beef cattle, sheep, and goats.

(4) Disease and parasite problems must be considered. Certain diseases and parasites hamper greatly the production of livestock. These must be controlled before considering the increased production of animals.

(5) Carcasses, milk, or eggs are not consumed immediately. Attention must be given to preservation and storage of these products until they reach the point of consumption. Means of preservation may be available to reduce waste, but it is also possible that the costs involved may increase the price beyond the means of the needed populace and its effectiveness also may be lost. This question of loss in food products before they reach the hungry and malnourished human stomach is one which must be given careful consideration.

(6) Transportation and distribution must be studied. Normally, livestock products are produced more efficiently on a large volume basis. Transportation must be available to move the products to the points of distribution where they will be available to the human for consumption.

(7) The animals to be produced must be efficient. Genetic improvements have greatly increased the capabilities of the animal to produce meat, milk, or eggs. At the same time, the most efficient types or strains of animals may not be adapted to climatic conditions and may not have the resistance to diseases or insect pests and parasites prevalent in given areas.

*5.8.3 Efficiency of Conversion of Feed*

Phillips[46] and Wilcke[47] have pointed out that the contribution of animals to the protein supply in the developing countries is very low (Figure 5–1). One must also consider the competition for food and feed between the human and animal in those areas of the world where food is not plentiful. One must recognize that the greater the percentage of food energy being supplied from animal products, the more land is needed to provide the food for each person (Figure 5–2). One must also recognize that the relative productivity of animal protein per acre of land varies with the type of plant grown and with the type of animal fed (Figure 5–3). The values of feed conversion by different animals may be understated in this particular chart but one must face the indisputable fact that human food cannot be produced as efficiently when one turns to animal production as when grains are consumed by man himself (Figures 5–3 and 5–4).

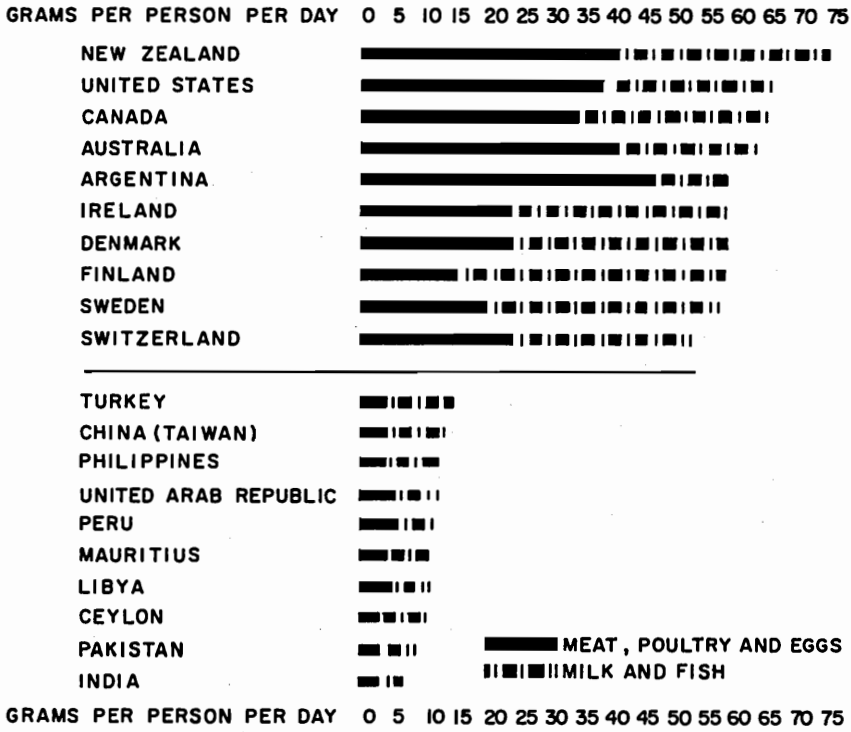
The efficiency of animals in converting feed to human food has been calculated and varies according to the methods of calculation, the efficiency of particular animals, and type of feed available. But the figures used here include all of the costs in terms of feed intake chargeable to the animal, including the cost of growing the animal to the point where it is capable of reproducing and, in the case of the young animals, the proportionate cost of maintaining the breeding flock or herd from which they are produced. It is evident that the hen and the dairy cow are the most efficient in converting protein in feed to human food products, followed by the broiler, swine and last, the beef animal (Table 5–16 and Figure 5–4). It must be recognized, however, that the ruminant can utilize feed that cannot be used directly by man and it is, therefore, salvaging this material and making it available to the human. It must also be recognized that the

[46] Phillips, R. W., Future programs for increasing food production with reference to the pre-school child. Nat. Res. Council Publ. 1282, 305–317. 1966.

[47] Wilcke, H. L., General outlook for animal protein in food supplies of developing areas. Advanc. in Chem. No. 57 : 16–26. 1966. Reference p. 17.

Figure 5-1

Available Total Edible Protein Supplies[1]

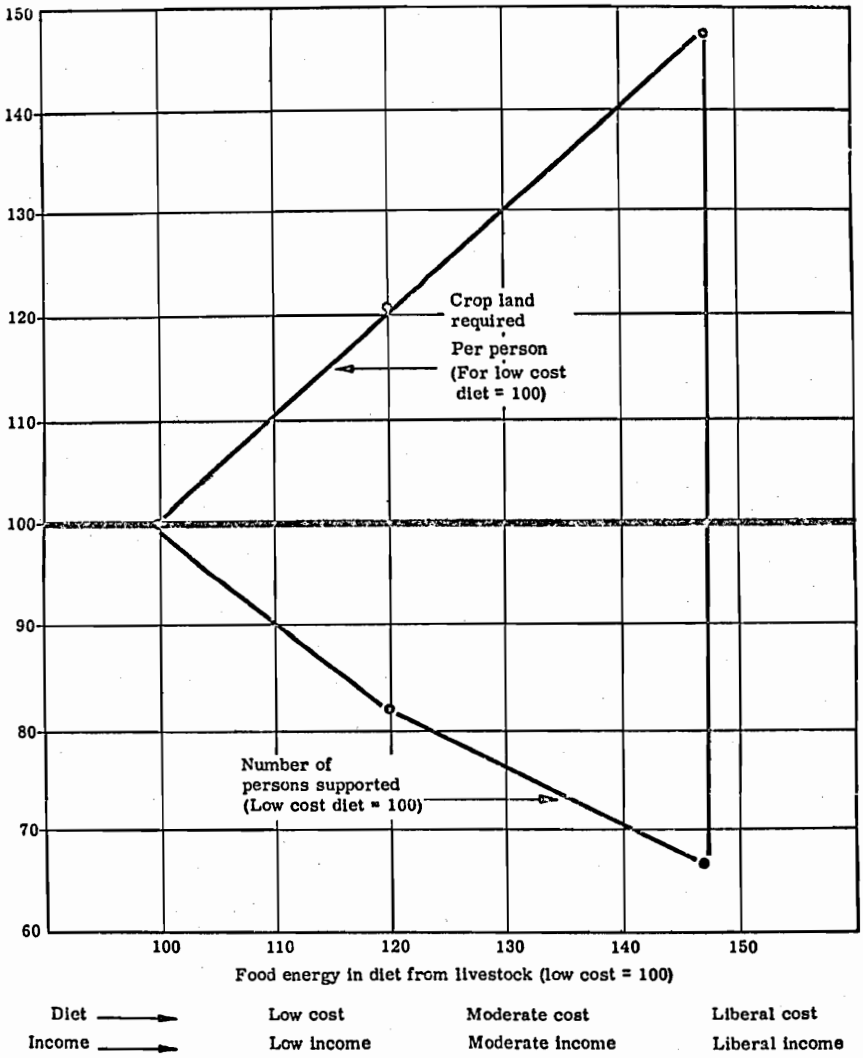



[1]Wilcke, Harold, General Outlook for Animal Protein in Food Supplies of Developing Areas; In: World Protein Resources, Adv. in Chem. Series 57, Amer. Chem. Soc., p. 17, Washington, D. C., 1966.

animal proteins are far higher in quality than the edible products consumed by the animals.

In every area, there are foodstuffs not suitable for direct human consumption. Some may be spoiled due to inadequate storage or preservation, some may be infected with insects or rodents, and some may be in a form that cannot be utilized by humans. Ruminants can play a very important role in converting inedible grasses and other forages into desirable food products in many parts of the world where this type of material is available. Poultry and swine may act as scavengers converting food products that, for various reasons, cannot be consumed by man, into products very desirable to man.

Figure 5-2 A DIET CONTAINING MORE LIVESTOCK PRODUCTS REQUIRES MORE LAND AND FEEDS FEWER PERSONS (1)

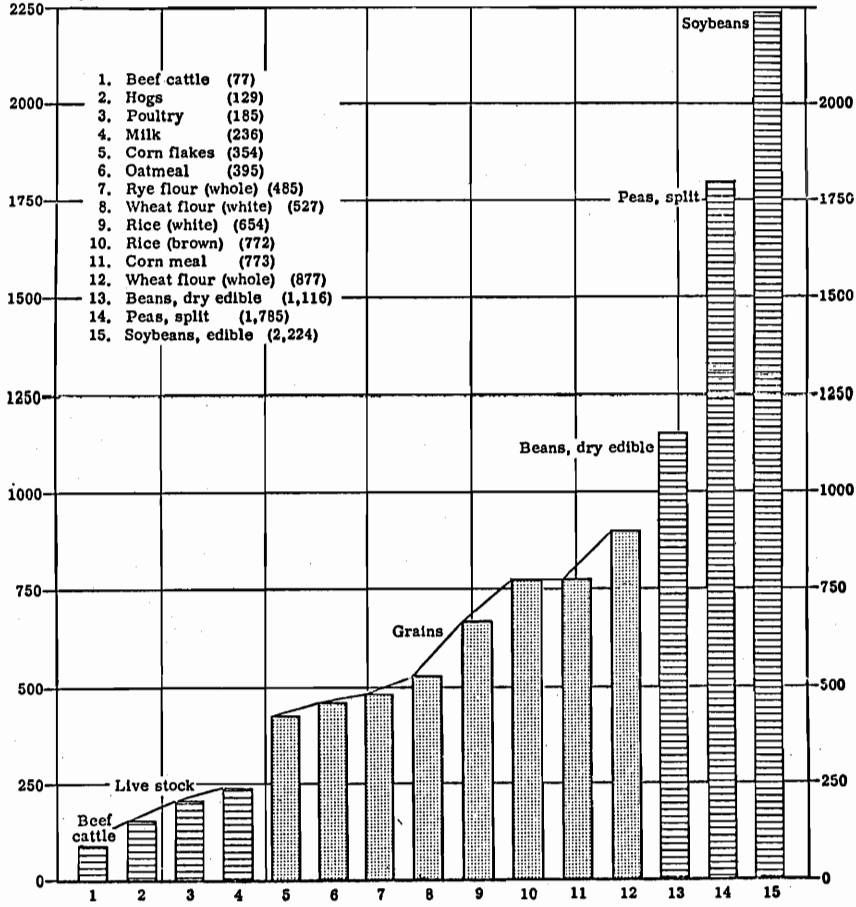



(1) From Bean, L. H. WHO/FAE/UNICEF Protein Advisory Group News Bulletin No. 6: 20-31 April 1966

## *5.9.0 Oilseed Proteins*

. . . Then said Daniel to the steward . . . "Try thy servants, I beseech thee, ten days; and let them give us pulse to eat, and water to drink. Then let our countenances be looked upon before thee and the countenances of the youths that eat of the king's food;" . . . And at the end of ten days their countenances

Figure 5-3 NUMBER OF DAYS OF PROTEIN REQUIREMENT
(by a moderately active man)
PRODUCED BY ONE ACRE, YIELDING SELECTED FOOD PRODUCT (1)



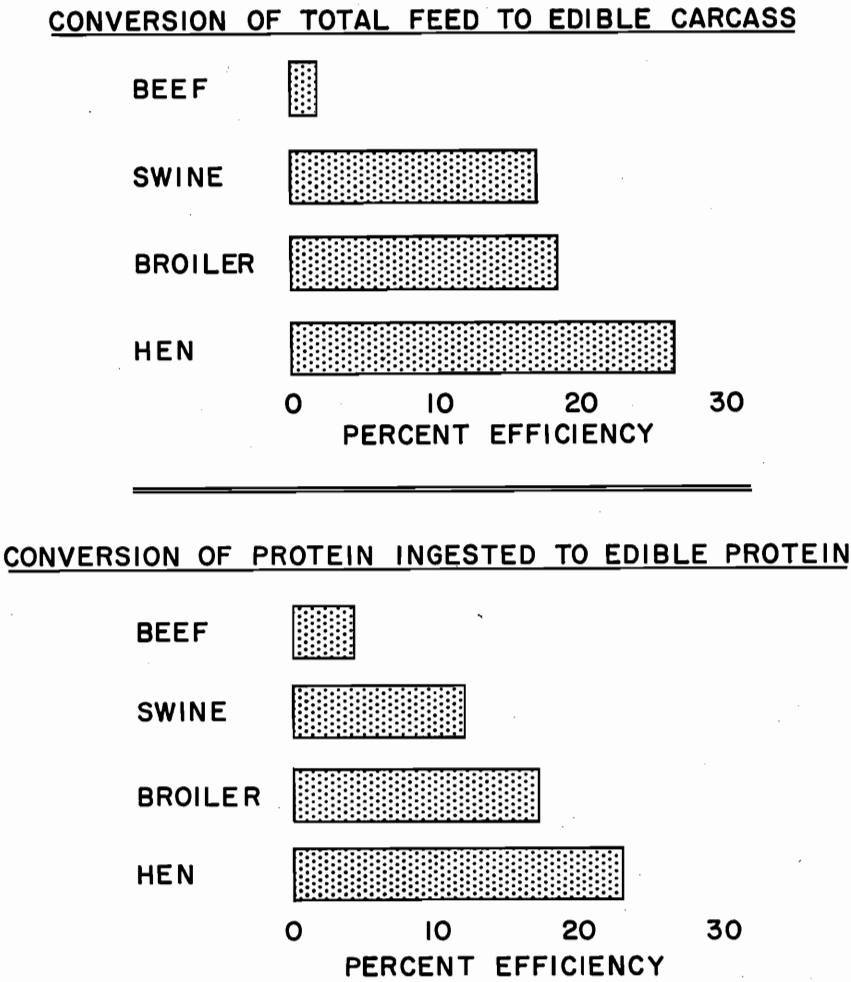

(1) From Bean, L. H. WHO/FAE/UNIEF Protein Advisory Group News Bulletin No. 6: 20-31 April 1966

**appeared fairer, and they were fatter in flesh, than all of the youths that did eat of the king's food . . .**

**—Book of Daniel 1: 3–16.**

The potential of protein for humans from present production of oilseeds equals the amount of protein now supplied by animal sources. Technologies exist and new ones are being developed rapidly to produce from these proteins a wide spectrum of food products which include flaked and extruded cereal protein mixtures, protein beverages, bakery products, desserts, spreads, and textured products. Only a small fraction of the proteins in oilseeds is consumed directly by humans.

Figure 5-4




In the United States few soybeans are used directly for human food and hardly any cottonseed or peanut protein is eaten by human beings anywhere. One of the greatest opportunities for increasing the world protein supply, without increasing agricultural production, is to utilize the presently available oilseed resources directly for humans.

About 70 percent of the world supply of proteins is derived from vegetable sources, mainly cereal grains. The largest concentrations of proteins in vegetables are found in the oilseeds. The major oilseeds in terms of total protein are soybeans, cottonseeds, and peanuts—(Table 5–17). The world production and distribution of these are given in Table 5–18.

TABLE 5–16.—*Feed protein required to produce edible protein from certain animal sources*

| Food | Edible protein (percent) | Protein efficiency (percent) | Millions of metric tons | | | Ratio of converting feed protein to animal protein [1] |
|---|---|---|---|---|---|---|
| | | | Total food produced | Protein produced | Feed protein required | |
| WORLD | | | | | | |
| Eggs [2] | 12.9 | 23.49 | 12.4 | 1.6 | 6.8 | 4.3 |
| Beef and veal [2] | 16.5 | 4.59 | 32.1 | 5.3 | 115.4 | 21.8 |
| Pork [2] | 10.2 | 12.50 | 29.2 | 3.0 | 23.8 | 8.0 |
| Poultry [2] | 18.6 | 17.70 | 7.3 | 1.4 | 7.7 | 5.5 |
| Cows milk [2] | 3.5 | 22.93 | 324.9 | 11.4 | 49.6 | 4.4 |
| REGIONS OF THE WORLD | | | | | | |
| Beef and veal: [3] | | | | | | |
| Europe | | | 7.2 | 1.2 | 25.6 | |
| North America | | | 9.5 | 1.6 | 34.2 | |
| Latin America | | | 5.7 | .9 | 20.5 | |
| Near East | | | .7 | .1 | 2.5 | |
| Far East | | | 1.1 | .2 | 4.0 | |
| Africa | | | 1.6 | .3 | 5.8 | |
| Oceania | | | 1.3 | .2 | 4.7 | |
| Pork: [3] | | | | | | |
| Europe | | | 9.7 | 1.0 | 7.9 | |
| North America | | | 6.2 | .6 | 5.0 | |
| Latin America | | | 1.2 | .1 | 1.0 | |
| Near East | | | | | | |
| Far East | | | 1.2 | .1 | 1.0 | |
| Africa | | | .2 | (.02) | .2 | |
| Oceania | | | .2 | (.02) | .2 | |
| Cows milk: [3] | | | | | | |
| Europe | | | 139.5 | 4.9 | 21.3 | |
| North America | | | 65.8 | 2.3 | 10.0 | |
| Latin America | | | 22.6 | .8 | 3.4 | |
| Near East | | | 6.7 | .2 | 1.0 | |
| Far East | | | 15.7 | .5 | 2.4 | |
| Africa | | | 9.9 | .3 | 1.5 | |
| Oceania | | | 12.7 | .4 | 1.9 | |

[1] This represents the number of metric tons of feed protein required to produce 1 metric ton of edible protein.

[2] From U.S. Department of Agriculture. "The world agricultural situation" review for 1966—outlook for 1967. Foreign Agr. Econ. Rpt. No. 28.

[3] From Food and Agriculture Organization of the United Nations. Production Yearbook 1965.

According to Abbott,[48] pulses, oilseeds, and nuts supply almost 13 percent of the world's protein supplies ranging from a high of 27 percent of the diet in India, probably about the same in mainland China, to as low as 5 percent in the United States and 1 percent in Argentina (Table 5–20).

[48] Abbott, J. C., Protein supplies and prospects: the problem. Advance. in Chem. No. 57: 1–15, 1966. Reference p. 2.

TABLE 5–17.—*Major oilseeds used as food* [1]

| Species | Botanical name | Protein content, average percent | Oil content, average percent | World production, 1,000 metric tons | Major producing countries | Problems in processing as food |
|---|---|---|---|---|---|---|
| Soybean | Glycine max | 42 | 20 | [2] 35,000 | United States, China. | Antitrypsin factors. Hemagglutinin factor. |
| Peanut | Arachis hypogea. | 27 | 48 | [3] 14,800 | India, Senegal, Nigeria. | Aflatoxin. |
| Cottonseed | Gossypium | 30 | 30 | [3] 20,600 | United States, India, U.S.S.R., Mexico, United Arab Republic, Brazil, Pakistan. | Gossypol, malvalic acid, aflatoxin. |
| Sesame | Sesamum indicum. | 25 | 50 | [3] 1,500 | China, India, Sudan, Mexico. | Fiber, oxalate. |
| Sunflower | Helianthus annus. | 30 | 40 | [3] 6,840 | U.S.S.R., Argentina, Uruguay, South Africa, Turkey. | Fiber. |
| Coconut | Cocus nucifera | [4] 8 | [4] 65 | [3] [4] 3,200 | Philippines, Indonesia, Ceylon, India, Malaysia. | Do. |

[1] From Milner, M., General outlook for seed protein concentrates. Advance. in Chem. No. 57: 52–62 1966. Reference p. 54.
[2] Estimated for 1965.
[3] (6).
[4] Dried meats (copra).

TABLE 5–18.—*World production of major oilseeds* [1]

| Region or country | Production 1961–62 (million metric tons) | | |
|---|---|---|---|
| | Peanuts (in shell) | Cottonseed | Soybeans |
| World production (excluding U.S.S.R.) | 14.1 | 20.6 | 31.0 |
| North America | .79 | 5.42 | 18.7 |
| Latin America | ---------- | 2.8 | .31 |
| Near East | .23 | 1.94 | .005 |
| Far East | 5.99 | 2.94 | 1.29 |
| Africa | 3.90 | .46 | .030 |
| India | 4.76 | 1.60 | ---------- |
| Indonesia | .40 | .002 | .43 |
| Mexico | .090 | .77 | ---------- |
| Nigeria | 1.25 | .056 | .015 |
| Brazil [2] | .58 | 1.15 | ---------- |

[1] From Parpia, H.A.B., and Subramanian, n., Plant protein foods in India. Advance. in Chem. No. 57: 112–132. 1966.
[2] 1960–61.

In 1965, the estimated production of meats alone for the 44 major producing countries was 50 million tons.[49] The total production of animal protein, including milk and eggs is estimated at 22 million metric tons for 1964 (Table 5–19). A cursory inspection of Table 5–17 shows that the three major oilseed meals could provide more protein annually for man than is now available from animal sources. The basic problem is that almost all of the soybean meal produced in the United States, one of the two largest producers in the world, goes into animal feed.

### *5.9.1 Soybeans*

The United States has been increasing its acreage and production of soybeans. After extraction of the oil, most of the meal is used for animal feeds. The production and "disappearance" of soybeans is given in Table 5–21.

TABLE 5–19.—*World production of animal protein in 1964* [1]

| Commodity: | *Protein production (million metric tons)* |
|---|---|
| Eggs | 1.6 |
| Beef and veal | 5.3 |
| Pork | 3.0 |
| Poultry | 1.4 |
| Cows milk | 11.0 |
| Total | 22.3 |

[1] Taken from Table 5–16.

Soybeans have been a source of protein for human beings for millennia. In large parts of the world, soybeans are still processed or fermented by ancient techniques to make them suitable for human food. Today four types of soy products are processed. They are, in order of increasing cost, full-fat soy flour (42 percent protein), standard soybean flour (52 percent protein), soy protein concentrate (70 percent protein), and soy protein isolate (90 percent protein). Prices range from 12 to 40 cents a pound of protein. The full-fat product as well as the 52 percent protein product can be used in cereal protein mixtures, in beverages, in baked products, and, in some instances, in textured products. Soy products have the advantage of low cost but these cheaper soy products still have the problem of poor flavor and often cause flatulence.

The 70 percent protein concentrate has a high nutritive value because practically all the protein is retained while the physiologically deleterious materials are removed during processing. It should have broader use because it can be incorporated into textured products more easily.

[49] U.S. Department of Agriculture, Economic Research Service. Foreign Agri. Econ. Report No. 2. 1965.

TABLE 5–20.—*Per capita protein supplies in selected countries* [1]

| Country | Total protein | Sources | | | | | |
|---|---|---|---|---|---|---|---|
| | | Animal | Grain | Starchy roots | Pulses, oilseeds, nuts | Meat and poultry | Milk and milk products |
| United States: | | | | | | | |
| Grams per day | 92 | 65 | 15 | 2 | 5 | 32 | 24 |
| Percent | 100 | 70 | 16 | 2 | 5 | 35 | 26 |
| Argentina: | | | | | | | |
| Grams per day | 98 | 57 | 34 | 3 | 1 | 43 | 11 |
| Percent | 100 | 58 | 35 | 3 | 1 | 44 | 11 |
| Peru: | | | | | | | |
| Grams per day | 49 | 12 | 22 | 6 | 5 | 6 | 3 |
| Percent | 100 | 24 | 45 | 12 | 10 | 12 | 6 |
| India: | | | | | | | |
| Grams per day | 51 | 6 | 30 | ---------- | 14 | 1 | ---------- |
| Percent | 100 | 12 | 59 | ---------- | 27 | 2 | ---------- |
| Japan: | | | | | | | |
| Grams per day | 67 | 17 | 31 | 2 | 13 | 3 | 1 |
| Percent | 100 | 26 | 46 | 3 | 19 | 5 | 1 |

[1] From Food and Agriculture Organization of the United Nations. State of food and agriculture, 1964. Rome, 1964. Ch. III.

TABLE 5–21.—*Soybeans: Supply and disappearance, 1953–66* [1]

[Million bushels]

| Year beginning September | Supply | | | Disappearance | | | | Soybean oil exports (bean equivalent) [3] |
|---|---|---|---|---|---|---|---|---|
| | Production | Stocks Sept. 1 | Total supply | Exports | Crushings | Seed | Residual [2] | |
| 1953 | 269.2 | 22.4 | 291.6 | 40.1 | 217.8 | 22.9 | 2.7 | 7.1 |
| 1954 | 341.1 | 8.1 | 349.2 | 57.3 | 241.4 | 23.4 | 4.5 | 4.5 |
| 1955 | 373.7 | 22.6 | 396.3 | 68.6 | 281.9 | 25.8 | −1.0 | 43.5 |
| 1956 | 449.3 | 21.0 | 470.3 | 83.7 | 313.6 | 26.4 | 15.0 | 78.5 |
| 1957 | 483.4 | 31.6 | 515.0 | 88.4 | 350.9 | 29.5 | 3.4 | 72.0 |
| 1958 | 580.2 | 42.8 | 623.0 | 105.0 | 398.8 | 27.4 | 4.0 | 84.8 |
| 1959 | 532.9 | 87.8 | 620.7 | 139.9 | 394.0 | 29.3 | 5.7 | 96.2 |
| 1960 | 555.3 | 51.8 | 607.1 | 134.7 | 406.1 | 32.9 | 6.3 | 65.4 |
| 1961 | 679.6 | 27.1 | 706.7 | 149.4 | 431.4 | 33.5 | 14.1 | 111.8 |
| 1962 | 669.2 | 78.3 | 747.5 | 180.5 | 472.7 | 34.4 | 13.9 | 107.0 |
| 1963 | 699.4 | 46.0 | 745.4 | 187.2 | 436.8 | 36.5 | 17.6 | 103.1 |
| 1964 | 701.9 | 67.3 | 769.2 | 212.2 | 479.0 | 40.5 | 7.9 | 125.2 |
| 1965 [4] | 843.7 | 29.7 | 873.4 | 255.0 | 535.0 | 42.0 | 11.0 | 93.5 |
| 1966 [5] | 860.0 | 30.0 | 890.0 | ---------- | ---------- | ---------- | ---------- | ---------- |

[1] From handbook of agricultural charts, 1966. U.S. Department of Agriculture, Agriculture Handbook 325, 155 pp., October 1966.

[2] Computed from unrounded numbers. Includes use for feed, direct use for food, and loss.

[3] Based on actual yield of oil per bushel of soybeans crushed.

[4] Partly estimated.

[5] Indicated Aug. 1.

NOTE.—Data published currently by U.S. Department of Agriculture, ERS, fats and oils situation.

The protein isolate, the most expensive product, can be spun into fiber or made into gels and can be incorporated into sophisticated textured products. Its disadvantages are higher cost and a lower nutritive value than the original protein because, in the process of isolation, protein is concentrated selectively. The methionine, for example, is much lower in the protein isolate. The limiting amino acid in soybean protein is methionine (See Table 5–3). This can be remedied by fortifying the soy protein with methionine [50] or other protein concentrates during the spinning and texturing operation. Products which simulate meat, fish, and poultry have been made from such material.

Soybeans have not been grown economically as yet in tropical climates and are not a major crop in Central America, most of South America, Africa, India, and Pakistan. Attempts are being made now to determine whether or not soybeans can be grown in countries such as India.[51] Soybeans could perhaps replace other crops presently used for non-food products. On the other hand, considering the efficiency of American production, it may be more economic to produce this commodity in the United States.

Soy products could be used effectively in fortification of cereals, in children's foods, or in new foods. In areas where soy products are now unavailable, it may be practical to import soy products for use in foods. The potential of using and producing soybeans should be evaluated in areas where there is need. Research should be accelerated on removing physiological and flavor factors in soybeans which may interfere with utilization as human foods.

The necessity of increased production of soybeans specifically for human use cannot be overstressed. For instance, based on a reported 1966 U.S. production of 626 million bushels of soybeans, each additional one percent increase in production would yield 30.3 thousand metric tons of oil and 61.5 thousand metric tons of protein or enough protein to correct the lysine deficiency of 1.0 million metric tons of wheat. If soybean meals now being used for animal feed were diverted to human use, some substitute protein would be needed for monogastric animal feed. To encourage more production of soybeans by U.S. farmers, price support will be needed because the yields are small compared to corn, an alternate crop.

### *5.9.2 Cottonseeds*

The world production of cotton has not been increasing as rapidly as other sources of oilseeds (Table 5–22). Production has lagged be-

[50] There is one problem with methionine fortification. Methionine has an objectionable taste detectable at about 0.02 percent. The taste can be masked with vanilla in liquids and presumably it could be masked also when used in solid foods.

[51] Experimental plantings of soybeans in India have produced good yields. However, it should be pointed out that the use of land for alternative crops may be more economic.

TABLE 5–22.—*Cotton: World production and consumption by areas, average 1955–59, annual 1960–65* [1, 2]

[Millions of bales]

| Year beginning Aug. 1 | Production | | | | | Consumption | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | United States | Foreign free world | | Communist | Total world | United States | Foreign free world | | Communist | Total world |
| | | Importing | Exporting | | | | Importing | Exporting | | |
| Average: | | | | | | | | | | |
| 1955–59 | 13.0 | 4.6 | 12.0 | 14.2 | 43.8 | 8.7 | 16.0 | 4.6 | 15.0 | 44.3 |
| 1960 | 14.4 | 5.3 | 13.7 | 13.1 | 46.5 | 8.3 | 17.9 | 5.4 | 15.4 | 47.0 |
| 1961 | 14.4 | 5.0 | 14.5 | 11.2 | 45.1 | 9.0 | 17.8 | 5.7 | 13.3 | 45.8 |
| 1962 | 14.9 | 5.8 | 16.1 | 11.0 | 47.8 | 8.4 | 77.6 | 5.6 | 13.3 | 44.9 |
| 1963 | 15.3 | 6.0 | 15.9 | 12.9 | 50.1 | 8.6 | 18.4 | 6.0 | 14.6 | 47.6 |
| 1964 | 15.2 | 5.8 | 17.1 | 13.8 | 51.9 | 9.2 | 18.9 | 6.2 | 15.4 | 49.7 |
| 1965 [3] | 15.0 | 5.7 | 77.2 | 14.6 | 52.5 | 9.5 | 18.5 | 6.1 | 16.2 | 50.3 |

[1] United States in running bales; others in bales of 480 lbs net.
[2] From handbook of agricultural charts, 1966. U.S. Department of Agriculture, Agriculture Handbook 325, 155 p. October 1966.
[3] Partly estimated.

cause the textile industry now uses synthetic fibers as well as cotton and wool. Since the major economic component of cotton is the lint, there probably will be only small increases in production of cottonseed unless new uses are found for cotton fibers.

Another limiting factor in the use of cottonseed as a source of protein for non-ruminants is gossypol, a polyphenol found in dark spots normally referred to as the pigment glands of the seed. This polyphenol is toxic to man and must be destroyed, removed by solvent extraction, or inactivated by binding to other seed components. During processing, careful control of heat is necessary to minimize loss of lysine. After processing, cottonseed meal contains 50 to 55 percent protein which can be increased to 70 percent by extraction of soluble carbohydrates.

About 10 years ago, a glandless variety of cottonseed was discovered. This year 15,000 acres of this variety were planted in Texas. The nutritive value of protein concentrate from glandless cottonseed is superior to that obtained from the seeds with glands presumably due to the absence of toxic factors. Further research on glandless cottonseed and larger plantings of this variety could provide larger amounts for human feeding. The efficacy of cottonseed protein in human feeding has been demonstrated on a large scale in Central America—cottonseed is used in the INCAP protein mixtures, Incaparina. Its use in formulations like Incaparina should be extended to other weaning

mixtures where it can replace milk solids and some of the soybean protein.

The great virtue of cottonseed protein is that it is indigenous to protein-poor tropical areas of Africa, Asia, and Latin America (See Tables 5–17, 5–18).

*5.9.3 Peanuts*

Peanuts (groundnuts) are one of the leading agricultural crops of the world for the production of oil and plant protein. Not only are peanuts an important crop in this country, but they are grown in the warmer parts of all six continents.

Although peanuts may be consumed directly by man, about 65 percent of the world's peanut production is crushed for oil. Peanut oil comprises about 20 percent of the world's trade in edible oils and oil-bearing materials.

In India, after the oil is removed by crushing and solvent extraction, a meal remains which contains about 50 percent protein. Further treatment removes most of the carbohydrates, yielding a protein concentrate with more than 70 percent protein. In addition, a peanut lipoprotein (70 percent protein—30 percent lipid) may be produced which could be used in beverages.

Peanut protein is deficient in three amino acids: methionine, lysine, and threonine (Table 5–3). Peanuts probably would not be used in foods unless supplemented with amino acids or with other higher quality protein to make up for the deficient amino acids. Peanuts are a more concentrated source of protein than cereal grains so their use should be encouraged wherever possible. Peanuts are indigenous to the Caribbean Islands, to South America, and Africa. Large amounts are grown in India. The addition of groundnuts to the world protein supply could measurably reduce protein malnutrition.

One of the difficulties with peanuts is the presence of aflatoxin, a mold metabolite, which is often prevalent because of the way in which the peanut is grown, harvested and stored. Considerable research is now underway, and this should be accelerated, on ways and means of removing aflatoxin from peanuts. Present development of peanut products should not be impeded because careful handling and picking does reduce the aflatoxin content to manageable proportions. The increased use of peanuts in dietaries should be encouraged using careful means of selection to assure freedom from aflatoxin.

In all instances it should be understood that oilseed protein concentrates involve a processing step. This processing is essential to render them suitable for human consumption. If it is not done correctly, the product may not be completely satisfactory and the protein value may be reduced by overheating. Therefore, it is not sufficient to talk about processed products from soy, cottonseed, peanuts, or the like. It is

necessary to talk about particular products meeting well-defined specifications. Such specifications have been prepared by UNICEF for cottonseed and peanut and soy products and no doubt will be refined as more information is available.

### *5.10.0 The Fishery Protential of the Ocean*

. . . There's fish in the sea, no doubt of it, as good as ever came out of it . . .

—W. S. Gilbert, *Patience* Act i. (1881).

Taken as a whole, the seas contain a tremendous potential for world feeding. Only a few dozen of the 20 to 25 thousand species of fish are used directly or indirectly as food by man. The potential, however, is but the beginning. In order to achieve even a part of this potential, large expenditures of money on boats and equipment to catch and process the fish will be required and this will entail time as well as money. The problem of whether acceptable fish are available off the coast of certain developing countries remains as does the acceptability of fish in some of these cultures. With concerted efforts and large expenditures for boats, fishing gear, docks, and preservation equipment, it is estimated that in 5 to 10 years a substantial increase in harvest and preservation of the ocean's potential could be achieved.

There is little doubt that the potential productivity of fish is considerably larger than the 1964 harvest of 56 million tons. Many species are not harvested today for lack of specialized gear and for lack of a market; yet, many of these species are not only of nutritive value equal to that of the few that are presently caught, but exist in unknown although in probably vast quantities. The estimates of potential fish catch are many and vary widely, mainly due to lack of adequate data and understanding of biological processes in the oceans. It is important to be aware of their range and the reasoning employed to arrive at the estimates. Some, although made quite recently by recognized experts, appear to be too low, some others appear to be fantastically high. It is generally agreed, however, that the catch of fish can be increased markedly.

One type of estimate (by Graham and Edwards) was based on the potentially productive area of the continental shelves and the output per acre of known fishing grounds (Table 5–23). It was concluded that an annual harvest of 20 pounds of fish per acre was a conservative average estimate for the known continental shelves, covering over 6 billion acres. This estimate led to a figure of 120 billion pounds of (presumably known and commonly used) fish per year, or 55 million metric tons. The estimate assumed that the catch of pelagic fish, not associated with the continental shelves, is negligible, and was only for bony fishes; whales, sharks, and invertebrates were not included. It is significant

that at the time when Graham and Edwards [52] made this calculation, the Peruvian catch was very small. It is now 350 pounds per acre or 9 million metric tons annually.

TABLE 5-23.—*Total sustainable annual fisheries harvest, as estimated by various authors*

| Author: | *Estimated total sustainable annual harvest in million metric tons* |
|---|---|
| Graham and Edwards [1] | 55 |
| Pike and Spilhaus [2] | 190 |
| Schaefer [3] | 200 |
| Larkin [4] | 500 |
| Kesteven and Holt [5] | 500 |
| Chapman [6] | 2,000 |
| Schmitt [7] | 2,000 |

[1] Graham, H. W., and Edwards, R. L., The world biomass of marine fishes. *In:* Heen, E., and Kreuzer, R. (eds). Fish in nutrition. London, Fishing News, 1962. 477 p. pp. 3–8.

[2] Pike, S. T., and Spilhaus, A., Marine resources. A report to the Committee on Natural Resources of the NAS/NRC. Nat. Res. Council Publ. 100–E: 1–8. 1962.

[3] Schaefer, M. B., The potential harvest of the sea. Amer. Fish. Soc. Trans. 94(2): 123–128. April 1965.

[4] Larkin, P. A. What is the potential of North American Fisheries? The Fish Boat 10(7): 21–23, 1965.

[5] Kesteven, G., and Holt, S. J., A note on the fisheries resources of the Northwest Atlantic. FAO Fishery paper No. 7. 1955.

[6] Chapman, W. M., Ocean fisheries—status and outlook. Paper presented to Marine Technological Society, Washington, D.C., 1966.

[7] Schmitt, W. R., The planetary food potential. New York Acad. Sci. Ann. 118 (art. 17): 645–718. Mar. 5, 1965.

Graham and Edwards also made another estimate of fishery potential of 115 million metric tons of marine fishes and invertebrates annually. This second type of estimate is based on the production of plants in the sea. Kesteven and Holt estimated that the net production of plants was between 12 and 15 billion tons of carbon per year; or 500 billion tons of phytoplankton. If this plant matter is fully harvested by herbivores and if a conversion efficiency of about 20 percent is assumed, the annual production of herbivores is 100 billion tons. If the conversion efficiences of primary and secondary carnivores are 10 percent, then 1 billion metric tons of bony fish are produced, of which 50 percent or 500 million metric tons might constitute a sustainable annual harvest.[53] Based on the estimate that 19 billion tons of carbon are fixed annually into living matter in the oceans, it was postulated that 2 billion tons of animals are available annually [54] that are "large enough and useful enough to form the basis of practical commercial harvesting." [55] A conversion efficiency of 10 percent was used in this estimate

[52] Graham, H. W., and Edwards, R. L., The world biomass of marine fishes. *In:* Heen, E., and Kreuzer, R. (eds). Fish in nutrition. London, Fishing News, 1962. 447 p. pp. 3–8.

[53] Kesteven, G., and Holt, S. J., A note on the fisheries resources of the Northwest Atlantic. FAO Fishery Paper No. 7. 1955.

[54] Chapman, W. M., Ocean fisheries—status and outlook. Paper presented to Marine Technological Society, Washington, D.C., 1966.

[55] Schmitt, W. R., The planetary food-potential. New York Acad. Sci. Ann. 118 (art. 17): 645–718. Mar. 5, 1965.

but it was assumed that some of the catch would be primary as well as secondary carnivores.

Of all the estimates, some of which are as great as two billion tons (Table 5–23), only the first estimate of Graham and Edwards [56] for bony fishes will be realized in the near future. The catch of bony marine fishes was 40 million tons in 1964 or 75 percent of their estimate of potential annual yield.

In the past decade the fish catch has increased about 7 percent annually. At this rate of increase, the catch of bony fishes by 1969 would be as great as Graham and Edwards [57] estimate. It is generally concluded that this estimate is conservative and that the annual yield will continue to increase as new fishing areas and new stocks are utilized.

It is evident on the other hand that, if the catch of fishes continues to increase at 7 percent annually, the estimated catches of 2 billion metric tons would not be realized for about 50 years. It is apparent that if the highly publicized potential of the oceans is to be utilized, there will have to be a significant improvement in the amount and type of fishing effort. This effort will have to include research and development of new fishing methods for pelagic species and, ultimately, to change fisheries harvest from hunting and capturing to herding and cultivating.

That marine and fresh-water fisheries could supply more protein and calories to diets in the lesser developed countries is discussed in Sections 5.11.0 and 5.12.0. Fish now provide a significant source of protein in some countries as shown in Table 5–24 which presents some statistics on the per capita consumption of fish and fish products.

### *5.11.0 Protein From Inland Fisheries*

Fish—an animal that inhabits water.

—Dr. Samuel Johnson.

The growing of fish in ponds, in rice paddies, and in natural man-made impoundments represents a realistic means of rapidly providing large quantities of animal protein in tropical climates.

Most of the inland fishery products are fishes with an annual catch estimated at 15 million metric tons live weight. This estimate includes noncommercial landings and is therefore greater than the 1964 fresh-water commercial catch of 6.6 million metric tons.[58] In some countries, the fresh-water catch is a larger fraction (Table 5–25). The catch is derived from natural waters and man-made impoundments, from

[56] Graham, H. W., and Edwards R. L., The world biomass of marine fishes. *In:* Heen, E., and Kreuzer, R. (eds). Fish in nutrition. London, Fishing News, 1962. 447 p. pp. 3–8.

[57] Ibid.

[58] Food and Agriculture Organization of the United Nations. Yearbook of fishery statistics, 1964. Vol. 18. Rome, 1965.

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TABLE 5-24.—*Per capita consumption of fish and fish products* [1]

| Country | FAO, 1957-59 edible weight (kilograms per year) | USDA, 1957-58 landed weight (kilograms per year) | Total animal protein 1954-57 (percent) | Total calories 1958 (percent) |
|---|---|---|---|---|
| Japan | [2] 22 | 40 | 72 | 3.0 |
| Portugal | 20 | 35 | 59 | 2.4 |
| Norway | 19 | 44 | 19 | 2.3 |
| Sweden | 18 | 20 | 12 | 1.2 |
| Philippines | 15 | 24 | NA | 1.9 |
| Denmark | 15 | 22 | 13 | 1.2 |
| Taiwan | 11 | 22 | 54 | 1.5 |
| Finland | 11 | 14 | 11 | .8 |
| Spain | 11 | 21 | NA | 1.4 |
| United Kingdom | 10 | 19 | 9 | 1.0 |
| Thailand | 9 | 28 | NA | 6.2 |
| Greece | 8 | 14 | 16 | .9 |

[1] From Christy, F. T., and Scott, A., The common wealth in ocean fisheries: some problems of growth and economic allocation. Baltimore, Johns Hopkins Press, 1966. 296 pp. Reference p. 19.

[2] 22 kg. per year of fresh edible weight is equivalent to about 9 g. of protein per day (based on protein content of 16 percent).

harvesting natural populations, and from farming and culturing desired species.

### *5.11.1 Usage of the Catch*

Most of the catch is sold locally as fresh fish, with a minor, but increasing, amount processed as frozen fish. Fresh-water fish, for the most part, are used in the diet as a source of high quality protein.

In the developing countries where there is no refrigeration, particularly in Asia and offshore Pacific islands, fish are processed by old techniques and sold dried, salted, smoked, and as sauce. These methods of processing preserve catches in excess of the current demand for fresh fish and make it possible to transport fisheries products to distant markets. Fish too small to market fresh can be processed into fish sauce. The basic process consists of placing alternate layers of fresh fish and salt in a tank and allowing enzymatic autodigestion to proceed until a clear liquid is produced. Sauces of this type are widely used over rice and other cereals to improve taste and to provide supplemental proteins and vitamins. Sauces can be produced very easily which is one advantage over such products as fish protein concentrate (FPC) that require extensive processing equipment, although sauces that have a somewhat lower nutritive value and a high salt content.

### *5.11.2 Amount and Origin of the Catch*

The inland fishery catch from rivers, streams, lakes, swamps, reservoirs, fresh-water ponds and brackish-water ponds, excluding

TABLE 5-25.—*Fresh-water fish as percent of total fish catch in 1962*[1]

| Country: | *Percent* |
|---|---|
| Mainland China (1959) | 40 |
| Indonesia | 43 |
| Pakistan | 66 |
| India | 34 |
| Thailand | 20 |
| Philippines | 3 |
| Japan | 1 |
| U.S.S.R. | 10 |
| United States | 2 |
| West Germany | 2 |
| Italy | 6 |

[1] From Christy, F. T., and Scott, A., The common wealth in ocean fisheries: some problems of growth and economic allocation. Baltimore, Johns Hopkins Press, 1966. 296 pp. Reference p. 23.

brackish bays and estuaries, is estimated at 30 percent of the world total. The annual catch from rivers and natural lakes varies from about 5 to 170 pounds per acre, with the average being about 20 pounds per acre. The overflow swamp fisheries along the great rivers of Asia and Africa are more productive because most of the crop can be harvested as the annual flood waters recede. The catch varies, depending upon the extent and length of time the swamps are flooded, from 30 to 400 pounds of fish per acre with the average being 100 pounds per acre. The annual catch is 270 thousand metric tons from the Mekong River Swamps, 3 thousand metric tons from the Nile flood-fisheries, and 45 thousand metric tons from the Middle Niger.[59] These catches will decrease as rivers are impounded for irrigation, power, and other purposes and as swamp lands are claimed for agriculture. The total catch from all natural waters is estimated at 13.2 million metric tons or 88 percent of the total inland catch.

The catch per acre in reservoirs ranges from 5 to more than 100 pounds per acre, with an average of about 25 pounds per acre. About 5 percent of the total inland catch or 0.75 million metric tons come from reservoirs.

More intensive fishing probably could increase the catch by 50 to 100 percent. The fish populations in reservoirs result from expansion of the riverine fish populations and often contain a large percentage of less desirable fish. Because of depth, the harvest of fish in most reservoirs is difficult with the primitive methods presently in use. Better management techniques are needed for poisoning or eliminating undesirable species, for stocking with desirable species, and increasing productivity with nutrient additions, and improved harvesting methods could be used to increase the catch significantly. Fishcultures have

[59] Hickling, C. F., Tropical inland fisheries. New York, Wiley, 1961. 287 pp.

been developed for a variety of conditions and for different intensities of management. They are estimated to supply more than 7 percent of the world catch of fresh-water fish or about one million tons annually.

*5.11.3 Types of Fish Cultures*

Fish are cultured in many different environments and under many different conditions. Fishcultures offer one attractive means of increasing local supplies of animal protein in developing countries because relatively small amounts of capital are required and because, in some instances, fishcultures can be undertaken as a part of the improvement of agricultural practices.

*5.11.3.1 Fresh-water Ponds.* Annual production in fresh-water ponds varies from 25 pounds per acre in low-fertility, unmanaged waters to more than 5 tons per acre in intensively managed tropical ponds. Production is dependent on the available fish feeds, the species of fish cultured, and the intensity of management.

The available food supply is used more efficiently if a mixture of fishes with different feeding habits is cultured. The length of the growing period (when water temperatures are 60° F or above) also affects annual production; therefore, other factors being equal, yields are highest in tropical areas.

*Unfertilized ponds:* The lowest level of management consists of eliminating undesirable species and stocking desirable species of fish. Productivity is limited by the fertility of the lands in the watershed, including that underlying the impoundment, and by the efficiency of food conversion of the stocked species. In areas of infertile land, the annual harvest from such ponds is low, seldom exceeding 50 to 100 pounds per acre when harvested by nets and lines, or 150 to 500 pounds per acre when harvested by draining. The richer ponds may yield as much as 1,000 pounds per acre annually.[60]

*Fertilized ponds:* The second level of management involves fertilization to correct nutrient deficiencies of bottom soil and water and the stocking of desirable species. The annual harvests from waters in poor land areas can be increased to approach or exceed the natural productivity of waters from the richest watersheds. Average annual yields per acre for net and line fishing may approach 150 to 500 pounds and for draining may be as much as 1,000 to 1,500 pounds.

*Feeding and fertilization with agricultural wastes:* The third level of management is culturing a mixture of fishes and feeding and fertilization with agricultural wastes. The classical example is the Chinese technique in which crop and animal wastes, weeds and grasses

[60] Huet, M., Aperçu de la pisciculture en Indonesia. Bull. Agr. du Congo Belge 47(4): 901–957. Aug. 1956.

fertilize the water and are also consumed directly by the fish. The pond muds which accumulate nutrients are removed periodically to be used as fertilizer for agricultural crops. Annual yields from this type of fish culture may be as much as 2,200 to 5,000 pounds per acre.[61]

*Feeding with grains, seed meals or prepared fish feeds:* The fourth level of management involves feeding selected species with prepared fish feeds such as grains, seed meals, fish meals, rice bran, waste rice, and materials containing high concentrations of vitamins. As little as 1.4 to 1.7 pounds of food were required to produce one pound of fish when brook and brown trout were raised in troughs.[62] In ponds, prepared foods were used to supplement natural foods, and 1.5 to 1.7 pounds of food were needed to produce one pound of channel catfish (*Ictalurus punctatus*) and as little as 0.7 to 1.0 pounds of food were needed to produce a pound of *Tilapia mossambica*.[63, 64] Certain species of fish are as efficient in food conversion as chickens, and more efficient than pigs, or other domestic animals produced for human consumption (Table 5–26).

Supplemental feeding of fish may be one means of converting oil seed meals, such as cottonseed, and other wastes containing protein that are not suitable for human food into a useful and desirable food source. Meals unfit for human consumption and damaged grains purchased on world markets are the basis for a productive pond fishery in Israel.

Maximum annual yields obtained by supplemental feeding of fish in ponds vary from 1,000 to 16,465 pounds per acre.[65, 66, 67]

It must be remembered that "pounds per acre" is misleading at this level of management because part or all of the feed comes from an unknown area outside the limits of the pond.

*5.11.3.2 Brackish water Ponds.* Most of the brackish water ponds are located in the Far East along the Asiatic mainland and in Japan, the Philippines, Formosa, and Indonesia. The annual production varies from 400 to 2,000 pounds per acre. Highest yields are from fertilized ponds and from ponds in which fish are fed supplementally with rice

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[61] Lin, S. Y., Pond culture of warm-water fishes. U.N.E./Conf. 7/Sec./W., 167, 1949. 13 p.

[62] Schumacher, R. E., Experimental feeding of a pelleted trout food to large fingerling and yearling brook, brown and rainbow trout, 1955–1956. Progr. Fish-Culturist 20(2) : 51–57. Apr. 1958.

[63] Swingle, H. S., Experiments on growing channel catfish to marketable size in ponds. SE Game & Fish Commissioners Ann. Conf. Proc. 12 : 63–72. 1958, publ. 1959.

[64] Swingle, H. S., Comparative evaluation of two tilapias as pond-fishes in Alabama. Amer. Fish. Soc. Trans. 89(2) : 142–148. Apr. 1960.

[65] De Bont, A. F., Techniques de pisciculture. Inst. pour la Rech. Sci. en Afrique Cent. Rapp. Annu. 1949 : 161–194.

[66] Kawamoto, N.Y., Production during intensive carp culture in Japan. Progr. Fish-Culturist 19(1) : 26–31. Jan. 1957.

[67] Pongsuwana, U., Production of Tilapia mossambica in an experimental pond at Bankhen, Thailand. Indo-Pacific Fish. Council Proc. 6(2) : 197–201. 1956.

TABLE 5–26.—*Efficiency of feed utilization of various animal species per 1,000 g. of feed intake* [1]

| Species | Liveweight gain (grams) | Energy gain (K calories) | Protein gain (grams) |
|---|---|---|---|
| Rat | 332 | 663 | 62 |
| Chicks | 356 | 782 | 101 |
| Pigs | 292 | 1,492 | 30 |
| Sheep | 185 | 832 | 22 |
| Steers | 163 | 748 | 26 |
| Catfish [2] | 715 | 935 | 118 |
| Trout [3] | 576 | 608 | 75 |

[1] Meyer, J. H., and Nelson, A. O., Efficiency of feed utilization by various animal species fed similar rations. J. Nutr. 80(4): 343–349, August 1963.

[2] Data reported in: U.S. Department of the Interior. Fish and Wildlife Service. Annual report on sport fisheries research, 1963. Washington, D.C., 1963.

[3] U. S. Department of the Interior. Bureau of Sport Fisheries and Wildlife. Cortland Hatchery Annual Report No. 31. 1963. 31 p.

bran and seed meals. The principal species raised are milkfish (*Chanos*), mullet (*Mugil*), and shrimp; Asiatic carps, common carp and tilapias are also raised in local areas.

*5.11.3.3 Flowing Water Cultures.* In ponds, feeding and production rates are limited by the rate at which wastes are eliminated from the water. A buildup of waste products in ponds can cause the loss of fish due to toxic materials or oxygen depletion. In flowing water cultures, these problems are eliminated as wastes are removed by rapid flows of uncontaminated water. Where high quality feeds are available, production is limited by the temperature, quality, and flow of water passing through the area containing the fish population. Under ideal conditions annual production is from 1 to 4 tons of fish per cubic foot per second of water flow.

Production of trout has ranged from 5 to 35 tons or more per surface acre of raceway. Similar or higher yields in flowing water have been reported for catfish (*Pangasius*) in Thailand and for carp (*Cyprinus carpio*) as much as 500 tons per acre in Japan. Here again, production "per acre" of surface is meaningless as it is a function of the amount of feed supplied and the flow of water. It merely serves to point out that large amounts of fish can be raised in small areas providing adequate water flow and feed are available.

Variations of flowing water cultures include raising fish in baskets or boxes suspended in streams or in the surface waters of lakes or reservoirs. These are of local importance in some areas of Asia.

*5.11.3.4 Fish Culture in Rice Fields.* There are approximately 197 million acres planted to rice annually. Approximately 30 percent of this acreage is covered with water long enough for a combined fish-rice culture. Despite repeated attempts to popularize the combined culture,

the idea has not met with the approval of most rice farmers. Higher and wider dikes must be built around the field to minimize erosion and a ditch must be dug in which the fish can survive when the field is dried. The fish also must be held in ponds and restocked into the second rice crop in many areas to grow them to marketable size.

There are 150 thousand acres of combined rice-fish cultures in Indonesia, producing an average of 300 pounds per acre, a total of 45 million pounds of fish. When supplemental feed is added, up to 1,000 pounds per acre are produced.

Wild fish grow in many paddy fields and the world production from this source is estimated at 150 thousand tons. Additional research upon suitable varieties of rice and suitable species of fish can increase yields for combined rice and fish production.

*5.11.4 Projected Future Demand*

At present, the availability and production of fish in inland waters are inadequate to provide protein needs for the existing human populations in Asia, Africa, and Latin America. In these regions, the availability of all fishery products (marine and fresh-water) is approximately 7 pounds per capita per annum. The total catch would have to be more than doubled to meet even minimum requirements for supplemental protein.

FAO has projected the probable demand for fish as food, allowing part of the increase for improved nutrition, as 40 to 45 million tons by 1970, approximately a 30 percent increase over the present demand. It would appear that this demand will increase to at least 90 million tons by the year 2000. If the fresh-water catch were increased in proportion to the projected demand, it would have to increase from the present 15 million metric tons to 40 million metric tons by 2000.

*5.11.4.1 Sources of the Projected Catch.* From the rivers, natural lakes and swamps which now produce 88 percent of the fresh-water catch, it is unrealistic to expect more than a 20 percent increase in sustainable catch, a maximum of 16 million metric tons. As pollution of many of these natural waters is increasing, the sustained yield in the year 2000 may actually be less than it is at present. Controlled fertilization of waters with effluent from sewage treatment could be used to increase production.

The catch from reservoirs could probably be increased to a sustainable yield of 50 pounds per acre with intensive fishing effort and utilization of somewhat less desirable but presently unutilized species. If water supply requirements double by the year 2000 and the acreage of reservoirs doubles also, the estimated sustained yield from this source would be approximately 3 million metric tons annually. Where phosphate fertilization of reservoirs is economically feasible, the yield might be as much as 100 or more pounds per acre. The possibility of

increasing production through fertilization has not been considered in the projections.

From combined rice-fish culture, approximately 30 percent of the 88 million acres in rice could produce an average of 100 pounds per acre or approximately 2.2 million metric tons.

To meet the remainder of the projected demand, 19 million tons will have to be produced from fish cultures (Table 5–27).

*5.11.4.2 Requirements for New Ponds.* To meet the demands as projected will require a 19-fold increase in production from fresh-water and brackish water fish cultures. The present world average yield per acre in pondcultures is approximately 450 pounds of fish annually. With no improvements in management, the present 5.2 million acres in ponds would have to be increased to 95 million to achieve the desired goal. Phosphate fertilazation and supplemental feeding will make it possible to reach the goal with only 20 million acres of ponds. Present distribution of ponds is not proportional to needs in the developing countries (Table 5–28). One of the primary values of pond culture, however, is that ponds can be built and operated where the food is most needed. They are especially valuable in developing countries where the catch must be consumed daily and locally because of lack of refrigeration and where there is a possibility of using the water for irrigation of gardens and other purposes.

*5.11.4.3 Requirements for Fertilizer and Feed.* Where phosphate fertilization of pond or reservoir waters is feasible, applications range from 20 to 50 pounds available $P_2O_5$ per acre. In general a pound of available $P_2O_5$ should increase annual yields from 5 to 8 pounds. In some areas, other nutrients may be limiting and must be supplied to increase yields.

Where supplemental feeding with a seed meal, rice bran, or fish meal alone or in various combinations is practiced, the conversion of food added to live weight of fish average 2.0 : 1, with the most efficient fish converting 0.7 to 1.7 pounds of feed to 1 pound of fish. If hays and waste organic residues are used as feed and fertilizer, the conversion

TABLE 5–27.—*Projected production of fresh-water fisheries; 1964 production and estimated sustainable yield in 2000*

[Million metric tons]

| | 1964 | 2000 |
|---|---|---|
| Rivers, swamps, and natural lakes | 13 | 16 |
| Reservoirs | 1 | 3 |
| Rice-fish culture | .02 | 2 |
| Fish cultures | 1 | 19 |
| Total | 15 | 40 |

ratio ranges from 20:1 to 40:1 for live weights of fish, emphasizing the need for research on ways to utilize these materials more efficiently.

*5.11.5 Time Goals for Expansion of Pond Areas*

Adequate sites are available world-wide for much greater expansion in pond acreage in both brackish waters and fresh-waters than that which is contemplated. The immediate deterrent to expanding production in developing countries, in addition to inadequate acreages in pond areas, is lack of trained manpower at all levels, from research to extension workers.

If by 2000, research can provide the necessary management inputs and 15 million acres of ponds are constructed, the projected increase in yield of 15 million tons can be obtained. This projection is based on an average yield of 2,200 pounds per acre in 2000, about five times the present average yield (Table 5–28). An extensive program of pond construction would have to be initiated in Africa and Latin America if protein needs are to be satisfied locally.

If the average cost for pond construction is $500 per acre, then the cost of new construction from 1967 to 1975 would average $80 millions annually, and from 1975 to 2000 would average about $200 millions annually.

## *5.12.0 Fish Protein Concentrate (FPC)*

. . . La mer, la mer toujours recommencée!

—Paul Valery.

To produce and utilize FPC will require an investment in plants and in boats to catch the fish. The possibility of "floating" or "factory" FPC plants has been suggested. But these remain to be proven feasible. Developments of factories and plants for its production, distribution and use can be achieved within a period of 5 years, given concerted effort (estimated to be several million dollars of initial capital investment for each megaration of FPC, see Section 5.12.1.2).

TABLE 5–28.—*Present and required fish pond areas to meet needs*

| Continent | Millions of acres in ponds | | |
|---|---|---|---|
| | Present | 1975 | 2000 |
| Asiatic, including Near East | 4.6 | 5.1 | 7 |
| Europe, including U.S.S.R. | 1.8 | 2.0 | 3 |
| Africa | .1 | .2 | 2 |
| Latin America | .1 | .2 | 5 |
| North America | 1.5 | 1.9 | 3 |
| Total | 8.1 | 9.4 | 20 |

Fish Protein Concentrate (FPC) is defined as any inexpensive, stable, wholesome product of high nutritive quality, hygienically prepared from fish. FPC is useful primarily as a protein additive for dietary staples and it must be produced in accordance with good food-handling practices in a manner that will not significantly lower its nutritive quality. If FPC is to be used by low-income groups, it must be inexpensive. The processing methods, ideally, should be relatively simple, safe, and adaptable for species of fish in different regions.

*5.12.1 The Potential FPC Resource*

*5.12.1.1 Introduction and Some Basic Assumptions.* It seems appropriate to examine the estimates of fisheries resources and the amounts of FPC that might be manufactured, realizing that fish will continue to be a dietary staple just as it is today. This analysis will attempt to indicate how much FPC, how much protein, and how much fish are required to supply a given population's protein needs.

This estimate is based upon the following assumptions:

1. The whole fisheries resource is composed of edible fish (in other words: it will be assumed that the number of toxic fish in existence is either insignificantly small or that the toxicity in certain fish can be eliminated by suitable means).

2. Unless otherwise specified, all fish, sharks, and marine animals that belong to other phyla and classes, such as whales, porpoises, squids, and mollusks contain about 16 percent by weight of protein.

3. Gear, vessels, and manpower will be available to harvest the fishery resource.

4. *All fish can be processed successfully into FPC with a protein content of 80 percent by weight and a yield of finished FPC of 15 percent by weight.* On the basis of the low figures, chosen to include processing losses, *100 metric tons of fish will yield 15 metric tons of FPC equivalent to 12 tons of 100 percent protein.*

5. An average daily consumption of the 20 grams of pure protein supplied by 25 grams of FPC is a sufficient daily supplement of quality protein.

6. A yearly ration for one person is 365 20-gram protein supplements or 9.1 kg of FPC.

*5.12.1.2 Definition of the "Mega Ration".* For the sake of simplicity, a mega ration (MR) is defined as that amount of FPC (80 percent protein) that will provide 1 million persons with 365 20-gram portions of pure protein.

*One MR* is, therefore, equivalent to:

$365 \times 20 \times 10^6$ gm. $= 7.3 \times 10^9$ gm., or
$7.3 \times 10^3$ metric tons of pure protein,
$9.1 \times 10^3$ metric tons of FPC, or
$61 \times 10^3$ metric tons of fresh fish.

Bearing the above assumptions in mind and converting the various estimates of total specific fisheries resources entirely into FPC, protein quantities, or "mega-rations", certain equivalents can be obtained and these are summarized in Table 5–29. From these figures it will be seen that, irrespective of whether these are based on the somewhat theoretical predictions of global fisheries resources (Table 5–29), or the more concrete availability estimates of particular fish species closer to home (Table 5–30), the volume of FPC that can be produced and the number of diets supplemented (even after taking conservative material losses into account) is impressive. For comparison purposes, the "mega-ration" equivalents of the total fishery harvest of 1964 for 11 principal fishing nations is presented in Table 5–31.

TABLE 5–29.—*Total sustainable annual fisheries harvest and their "mega-ration" equivalents* [1] *as estimated by various authors*

| Author | Estimated total sustainable annual harvest in million metric tons | Thousand mega-ration equivalents MR [1] |
|---|---|---|
| Graham and Edwards [2] | 115 | 1.9 |
| Pike and Spilhaus | 190 | 3.1 |
| Schaefer | 200 | 3.3 |
| Larkin | 500 | 8.3 |
| Kesteven and Holt | 500 | 8.3 |
| Chapman | 2,000 | 33.0 |
| Schmitt | 2,000 | 33.0 |

[1] Mega-ration: 1 "MR" or mega-ration is that amount of FPC (80 percent protein) that provides every day for 365 days 1,000,000 persons with 20 g. of pure protein. 1 MR=$7.3\times10^6$g. FPC=$9.1\times10^3$ metric tons of FPC=$60.52\times10^3$ metric tons fresh fish.

[2] See Table 5–23 for references.

TABLE 5–30.—*Estimated unutilized and underutilized fish stocks in U.S. coastal waters and their "mega-ration" equivalents* [1]

| Region | Estimated total sustainable annual harvest | | Mega-ration equivalents MR [1] |
|---|---|---|---|
| | In millions of pounds | In millions of metric tons | |
| Atlantic coast | 420 | .19 | 3.1 |
| Gulf of Mexico | 5,300 | 2.4 | 40.0 |
| Pacific coast plus Alaska | 6,458 | 2.9 | 47.8 |

[1] Mega-ration: 1 MR or mega-ration is that amount of FPC (80 percent protein) that provides every day for 365 days 1,000,000 persons with 20 g. of pure protein. 1 MR=$7.3\times10^6$g. FPC=$9.1\times10^3$ metric tons of FPC=$60.52\times10^3$ metric tons fresh fish.

TABLE 5–31.—*Total sea harvest for 1964 of the 11 principal fishing nations and the mega-ration equivalents of their catch*

| Country | Billion pounds [1] | In million metric tons | Number of people [2] (millions) |
|---|---|---|---|
| Peru | 20.13 | 9.1 | 150 |
| Japan | 13.97 | 6.4 | 110 |
| China (mainland) | 12.79 | 5.8 | 96 |
| U.S.S.R. | 9.87 | 4.5 | 75 |
| United States | 5.84 | 2.7 | 45 |
| Norway | 3.55 | 1.6 | 26 |
| India | 2.91 | 1.3 | 21 |
| Canada | 2.67 | 1.2 | 20 |
| Spain | 2.64 | 1.2 | 20 |
| United Kingdom | 2.15 | .9 | 15 |
| Iceland | 2.14 | .9 | 15 |

[1] Food and Agriculture Organization of the United Nations. Yearbook of fishery statistics, 1964. Vol. 18, Rome, 1965.
[2] That could be provided with 20 g. of protein daily if fish were converted to FPC.

### *5.12.2 Preservation of Fish*

The keeping qualities of foods in general, and of fish in particular, are related to water content. Thus, salting and sun-drying techniques were developed long ago for the conservation of fish and other foods. Another important reason for dehydration is reduction in weight and volume, reducing transportation costs of the dried products. Fish oils, fats and related compounds which are referred to by the generic term of "lipids" are of great importance because they become rancid, reducing both palatability and nutritive value.

Preparation of FPC must then include removal of water and lipids from the raw fish.

### *5.12.3 FPC Manufacturing Methods*

Most modern methods, currently in use or under development employ solvent extraction to remove water and lipids from the raw material, leading to the production of bland-tasting, light-colored protein powders. Most of these methods, are being used in the Western Hemisphere.

Probably equal in importance are the much older or biological methods of fermentation and enzymatic procedures employed primarily in the Far East for the production of flavorful fish sauces and pastes. (See 5.11.1.)

There are, finally, the methods that have been classed collectively as "physical" methods, since they use a variety of nonchemical techniques (such as high voltage currents) to assist in the separation of tissue components.

*5.12.3.1 Chemical Methods.* Methods have been developed to concentrate the protein from two types of raw material: *fish meal* produced

either by conventional means or by equipment designed to protect the fish tissues from excessive heat; and *raw fish.*

Fish meal extraction may be somewhat simpler than extraction of raw fish since the water content of meal is quite low and only lipids and odor-bearing compounds remain to be extracted. However, fish meal, in its normal method of preparation, is overheated and the protein greatly damaged for manufacture into FPC for human feeding.

The extraction of protein from raw fish is complicated by the presence of large amounts of water and the restrictions as to the choice of solvent: water and lipids must be extracted either simultaneously or water extracted first and then lipids extracted.

Solvents used for extraction should, ideally, have certain characteristics: They should be nontoxic, be available economically in pure form, be easy and safe to handle, constitute a low fire or explosion hazard, and be efficient in the removal of water, triglycerides, other lipids, and odor-bearing compounds without dissolving, or reacting with proteinaceous components. They should have a low boiling point to allow for inexpensive desolvenization of the concentrate and avoid the necessity to heat the extracted material to excessive temperatures; solvent recovery, deodorization, and recycling should be feasible; and, should be inert for the usual construction materials.

*5.12.3.2 Biological Methods.* FPC produced by solvent extraction (a chemical method), consists of intact proteins but the fish products produced by most biological methods consist of a liquid mixture of protein breakdown products. Subsequent separation of the liquid containing proteins from the lipids is by simple physical means.

Digestion of fish tissue can be achieved by fermentation, by deliberate introduction of living proteolytic microorganisms, such as yeasts, bacteria, or molds or by enzymatic reactions. Separation of the resulting amino acid and peptide solutions from any undigested sludge can be carried out by decanting, filtration, or centrifugation. In the Far East, according to FAO, this type of process is used to manufacture vast quantities of very popular pastes and sauces. But these products are expensive, produced under primitive conditions and are of minimal nutritive quality, and the large quantities of salt added to the fermenting mixture, as a preservative, make the food unsuitable for very small children and expectant mothers. Similar fermented sauces and pastes are also prepared from shrimp and other seafoods. In certain areas almost all food is eaten with some of these condiments added.

The rate of production of such pastes and sauces is limited by the duration of the fermentation process which may take months or years. Duration of fermentation is also influenced by the kind of fish, temperature, amount of added salt, and, in some processes, addition of bran and carbohydrates.

Fermentation or enzymatic products are strongly flavored, differing strikingly from the bland tasting solvent-extracted products. FPC can be prepared by biological procedures simply, requires no expensive or potentially toxic chemicals, and produces flavorful foods that are desirable for many groups of people. If desired, a solid form could be produced.

Many of the products manufactured by biological methods have a low pH and contain enough lactic acid to enhance storage stability by preventing bacterial spoilage.

Apart from the traditional methods of the Far East, a number of quite different biological methods show promise for producing FPC in the future. An example is the process developed by Dr. Victor Bertullo of the University of Uruguay in Montevideo. The process, patented in the U.S. in 1961, utilizes a proteolytic yeast that has the capacity to break down the protein of comminuted fish to an almost uniform liquid containing mostly proteins or protein breakdown products with only tiny residues of bone and scale. Experiments with this material have shown that the amino acids and peptide can be separated by centrifugation from the sludge and oil.

Similarly, papain, trypsin and other proprietary enzymes have been used by workers in this country, Canada and India with interesting results. In sum, FPC made by biological methods is highly flavorful, whereas solvent-extracted FPC is bland and odorless and easily incorporated into other foods.

*5.12.3.3 Physical Methods.* These include processes involving electrokinetic phenomena—electroosmosis and the use of electric discharge—and those involving heat transfer. Both instances, although promising, require much more research before practicality can be appraised.

At the present time, the solvent extraction of protein from raw fish (a chemical procedure) is nearest to commercial reality. A process has been developed by the Bureau of Commercial Fisheries in the United States, and approved by a special advisory committee of the National Academy of Sciences—National Research Council, as producing a safe, wholesome, and nutritious product. The Food and Drug Administration recently approved the distribution to consumers of FPC, packaged in one pound packages, processed from hake and hake-like fishes. Either the isopropanol process of BCF or the ethylene dichloride process developed by the Viobin Corporation can be used with FDA approval.

### *5.12.4 Costs of FPC Production*

Detailed cost estimates for an FPC plant utilizing a 50 ton per day raw material input have been made.[68] Such a plant can produce 15,000

[68] Marine protein concentrate. U.S. Bur. Commercial Fish. Leafl. 584, Apr. 1966.

pounds of FPC per day on a 250-day per year basis, and would produce 1,700 metric tons per year or 18.7 percent of one mega-ration. This plant would require a capital investment of about $900,000 and it is estimated that the cost per pound of FPC (*on a fish-free basis*) would be about 7.3¢ per pound. If we were to assume that the raw material cost 1¢/lb., the cost of the FPC would be 13.9¢/lb. (80 percent protein).

To produce one mega-ration, one would need a plant with a capacity six times the 15 ton plant described above. This would require a capital of about $2.5 million. The associated fishing vessels needed, two modern vessels, 120 feet long, would require an estimated capital of about $3.0 million, in addition to dock facilities, etc.

## *5.13.0 Single Cell Protein*

. . . All the nitrogen in the world found in different nitrogeneous compounds has its origin in the atmosphere, and . . . by far the greater part of it has been formed through the activity of micro-organisms.

—A. I. Virtanen.

Single cell protein, produced by the culture of yeasts or bacteria on various substrates, particularly hydrocarbons, has recently attracted attention as one means of meeting the demand for new sources of protein.

A major advantage of single cell protein is that it can be produced on a large scale independently of agriculture or climatic conditions. However, as will be discussed, there are many unsolved problems dealing with production, processing characteristics, and nutritive quality that make it unlikely that single cell protein will have a major impact on malnourished populations before 1971–1975. Furthermore, it is probable that the cost of single cell protein will be in the range of $0.20–0.40 per pound of protein, which is considerably above the present price of protein from oilseed meal with 40 to 50 percent protein.

### *5.13.1 Hydrocarbons and Carbohydrates as Substrates*

A wide variety of bacteria and yeasts can be isolated which grow on various hydrocarbons as the sole source of carbon. In usual enrichment cultures, a relatively narrow spectrum of genera are obtained, but if standard culture collections are tested it is found that species of many genera can grow on hydrocarbons.[69] In general, the straight chain hydrocarbons are preferred. Strains which can attack branched chain hydrocarbons are fewer and grow slower.[70] Aromatic structures also are relatively more resistant to microbial attack. A great many organisms grow well on alkanes of chain length C10–C20. Lesser num-

[69] Foster, J. W., Hydrocarbons as substrates for microorganisms. Antonie van Leeuwenhoek J. Microbiol. & Serol. 28(3) : 241–274. 1962.

[70] McKenna, E. J., and Kallio, R. E., Hydrocarbon structure: its effect on bacterial utilization of hydrocarbons. *In: Heukelekian,* H., and Dondero, N. C. (eds). Principles and application in aquatic microbiology. New York, Wiley, 1964. 452 p. pp. 1—14.

bers are found which can use C2–C10 hydrocarbons; only a few species are known to grow on methane.

*5.13.1.1 Yields from Hydrocarbons and Carbohydrates.* In general, about one pound of dry cell material will be produced from one pound of hydrocarbon when C10–C20 paraffins are used as the carbon source. The yield depends on the type of microorganism and the culture conditions. The amount of carbohydrate substrate required to produce a pound of cells is about twice as much as for paraffins. Yields of a half pound of cells per pound of methane have been reported in the lay press, but unpublished statements of workers in the field indicate that yields are the same as for other hydrocarbons.

*5.13.1.2 Cost Comparisons for Power, Oxygen, and Substrates.* The oxygen requirement per pound of cells produced is about three times as much for hydrocarbons as carbohydrates (Table 5–32) because the hydrocarbons contain no bound oxygen.

TABLE 5–32.—*Material balance for production of single cell protein from hydrocarbon and carbohydrate*

[In pounds]

| Process | Substrate | $O_2$ needed | Cells |
|---|---|---|---|
| Carbohydrate (CHO) | 200 | 67 | 100 |
| Hydrocarbon ($CH_2$) | 100 | 200 | 100 |

Although the yield of cells per pound of substrate is more for the hydrocarbon process, the yield of cells per pound of oxygen is considerably less. The economic implications of this can be seen from an analysis of the costs of substrate and oxygen in producing cells. The substrate costs and costs of cells produced from different substrates are shown in Table 5–33.

TABLE 5–33.—*Substrate cost for cell production*

| Substrate | Cost | | |
|---|---|---|---|
| | Per hundred pounds | Per hundred pounds carbon | Per hundred pounds, cells |
| Sucrose (United States) | $10.05 | $23.90 | $20.00 |
| Molasses: | | | |
| (New Orleans) | 1.75 | 4.15 | 3.50 |
| (New York) | 2.54 | 6.03 | 5.00 |
| Soybean oil | 12.00 | 15.70 | 14.00 |
| Kerosene (Gulf) | 1.30 | 1.52 | 1.30 |
| Distillate No. 2 (Gulf) | 1.23 | 1.43 | 1.25 |

In order to calculate the costs of oxygen, it is assumed that the carbohydrate process is operating at a power input to the fermentor agitator of 0.25 h.p./100 gallons and at atmospheric pressure with air as the aerating gas. The oxygen transfer rate under these conditions is about 40 millimols of $O_2$/liter-hour, or about 1.28 gm $O_2$/liter-hour. The power costs to operate a continuous culture are approximately triple for the hydrocarbon process (Table 5–34), but the hydrocarbon process is more economical if power and substrate costs are *added* because the costs of power are a small part of the total cost.

TABLE 5–34.—*Power cost of 100-gal. fermentor for continuous culture with a power input of 0.25 hp.*

| Process | Pounds of cells per hour | Power cost dollars per 100 pounds of cell |
|---|---|---|
| Carbohydrate | 725 | 0.13 |
| Hydrocarbon | 240 | .38 |

The calculations in Table 5–34 consider that the carbohydrate fermentor is operating at only one-third capacity. The costs should be compared with the fermentors operating at the same output rate of cells. To do this the oxygen supply capability of the fermentor must be increased for the hydrocarbon process by increasing the power input to the agitator. The relationship between oxygen supply capability, as reflected by the mass transfer coefficient, $K_La$, and the power input per unit volume, P/V, is

$$K_L{}^a \propto (P/V)^x$$

where x has been observed to vary form 0.4 to 1.0.[71] As can be seen from Table 5–35, the comparative economics of the scaled-up hydrocarbon process depend strongly on the value of the scale-up exponent, x, which is not adequately characterized at present.

In addition to agitation, there are other techniques for increasing the rate of oxygen transfer. These include using air enriched with oxygen, running the fermentor at pressures greater than one atmosphere, and modifying the fermentor design to increase oxygen transfer. These possibilities have not been evaluated adequately to determine whether they are cheaper than the alternative consider in Table 5–35.

In addition to the increased oxygen requirement, about twice as much heat is produced for the hydrocarbon process as for the carbohydrate process. If auxiliary mechanical refrigeration is required to maintain the temperature at about 30° C, the cost of cells produced in the hydrocarbon process might be increased as much as $0.50 to

[71] Richards, J. W., Studies in aeration and agitation. Progress in Industrial Microbiology 3: 141–172. 1961.

263–880 O—67——25

$1.50 per 100 pounds of cells and the cost advantage shown in Table 5–35 may be very small.

TABLE 5–35.—*Cost comparison of hydrocarbon and carbohydrate process, showing influence of scale-up exponent*

| Where x= | 0.5 | 0.7 | 0.9 |
|---|---|---|---|
| Horsepower per 100 gal | 2.25 | 1.18 | 0.83 |
| Power cost (dollars per 100 lb) | 1.05 | .55 | .39 |
| Cost for substrate and power hydrocarbon process | 2.35 | 1.85 | 1.69 |
| Cost for substrate and power carbohydrate process | 3.63 | 3.63 | 3.63 |

Surface water could be used for cooling if organisms were used that grew at temperatures greater than 50°. No such thermophilic bacteria or yeasts that utilize hydrocarbons are known at present. There are thermophilic bacteria and yeasts that utilize carbohydrates and there may be undiscovered thermophilic microorganisms that utilize hydrocarbons. There has been little research on microorganisms that are adapted to high temperatures. Cooling with water is very cheap if water temperatures are sufficiently cooler than the process temperture. In much of the world, temperatures of surface waters are greater than 30° C, at least during parts of the year. However, if the process could be carried out at 50° C or higher, surface water could be used readily for cooling purposes.

### *5.13.2 Methane as a Substrate*

Methane is an alternative substrate for production of single cell protein with an apparent advantage of low cost, even in comparison to other hydrocarbons. Low cost of substrate, in itself, is not sufficient justification as discussed in 5.13.1.2. Even though methane is burned at many oil wells, once it has reached a market, it has a value similar to other hydrocarbons. If fermentation plants were constructed at the oil well, or gas well, there might be significant savings provided that water, ammonia, and other necessary supplies, and transportation were also available.

Methane has the advantage that it is "clean" in comparison to crude oil. There would be no problems with residues on the cells. Problems of mass transfer would be accentuated because the methane is a gas rather than liquid so a certain amount of it would be lost with the effluent gas from the fermentor.

Bacteria grow slowly on methane but this is not a major disadvantage because the slow rate of growth can be compensated for by operating the fermentor at a higher cell concentration since the rate of production of cells in a continuous fermentation system is equal to the product of growth rate times cell concentration.

### *5.13.3 Cellulose as Substrate*

Cellulose is a less exotic substrate for microbial growth. It is readily degraded in nature in the soil or in the rumen of animals, but it is relatively resistant to attack by pure cultures of microorganisms in the laboratory. Rumen organisms are in large part obligately anaerobic and difficult to cultivate outside the rumen. It is not likely that a pure culture process to degrade cellulose at an economic rate will be developed in the near future. It is possible that in a mixed culture process, involving an anaerobic first stage, cellulose could be degraded faster than in a pure culture.

Another possibility is the chemical degradation of cellulose, possibly by acid hydrolysis. In the past this approach has foundered on the costs of acid. If an economic means of recovering the acid could be developed, a combination of chemical hydrolysis followed by fermentation might be practical. Possible means for recovering the acid include electrodialysis, ultrafiltration, or other novel separation techniques.

Tremendous quantities of cellulose are available as waste paper, surplus and spoiled fruits and vegetables, bagasse, and as byproducts of various types of paper and wood production. At present they are discarded for the most part and, in fact, constitute a significant source of pollution.

### *5.13.4 Fungi*

Despite considerable research,[72] it appears that fungi are less suitable than either bacteria or yeasts as sources of single cell protein. On the one hand they grow no faster and are less efficient in converting either nitrogen or carbon sources into protein; on the other hand they are considerably lower in protein content (about 15–30 percent by weight) than is generally the case for bacteria or yeasts (about 25–50 percent by weight). The cell wall of fungi is a greater fraction of the cell, and would presumably furnish only roughage. The problems arising from the production of toxic secondary metabolites are at least as great as for bacteria and yeasts. The only significant advantage that filamentous fungi possess as compared to bacteria and yeasts is that they can be recovered from the fermentation broths by relatively simple operations such as string filtration, whereas for bacteria and yeasts more expensive means such as centrifugation will probably be required.

Molds can be used as animal feeds [73] and this is one means of utilizing a byproduct of industrial fermentations such as antibiotics production which would otherwise be discarded, constituting a nuisance.

Higher fungi, such as mushrooms, constitute a desirable food, but as a protein source are likely to be far too expensive to consider on a worldwide basis. At present they are produced by fermentation

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[72] Gray, W. D., Microbiol protein for the space age. Develop. Industr. Microbiol. 3 : 63–71. 1962.

[73] Stokes, J. L. *In:* Altschul, A. M. (ed). Processed plant protein foodstuffs. New York, Academic Press, 1958. 955 p.

means [74] by at least one American firm at a price of approximately $3.00 per pound (dry weight) and used mainly as a flavoring material.

*5.13.5 Nutritive Value of Cells*

The literature indicates that, in general, the amino acid composition of single cell proteins is comparable to other plant proteins.[75] The analytical data, unfortunately, do not distinguish between amino acids in the cytoplasmic protein and amino acids in the cell wall or capsular material which cannot be digested.

It should be possible to obtain cells with the desired composition of amino acids from different strains of organisms. The protein in rumen bacteria contains as much as 15 percent lysine and as much as 4 percent methionine + cystine.[76] The composition of amino acids shows some correlation with the ratio of guanine + cystosine to adenine + thymine in the genetic material,[77] suggesting that it might be possible to screen for particularly favorable strains according to phylogenetic patterns rather than testing random isolates.

Little information is available on the digestibility of bacteria or yeasts. Experimental work will be required to predict the effects of relatively high amounts of nucleic acids and components of cell walls on the organism consuming the cells. It may be necessary to fractionate microorganisms before they can be used as food. One advantage would be that protein isolates could be produced with a better protein quality than the over-all protein of the cell.[78] The less desirable fractions might be recycled in the system or used for animal feeds.

One disadvantage of combining production of single cell proteins with petroleum refining processes is the necessity to wash the cells extensively to remove any aromatic contaminants. Washing substantially increases costs, so that feeds, such as paraffins obtained elsewhere in the refining process, and feeds containing oxygen such as ethanol, acetate, formic acid, are desirable.

Different strains of microorganisms will probably have different organoleptic properties. It should be possible to find strains which have attractive tastes, although at present much effort is directed toward obtaining a tasteless product which can be incorporated into other food products.

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[74] Litchfield, J. H., Overbeck, R. C., and Davidson, R. S. Factors affecting the growth of morel mushroom myceleum in submerged culture. J. Agr. Food Chem. 11(2): 158–162. Mar./Apr. 1963.

[75] c.f. Atsuka, S.–I., Ishii, R., and Katsuya, N., Utilization of hydrocarbons as carbon sources in production of yeast cells. J. Gen. Appl. Microbiol. 12(1): 1–11. Mar. 1966.

[76] Purser, D. B., and Buechler, S. M., Amino acid composition of rumen organisms. J. Dairy Sci. 49(1): 81–84. Jan. 1966.

[77] Sueoka, N., Compositional correlation between deoxyribonucleic acid and protein. Cold Spring Harbor Symp. Quant. Biol. 26: 35–43. 1961.

[78] Tannenbaum, S. R., Mateles, R. I., and Capco, G. R., Processing of bacteria for production of protein concentrates. Advanc. in Chem. No. 57: 254–260. 1966.

*5.13.6 Price Estimates*

Available price estimates (generally unpublished) indicate that single cell protein can be produced from hydrocarbons for about $0.10–0.20 per pound of cells, or about $0.20–0.40 per pound of protein. This is now more expensive than oilseed meal containing 40 to 50 percent protein. The price, however, would not depend on climatic and environmental conditions as would an agricultural commodity.

Low cost of substrate or product is not the only reason for contemplating the production of single cell protein from hydrocarbons. The potentially large amounts available without disruption of the economics of petroleum processing, and the fact that the agricultural sector would not be involved should also be considered. In some cases the cost of substrate may be negative. The food yeast industry, for example, uses sulfite waste liquor or waste whey which would otherwise have to be disposed of at some cost. A low cost product can be produced which sells for about $0.10 per pound for feed grade and about $0.20 per pound for human grade.

*5.13.7 Potential Requirements for Development*

Since the production of single cell protein involves the development of new technology and additional basic research in microbiology, food science, and nutrition, it is probably not reasonable to expect it to play a significant part in world protein nutrition before 1971–1975 or perhaps even 1980. Because considerable work remains to be done in this area, it may be wise to concentrate on producing single cell protein for human consumption rather than animal feed. The costs of development and production of processes for human food and animal feed would be similar. The acute need for protein and energy may in itself justify this approach.

To assess the contributions that single cell protein could make to the problem of world food supply, it will be necessary to develop further basic information. In particular it seems apparent that the research outlined below must be initiated or extended.

*Cell growth and recovery:* screening programs for cells of high nutritional value, studies of the effects of culture conditions on the composition of amino acids, searching for thermophilic organisms capable of growing on hydrocarbons, metabolism of hydrocarbons, mechanisms of hydrocarbon transfer into cells, influence of mechanical design on the rate of mass transfer, correlations of mass transfer with power input at high power inputs, problems of scale-up, techniques for recovery and separation of cell material from culture broths.

*Processing and utilization:* determination of composition of cells with particular reference to amino acids, biological availability of amino acids in various cell structures, production of protein isolates, storage stability of products with reference to nutritional and organoleptic qualities, incorporation of products in textured foods.

*Nutrition and toxicology in reference to humans:* utilization of protein under different physiological conditions, effects of ingestion of nucleic acids and other nonprotein cell components, possible allergens in single cell protein, effects of unusual amino acids, use of single cell protein as the sole source of protein and as a protein supplement.

The topics mentioned serve only as examples of the areas in which little information is now available and are not meant to be comprehensive.

It is not possible to estimate the cost of the basic research program required but it is probable that significant progress could be made by university groups in the U.S. and other countries in two to four years at a total cost of $10 to $30 million. In addition, industry would need to spend significant amounts of money to develop particular processes and technologies.

### *5.14.0 Leaf Protein*

Leaf protein is defined as the protein-containing material which can be isolated from leaves of plants and grasses by various extraction techniques.[79] In composition it approximates other plant proteins.[80] It deserves consideration as a source of protein primarily because the materials from which it can be made are frequently wasted, or at best fed to animals with the concomitant inefficient utilization of protein through the food chain.

Almost all of the essential amino acids consumed by man are derived from amino acids initially synthesized in the leaves of green plants. There is some loss when these amino acids are concentrated into the protein of seeds and tubers and a greater loss when the plant protein is converted into animal products for human consumption.

The composition of amino acids in green leaves is similar to that of animal protein except leaf protein contains only about half as much methionine as animal protein.[81]

Leaf protein is utilized directly for human food as the leaves of green vegetables. This can be a significant source of protein in the diet when leaves of high protein content, such as those of cassava and sweet potatoes, are consumed; especially in regions in which the tubers are staples in the diet because the tubers have a very low protein content. (See Table 5–4.)

The leaves of cassava contain 7 to 8 percent protein on the green basis and 30 to 32 percent dry weight.[82] From 200 to 500 grams per

[79] Davys, M. N. G., and Pirie, N. W., Protein from leaves by bulk extraction. Engineering 190 (4923) : 274–275. Aug. 26, 1960; Chayen, I. H., and others, The isolation of leaf components. I. J. Sci. Food Agr. 12(7) : 502–512. July 1961.

[80] Wilson, R. F., and Tilley, J. M. A., Amino-acid composition of lucerne and of lucerne and grass protein preparations. J. Sci. Food Agr. 16(4) : 173–178. Apr. 1965.

[81] Gerloff, E. D., Lima, I. H., and Stahmann, M. A., Amino acid composition of leaf protein concentrates. J. Agr. Food Chem. 13(2) : 139–143. Mar./Apr. 1965.

[82] Terra, G. J. A., The significance of leaf vegetables, especially of cassava, in tropical nutrition. Trop. Geog. Med. 16(2) : 97–108. June 1964.

person per day are eaten in some areas in the Congo and in Java, adding 15 to 35 grams of good quality protein to the diet. The leaves supplement the tubers which contain only 1 or 2 percent protein.

A recent study in New Guinea showed it was customary to include some green leaves in the diet.[83] The sweet potato is the staple and its leaves are eaten frequently, though other leaves are used in some places. In certain regions the soil is too poor to produce tubers, and there the sweet potato is cultivated for its leaves alone.

Leaf protein could be utilized in the human diet by: (1) encouragement of the cultivation and use of high-protein leafy vegetables in the diet; and (2) large-scale production of leaf protein concentrates and its introduction into the diet. Increases in the consumption of leafy vegetables also would be desirable because they contain vitamins, minerals, and other micronutrients.

Leaf protein can be prepared by mechanically pulping the plant material and pressing it to expel the juice.[84] Approximately 40 to 70 percent of the protein present in the leaf can be recovered in the press juice. The remaining fiber may be used as animal feed. The protein is isolated from the press juice by filtration or centrifugation after it has been coagulated by heating to about 70° C. In addition to heating, acidification or treatment with salts can be used to coagulate the protein prior to collection. A typical analysis of a leaf protein product,[85] after washing and pressing the collected protein is: water, 60 percent; nitrogen, 48 percent; lipid, 9 percent; starch, 2 percent. On a dry weight basis the product is approximately 60–65 percent protein. This pressed cake must be consumed within one or two days, or further dried, or refrigerated, to prevent microbial deterioration.

The commercial production of leaf protein concentrates would require large quantities of leafy material which, for the most part, do not now exist in the developing countries. Sources may become available as canning factories and other facilities for the large scale processing of food are established. A large potential may exist in the natural vegetation of certain tropical areas.

The acceptability of the product as food is not well known. The press cake has a greenish color and a taste described as spinach or tealike.[86] Most of the pigments and flavor can be removed as is being done presently on a semi-commercial basis in Israel, by alkaline extraction of the protein (the Chayen process), and by solvent extraction of the pigments from the coagulated protein. The protein residue is grayish and bland in taste. The Israeli press cake is at present used in chicken

[83] Sorensen, Richard, private communication 1966.

[84] Davys, M. N. G., and Pirie, N. W., Protein from leaves by bulk extraction. Engineering 190(4923): 274–275, Aug. 26, 1960; Chayen, I. H., and others, The isolation of leaf components. I. J. Sci. Food Agr. 12(7): 502–512. July 1961.

[85] Pirie, N. W., Leaf protein as a human food. Science 152(3730): 1701–1705. June 24, 1966.

[86] Ibid.

feed as a source of xanthophylls, and the protein is an incidental benefit. The economics of the production of a bland product by solvent extraction to produce a bland protein probably depend on a market for the pigments with the protein being a byproduct.

It would appear from a cursory examination of the economics of a unit operated in a village (village unit), (see Table 5–36) that the protein may not be any cheaper than that produced from oilseed meal. Leaf protein apparently is acceptable nutritionally but it does not appear to be significantly better than oilseed meal proteins. There may be problems of digestion and utilization by humans.[87]

TABLE 5–36.—*Crude estimate of economics of production of leaf protein from a "Village Unit"*

[Capacity of 2 tons per hour of feed and output of 60 kg. protein per hour]

| | |
|---|---|
| *Operating costs*: | |
| Power: 8 kw. hr. per ton on feed, or at 3 percent protein yield and .03 per kw. hr. | $0.008 per kg. |
| Labor: 2 men at $0.15 per hour (village unit), with production of 60 kg. per hour | .005 |
| Heating to 70°, filtering, pressing, material, and power | .008? |
| Labor: 1 man at $0.15 | .003? |
| | .027 |
| *Capital* | |
| Crusher. | |
| Source of heat ~$10,000? 3-year amortization; 8 hr. per day, 180 days per year =$250 per hour or 0.04 kilogram. | |
| Filter. | |
| Press. | |

Leaf protein, as well as other protein flours or isolates, could best be utilized by developing a technology that would permit their use in foods. So cost of processing is at least $0.06–$0.07/kgm protein, if labor is taken at $0.15/hr. If labor is at $1.00/hr, then cost rises to $0.10–0.11/kgm for a product which is not stable. To dry it (other than in the sun), may add as much as $0.02–.04/kgm.

### *5.15.0 Algae*

The use of microscopic algae as a protein source has often been suggested[88] and a great deal of work has been carried out on these plants, much of it with the aim of providing a food source during extended space flights.[89]

[87] Henry, K. M., and Ford, J. E., Nutritive value of leaf protein concentrates determined in biological tests with rats and by microbiological methods. J. Sci. Food Agr. 16(8): 425–432. 1965; Waterlow, J. C., The absorption and retention of nitrogen from leaf protein by infants recovering from malnutrition. Brit. J. Nutr. 16(4): 531–540. 1962.

[88] Krauss, R. W., Mass culture of algae for food and other organic compounds. Amer. J. Bot. 49(4): 425–435. Apr. 1962.

[89] McDowell, M. E., and Leveille, G. A., Algae systems, *In* Conference on Nutrition in Space and Related Waste Problems, NASA SP–70, 1964. pp. 317–322.

Although the composition of algal protein is comparable in composition to other plant proteins, the major question concerning its use as food is economic. Early estimates of the cost of Chlorella were $0.25–0.30 per pound, about $0.60–0.75 per pound of protein.[90 91] A recent estimate [92] was $0.06 per pound of algae (about $0.15 per pound of protein), but this was for a product, grown on sewage, that would not be suitable for human food. A credit against this cost, however, would be the water which would be reclaimed. A similar process has been described by the group working at Berkeley.[93]

Though the economic factor is a major one, there are other unanswered questions concerning the use of algae as a protein source for humans. These are concerned with digestibility, palatability, and toxicity.[88] These problems could be avoided if algae were used as animal feed.[94]

It would appear that the major contribution of microscopic algae to human nutrition would be through serving as an animal feed stuff produced during the process of reclaiming sewage and other waste streams, and in which a major part of the production cost would be borne by the water treatment process.

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[90] Milner, H. W., Algae as food. Sci. Amer. 189(4) : 31–35. Oct. 1953.

[91] Tamiya, H., Mass culture of algae. Annu. Rev. Plant Physiol. 8 : 309–334. 1957.

[92] Mattani, R. H. T., Personal communication (No. Amer. Avn. Co.)

[93] Golueke, C. G., and Oswald, W. J., Harvesting and processing sewage-grown planktonic algae. Water Pollut. Contr. Federation J. 37(4) : 471–498. Apr. 1965.

[94] McDowell, M. E., and Leveille, G. A., Feeding experiments with algae. Federation Proc. 22(6) Part 1 : 1431–1438. Nov./Dec. 1963.

# CHAPTER 6

# MANUFACTURED PHYSICAL AND BIOLOGICAL INPUTS

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## Contents

| | | Page |
|---|---|---|
| 6.1.0 | Summary | 375 |
| 6.2.0 | Introduction | 377 |
| 6.3.0 | Fertilizer | 379 |
| | 6.3.1 Projected Needs | 380 |
| | 6.3.2 Cost of Fertilizer Requirements | 382 |
| | 6.3.3 Personnel Requirements | 383 |
| | 6.3.4 The Production of Nitrogen | 383 |
| | 6.3.5 The Production of Phosphate and Potash | 385 |
| | 6.3.6 The Economics of Fertilizer Production | 387 |
| 6.4.0 | Seeds | 387 |
| | 6.4.1 Recognition of Requirement for Good Seeds | 387 |
| | 6.4.2 Processing Plant Requirements | 388 |
| | 6.4.3 Nature and Subtleties of the Seed Business | 389 |
| | 6.4.4 Technology for Seed Production and Distribution | 391 |
| 6.5.0 | Pesticides | 392 |
| | 6.5.1 Importance of Pest Control for Crop Production | 392 |
| | 6.5.2 Chemical Pesticide Requirements | 392 |
| | 6.5.3 Capital and Personnel Requirements | 395 |
| | 6.5.4 Research and Other Technological Requirements | 395 |
| 6.6.0 | Machinery | 396 |
| | 6.6.1 Importance of Machinery for Improved Crop Production | 396 |
| | 6.6.2 Kinds of Machinery Needed | 399 |
| | 6.6.3 Estimated Machinery Costs | 400 |
| 6.7.0 | Interrelationships of Inputs | 402 |



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# 6.0 FERTILIZER, SEED, PESTICIDES, AND MACHINERY

## *6.1.0 Summary*

In this report, the quantities of fertilizers, seeds, pesticides and machinery required to meet the food needs of the probable population of the developing world, outside of Mainland China, by the year 1985 are projected. The report cites capital needs, develops guidelines to be considered in providing these inputs, and discusses the principal problems which are anticipated. The estimates were made as to the requirements for increasing food production on land now in cultivation in proportion to population growth. The following are concluded:

1. Fertilizer needed to double agricultural production in the developing free world will increase from the 6 million metric tons used in 1966 to 67 million metric tons per year in 1985. Increases to 11, 19, 28, and 40 million metric tons of plant nutrients per year, respectively, will be needed to provide food for the expected populations in 1970, 1975, 1980, and 1985. It is anticipated that by the year 1985 capital totaling approximately $17 billion will be required for mining, manufacturing, and distribution of fertilizer. It should be noted that immediate, as well as future, needs for capital are quite large.

2. There will be large increases in intercontinental shipping and international trade in fertilizer and fertilizer raw materials, since efficient nitrogen plants and potash and phosphate mining operations are large and complex. By necessity, these plants are located at the source of raw materials and are not uniformly distributed around the world.

3. Improved seed must be available and utilized by the farmers if production requirements are to be met. Food production can be doubled if 25 percent of the seed requirement flows through commercial channels, provided that the use of improved varieties is coupled with the other improvements in agricultural practices. The capital required for seed processing is relatively low, estimated to be approximately $300 million.

4. Large increases in the use of pesticides will be necessary to increase food production. All types will be needed: insecticides, fungicides, herbicides, nematocides, and rodenticides. At the present time, only 120,000 metric tons of these materials are used each year by the developing world, excluding Mainland China. If food production is



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to be doubled, this annual usage must increase to over 700,000 metric tons. To provide this quantity of pesticides will require $1.2 billion in capital for manufacturing plants and $670 million for formulation and distribution facilities. Pesticides should be manufactured largely in the developed nations, where skilled manpower, utilities, and raw materials are available, but because of trade and monetary restrictions and excessive nationalism this may not be possible. On the other hand, formulation of pesticides, a relatively simple operation, can be carried out locally.

5. In the developing free world, more machinery is badly needed—not to save labor, but to increase productivity. At the present time, machine power available to the farmers of Asia, Africa, and Latin America is only a fraction of the one horsepower per hectare utilized by the farmers of Europe and the United States. Lack of machine power makes it difficult to prepare seedbeds in an efficient and timely manner and to place seed and fertilizer accurately, both of which can contribute markedly to improved yields. Although there are one or two exceptions, there is substantial evidence indicating that a power level approaching 0.5 horsepower per hectare is needed for efficient agriculture. It is estimated that by the end of this century almost $2 billion may be invested in plants to produce farm machinery for use in the developing free world.

6. The optimum return on the investment and effort in food produc- and proper use of the agricultural inputs must be provided if food production is to be increased. The estimate of technical manpower cultural practices, including water management. Fertilizer accounts for most of the capital required to provide these inputs (two-thirds of the farmer's costs), but it is an absolute necessity for improved yields.

7. Adequately-trained manpower for the production, distribution, and proper use of the Agricultural inputs must be provided if food production is to be increased. The estimate of technical manpower needed to produce and distribute these inputs in the developing free world is 75,000 university graduates or their equivalent by 1985. Additional specially-trained people will be required for research and extension.

8. It is estimated that the cost of improved inputs—fertilizers, seeds, pesticides, and machinery—will increase from about $3 billion per year in 1966 to approximately $14 billion per year by 1985, and this will make it necessary to provide credit to farmers on a scale many fold greater than is the case today.

9. Research to adapt presently available pesticides to local use will be needed, as well as pioneering research intended to create entirely new pesticides especially adapted for use in tropical areas. Research on minimum tillage methods and on harvesting and threshing equipment for paddy should be increased. Research, development, and

extension on seed technology are also needed, and work intended to define optimum systems combining all inputs is a necessity.

10. The improved inputs considered will be effectively used only if there is a massive extension effort. The organization producing the inputs must accept some responsibility for providing the information and technical services needed to insure their proper use.

### *6.2.0 Introduction*

This report deals with the amount and kinds of purchased inputs needed for increasing agricultural yields per acre in proportion to the population increases up until the year 1985, and for further increasing yields to a maximum of 100 percent above the present level, corresponding to population growth for some undefined year near the end of the century. Table 6–1 gives the predicted populations of Asia (except Mainland China and Japan), Africa, and Latin America, at five-year intervals from 1966 until 1985. The assumption that yields per acre must be increased in approximate proportion to population during the next two decades is based upon a review and analysis of both past trends and future possibilities for improving food availability in the developing countries through increased importations, increasing the acreage under cultivation, and improving yields per acre.

As late as 1954, the developing free world was a net supplier of grain to world markets, exporting almost 4 million metric tons in that year, or about 2 percent of their total production. Since 1955 the food deficit has grown rapidly and, in 1965, 16.5 million metric tons of grain were imported.[1] Obviously, this level of imports can be increased, but not indefinitely, since the combination of logistic problems, production levels in the developed countries, and the problem of concessional sales make this increasingly impractical. These are discussed in detail elsewhere in this report.

TABLE 6–1.—*Population data for the developing free world* [1]

[Millions]

| Year | Asia [2] | Africa | Latin America | Total [2] | Percent increase (cumulative from 1966) |
|---|---|---|---|---|---|
| 1966 | 1,060 | 315 | 253 | 1,628 | |
| 1970 | 1,161 | 348 | 283 | 1,792 | 10 |
| 1975 | 1,318 | 400 | 330 | 2,048 | 26 |
| 1980 | 1,489 | 463 | 383 | 2,335 | 43 |
| 1985 | 1,677 | 535 | 442 | 2,654 | 63 |

[1] United Nations high estimates.
[2] Except Mainland China and Japan.

[1] Handbook of Agricultural Charts 1966. U.S. Dep. Agr. Handbook 325, 155 p. Oct. 1966.

Food production in the developing free world has increased during the last ten years at about 2.5 percent per year.[2, 3] But the rate of increase in recent years has tended to decrease, although it is too early to determine as yet whether or not this is only a temporary fluctuation or a definite leveling off.

Examination of both FAO and USDA [2, 3] data indicates that most of the increases in production in the developing countries during the past decade have come from increasing the area of land under cultivation, rather than from increasing yields per unit of area. There are definite indications, however, that increasing production by expanding areas of traditional agriculture is coming to an end, especially in Asia, where, according to the Department of Agriculture, 85 percent of the current nutritional deficit exists.[4] Table 6–2 shows that during the seven-year period from 1950–51 to 1957–58, Asia increased its grain cropland by 14 percent, but was able to expand this area by only 10 percent during the seven-year period from 1957–58 to 1964–65. Africa, on the other hand, increased its grain cropland by 10 percent and 12 percent, respectively, during these two-seven year periods, and the comparable figures for Latin America are 19 percent and 28 percent.[5] Since 60 percent of the people in the developing countries reside in land-scarce Asia, our analysis is based upon the conclusion that most of the needed increases in food production in the future must come from increasing yields on existing croplands.

Sustained yield increases of the magnitude under consideration, 2.5 percent a year or better, would constitute what Brown has termed a "yield takeoff," or the sudden transition from a near-static situation with respect to yields to a situation in which yields increase steadily each year. Most yield takeoffs have occurred in the developed nations, such as Japan, Australia, the United States, and the United Kingdom, all of which experienced yield takeoffs twenty-five or more years ago. Yields in these nations are now increasing from a low of 1 or 2 percent a year for Japan to a high of almost 3 percent for the United States. Since yield takeoffs in the past have required educated, alert farmers, capital, and a commercial system of agriculture, they will be extremely difficult to achieve in the developing nations.[6]

This section of the report is intended to provide the basis for decisions concerning the inputs of fertilizers, seeds, pesticides, and machinery required for similar increases in agricultural productivity in the developing nations. Emphasis is given to the necessity of including all of these inputs into the "package of practices" to be stressed.

[2] Handbook of Agricultural Charts 1966, U.S. Dep. Agr. Handbook 325, 155 p. Oct. 1966.

[3] Food and Agriculture Organization of the United Nations, Production Yearbook. Vol. 14, 1960 and Vol. 19, 1965.

[4] World food budget 1970. U.S. Dep. Agr. Foreign Agr. Econ. Rep. No. 19, 105 p. 1964.

[5] Food and Agriculture Organization of the United Nations. Production Yearbook. Vol. 14, 1960 and Vol. 19, 1965.

[6] Brown, L. R., Increasing world food output; problems and prospects. U.S. Dep. Agr. Foreign Agr. Econ. Rep. No. 25, 140 p. Apr. 1965.

TABLE 6-2.—*Area in grains in the developing free world, 1948-53* [1] *to 1964-65*

| | Million hectares | | | Percent increase | | |
|---|---|---|---|---|---|---|
| | 1948-53 [1] | 1957-58 | 1964-65 | 1948-53[1]—1957-58 | 1957-58—1964-65 | 1948-53[1]—1964-65 |
| Asia: | | | | | | |
| India | 78.4 | 88.4 | 93.6 | 13 | 6 | 19 |
| Pakistan | 15.3 | 15.8 | 17.8 | 3 | 13 | 16 |
| Indonesia | 8.1 | 8.9 | 10.0 | 10 | 11 | 23 |
| Philippines | 3.3 | 4.9 | 5.1 | 49 | 4 | 55 |
| Turkey | 8.2 | 11.8 | 12.6 | 44 | 7 | 54 |
| Thailand | 5.2 | 4.5 | 6.4 | −13 | 42 | 23 |
| South Korea | 1.9 | 2.2 | 2.5 | 16 | 14 | 32 |
| Burma | 4.0 | 4.1 | 5.3 | 2.5 | 29 | 33 |
| Rest of Asia (excluding China and Japan) | 21.1 | 25.4 | 29.9 | 20 | 18 | 42 |
| Asia, subtotal | 145.5 | 166.0 | 183.2 | 14 | 10 | 25 |
| Africa: | | | | | | |
| United Arab Republic (Egypt) | 1.8 | 1.9 | 1.9 | 6 | 0 | 6 |
| South Africa | 4.4 | 5.1 | 6.5 | 16 | 28 | 48 |
| Rest of Africa | 38.9 | 42.5 | 47.1 | 9 | 11 | 21 |
| Africa, subtotal | 45.1 | 49.5 | 55.5 | 10 | 12 | 23 |
| Latin America: | | | | | | |
| Brazil | 7.4 | 9.5 | 13.5 | 28 | 42 | 82 |
| Mexico | 5.1 | 6.8 | 9.3 | 33 | 37 | 82 |
| Argentina | 8.4 | 9.7 | 11.5 | 15 | 19 | 37 |
| Colombia | 1.0 | 1.1 | 1.8 | 10 | 64 | 80 |
| Peru | .6 | .6 | .7 | 0 | 17 | 17 |
| Rest of Latin America | 5.7 | 6.0 | 6.4 | 5 | 7 | 12 |
| Latin America, subtotal | 28.2 | 33.7 | 43.2 | 19 | 28 | 53 |
| Total, developing areas | 218.8 | 249.2 | 281.9 | 14 | 13 | 28 |

[1] Food and Agriculture Organization of the United Nations. Production Yearbook, Vol. 14, 1960, and Vol. 19, 1965. (1948-53 is an average of 5 years, 1948-59—1952-53, centered on 1950-51. Therefore, each of the 2 time periods shown above is a 7-year period.)

## *6.3.0 Fertilizer*

The appropriate use of fertilizer is essential to achieve high yields, although no attempt has been made to assign the percentage of increased yields which might be attributed to fertilizer alone. Instead, the optimum approach to increased yields involves improvements in *all* essential inputs: fertilizers, seeds, pesticides, machinery, and water management in the case of irrigated plots. Very little fertilizer is now used in Asia, Africa, and Latin America. The total world-wide use of plant nutrients (nitrogen (N), phosphorous pentoxide ($P_2O_5$), potassium oxide ($K_2O$)) in 1965-66 exceeded 44 million metric tons, with about 6 million metric tons used in the developing countries. Less than 15 percent of the world's fertilizer is used in areas whose agriculture must feed half the world's people.

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Control of soil acidity is absolutely essential if fertilizer is to be effective and if crops are to have optimum growth. Calcitic limestone and dolomitic limestone are usually used for the control of soil acidity. The effectiveness of other nutrients, especially phosphorous, is affected by high soil acidity. Deposits of these and other sources of lime are scattered widely throughout the world, although they may not occur in some countries or may be located at a considerable distance from areas where applications are needed. Principal difficulties in the use of limestone are: (1) grinding to a fineness required to ensure effectiveness, (2) transporting to the area where acid soils occur and ultimately to the consumer, and (3) applying to the soil.

Lime is likely to be needed on soils in areas where more than 30 inches of rainfall are received annually. Rates of application of 10 or more metric tons per hectare are often required. Such quantities are difficult to transport and apply by the primitive methods usually used in the developing countries.

An energetic educational and demonstrational program will be necessary in many areas to convince farmers engaged in traditional agriculture to adopt good liming practices. To illustrate the magnitude of this problem, educational efforts in the United States conducted over a relatively long period of time have resulted in the use of only 50 percent of the total amount of lime actually needed.

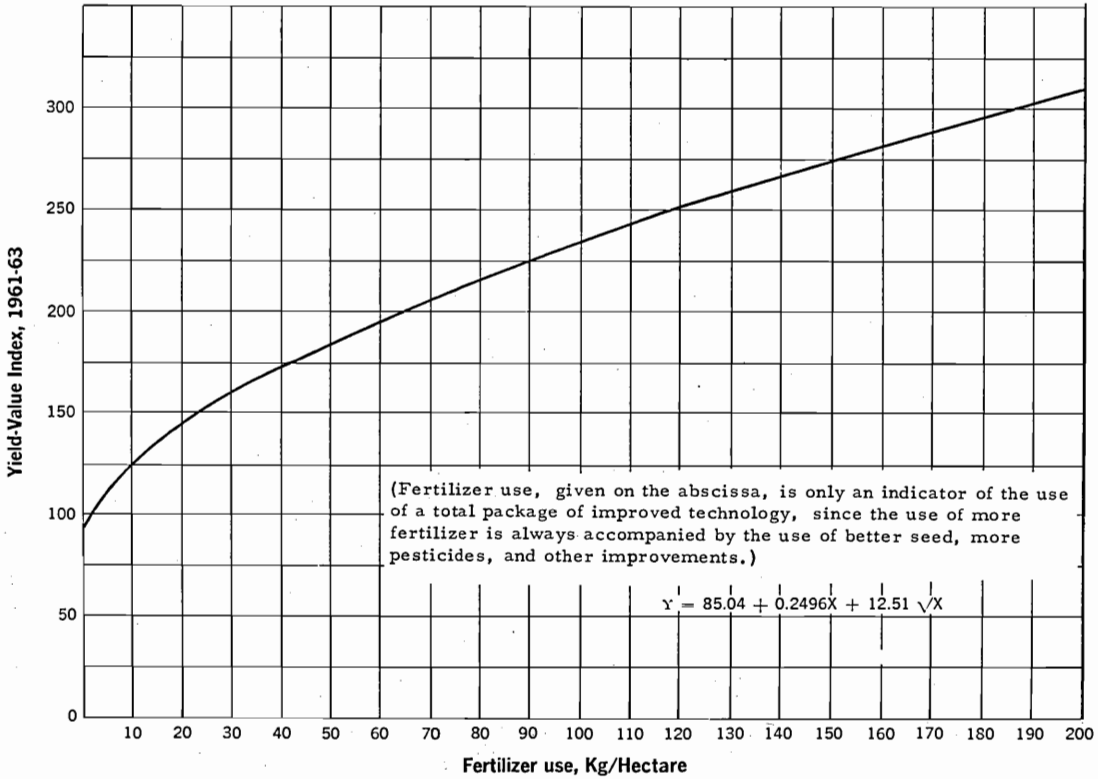
### *6.3.1 Projected Needs*

The amounts of fertilizer required to increase agricultural production by various percentages, up to and including 100 percent, was determined. For this purpose, the approach used by the Food and Agriculture Organization of the United Nations, known as the "yield value index," was employed.[7] Essentially, the FAO method assumes that the level of fertilizer used is related to the yield of crops per hectare of cultivated land. FAO has used data from 41 developed and developing countries to produce a curve showing the average relationship between fertilizer use and the yield value index of crop production, in which the yield value index is an approximation of productivity. With this curve, it is possible to estimate the quantity of fertilizer a country will need to attain a given level of crop production. (Figure 6–1.) The cumulative data for the developing countries indicates projected use of fertilizer from 6 million metric tons in 1966 to 40 million metric tons by 1985. (See Table 6–3.)

These projections are based upon the requirement of agricultural production increasing at the same rate as is predicted for population growth to the year 1985. It is assumed that the increased use of fertilizer will be accompanied by necessary and appropriate increases of

[7] Parker, F. W., Fertilizer and economic development. *In;* McVickar, M. H. (ed). Fertilizer technology and usage; proceedings of a short course held at Purdue University, Feb. 12–13, 1962. Madison, Wis., Soil Science Society of America, 1963. 464 p. pp. 1–21.

Figure 6-1
**Yield-Value Index vs. Fertilizer Use—1961/63**



other inputs required for improved farming practices including seeds, pesticides, machinery, and water. It is further assumed that the increased production will come largely from increasing yields on lands already in production. The new lands that may be added during the next two decades will contribute to the improvement of the diet beyond the highly inadequate level available to many people today.

### *6.3.2 Cost of Fertilizer Requirements*

An estimate has been made of the capital required to provide the nutrients specified in Table 6–3. For this purpose, a ratio of 4–2–1 was assumed for N, $P_2O_5$, and $K_2O$, as these were used in the developing free world in a ratio of 4–2–1.2 in 1965. The total capital requirement for mining or manufacturing, and distribution of fertilizer in the developing nations was estimated to be approximately $500 per annual metric ton of plant nutrients. It is recognized that this figure is higher than would be expected in a developed nation, but the value is thought to be realistic. The $500 allowance includes warehousing, railroad cars or equivalent, vehicles, distribution outlets, and working capital, as well as actual mines and plants, but makes no allowance for any developments in the infra-structure, such as port facilities, roads, or railroads which might be required.

To increase the annual production of fertilizer 34 million metric tons by 1985 will require a cumulative investment of $17 billion in capital. The annual cost to the farmer will be approximately $9 billion (Table 6–3). It should be emphasized that a lead time of at least five years is required from the planning of the production plants to their completion. Projects for 1970 must already be under way; it is not too soon to begin programming for the needs of 1975.

TABLE 6–3.—*Fertilizer needed to increase agricultural production on acreage now under cultivation in Asia,*[1] *Africa, and Latin America by the percentages indicated*

| Percent increase in agricultural production | Tonnage of plant nutrients needed (millions of metric tons) | Percent increase in fertilizer use | Capital needed | Total annual cost |
|---|---|---|---|---|
| | | | (Millions of United States dollars) | |
| ---------- | [2] 6 | ---------- | ---------- | 1,300 |
| 10 | 11 | 80 | 2,500 | 2,400 |
| 20 | 16 | 165 | 5,000 | 3,500 |
| 30 | 21 | 257 | 7,500 | 4,600 |
| 40 | 26 | 345 | 10,000 | 5,700 |
| 50 | 32 | 440 | 13,000 | 7,000 |
| 60 | 38 | 535 | 16,000 | 8,400 |
| 70 | 46 | 645 | 20,000 | 10,100 |
| 80 | 53 | 765 | 23,500 | 11,600 |
| 90 | 60 | 885 | 27,000 | 13,200 |
| 100 | 67 | 1,000 | 30,500 | 14,700 |

[1] Except Mainland China and Japan.
[2] Actual consumption in 1966.

### *6.3.3 Personnel Requirements*

Even though these amounts of capital are quite impressive, it is the judgment of the subpanel that it will be much easier to obtain the needed capital than to provide the necessary manpower. It is estimated that three skilled and five unskilled people are required for each thousand tons of plant nutrients that are produced and distributed per year. Of the skilled personnel, approximately half would need to be college graduates or equivalent, while the remainder could be high school graduates or equivalent with on-the-job technical training. This suggests that 50,000 college graduates would be needed by 1985 in the fertilizer and associated industries.

### *6.3.4 The Production of Nitrogen*

Of the three primary plant nutrients, more nitrogen is used than either phosphorus or potassium, and nitrogen production requires more capital investment per unit of plant nutrient than either of the others. About 98 percent of all nitrogen fertilizers is made with ammonia ($NH_3$) as an intermediate product. The remaining 2 percent is made from synthetic calcium cyanamide ($CaCN_2$) and natural sodium nitrate ($NaNO_3$).

Ammonia is made by the combination of nitrogen and hydrogen under pressure and over a catalyst, by the simple chemical reaction:

$$N_2+3H_2 \rightarrow 2NH_3$$

The nitrogen comes from the air. The hydrogen can be obtained from any carbonaceous or hydrocarbonaceous material, such as natural gas, petroleum, or coal, by the action of steam over appropriate catalysts. Typical hydrogen-producing reactions are:

$$C+2H_2O \rightarrow 2H_2+CO_2$$
$$CH_4+2H_2O \rightarrow 4H_2+CO_2$$

Gaseous hydrocarbons such as natural gas are the best and most economical raw materials to use, and liquid hydrocarbons such as naphtha are next best. The least desirable are solid carbonaceous materials such as coal, coke, and lignite, but they can be and are used. Even wood has been used in the past.

Most of the ammonia produced in the world is made from natural gas by the action of steam and air by a process known as steam reforming. The process is carried out in several stages and the overall chemical reaction is approximately as follows:

$$7CH_4+10H_2O\ (\text{steam})+4N_4O\ (\text{air}) \rightarrow 16NH_3+7CO_2$$

Similar processes use liquid hydrocarbons and solid carbonaceous materials, but the production plants are more complex and more ex-

pensive to build, and operating costs are much higher than if natural gas is the raw material. Therefore, a constantly increasing percentage of the world's ammonia is being made from natural gas.

The production of ammonia has undergone a tremendous technological change in the past five years. This has been one of the most rapid and most dramatic technological changes in history. Its effect has been to reduce the capital and operating costs of ammonia plants. In the United States, the capital cost of a basic ammonia plant with a production capacity of 350,000 tons of ammonia per year would have been about $30 million in 1962, but in 1966 the capital cost of such a plant dropped to about $15 million. As a consequence of lower operating costs and lower capital charges, the production costs of ammonia have been reduced from $45 to $60 per ton in the older plants to $20 to $30 per ton in plants using the "new technology". Figure 6–2 shows a simplified flow chart for the production of ammonia.

The lower production cost of ammonia in the new plants has not yet been reflected in lower prices of fertilizer to the farmer, but prices should be lower in a few years as the "new technology" plants take over more and more of the world's production of ammonia.

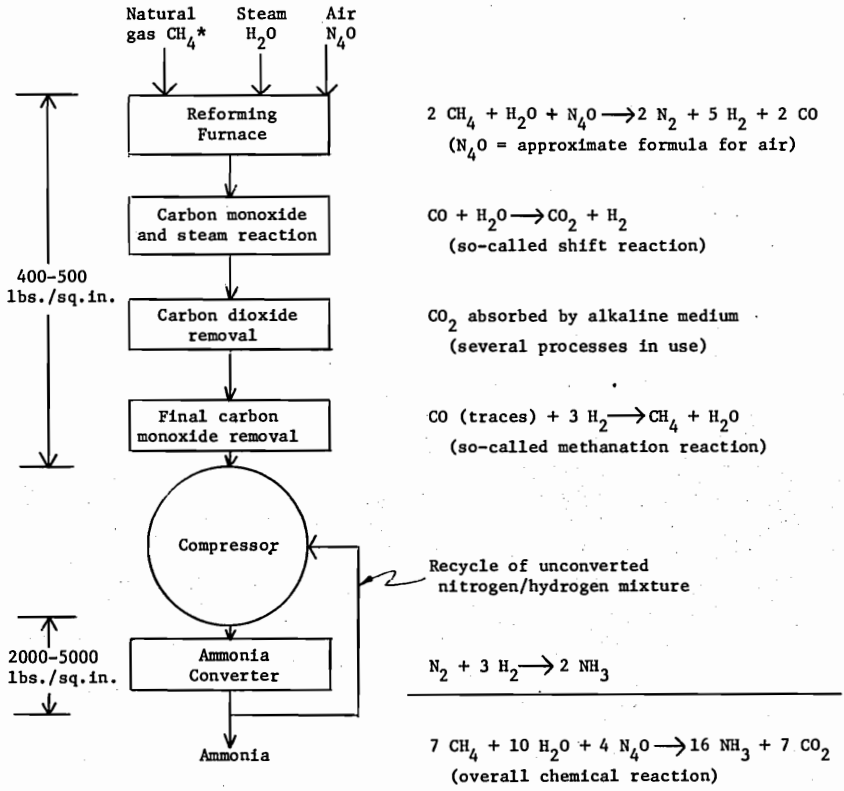
Ammonia is used directly as a fertilizer to a substantial extent in the United States and to a lesser extent in Europe, the Soviet Union, and Japan. On a world-wide basis, most of the ammonia is converted to solid fertilizers such as urea, ammonium sulphate, ammonium nitrate, di- and mono-ammonium phosphate, ammonium chloride, calcium nitrate, and nitrophosphates. Figure 6–3 shows the product and process interrelationships of the principal nitrogen and phosphate fertilizers.

Since natural gas is the preferred raw material for production of ammonia, the nitrogen fertilizer industry is more concentrated in areas where large quantities of natural gas are available at low prices. The principal natural-gas-producing countries rnaked on the basis of gas produced and used for useful purposes are United States, Union of Soviet Socialist Republics, Canada, Rumania, Mexico, Italy, Venezuela, and France. In addition, vast quantities of gas are flared, particularly in the newly-developed, petroleum-producing countries, such as Iran, Saudi Arabia, Kuwait, Libya, Nigeria, and Venezuela. A recent United Nations study found that these six countries flared 1.6 trillion cubic feet of natural gas in 1965, which would be enough gas to make 40 million tons of ammonia (compared with the total world production of ammonia of 24 million tons in 1965).

Besides the six countries cited above, other developing countries with large reserves of natural gas include Iraq, United Arab Republic, Algeria, Indonesia, Pakistan, Burma, Brunei, Colombia, Peru, Chile, Argentina, and Bolivia.

FIGURE 6-2

Process Flow Chart of Ammonia Synthesis




*Natural gas is usually largely methane, but may contain also ethane, propane, butane, higher hydrocarbons, carbon dioxide, nitrogen, hydorgen sulphide, and other gases. Ethane, liquefied petroleum gases (LPG), refinery off-gas, and light haphtha can also be used as feedstocks for the reforming process. With heavier hydrocarbons, partial oxidation processes would have to be used, which require higher capital costs than the reforming process.

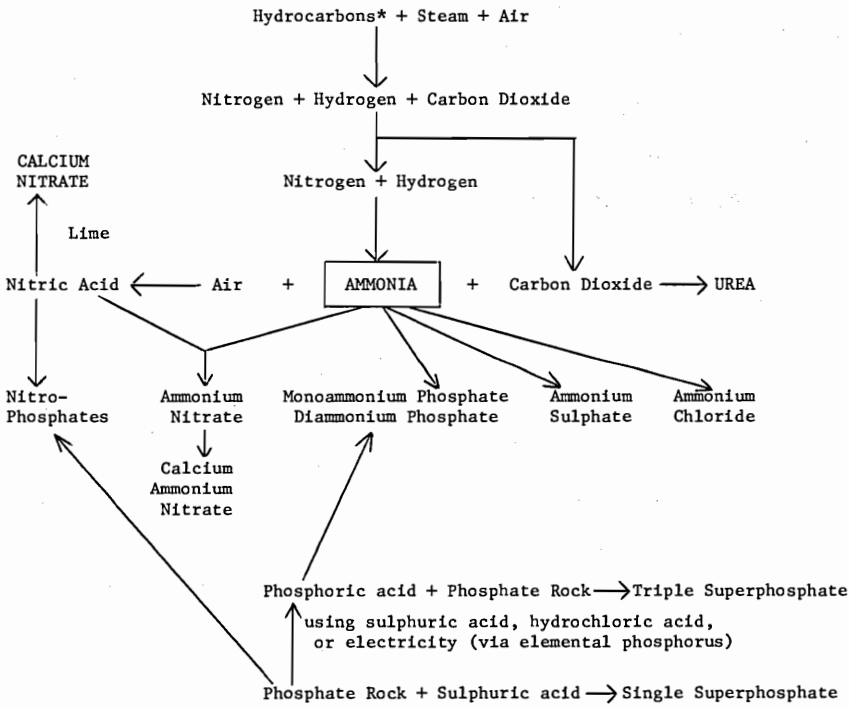
### *6.3.5. The Production of Phosphate and Potash*

The known and probable reserves of phosphate and potash are shown in Tables 6–4 and 6–5. It will be noted that the supply of these materials is quite ample for the foreseeable future, but that they are unevenly distributed geographically. For example, Canada is emerging as a major supplier of potash, while little, if any, potash is found in South America.

Sulfur, used in the prepartion of available $P_2O_5$, is currently in short supply, and prices are rising. The shortage has stimulated further

FIGURE 6-3

Product Interrelationships of Nitrogen and Phosphate Fertilizers




*Hydrocarbon feedstock can be natural gas, ethane, liquefied petroleum gases (LPG), or light naphtha for the reforming process. With heavier hydrocarbon feedstocks, partial oxidation processes would have to be used, which require higher capital costs than the reforming process.

exploration for elemental (Frasch) sulfur and is increasing production from other sources, such as iron pyrites and sour natural gas. It is likely that supply will again be in balance with demand by 1970, but additional price increases are probable. Ultimately, other processes, such as the use of nitric acid for acidulation and the production of phosphates from elemental (electric furnace) phosphorous, will become more important. Technically, sulfur recycle is feasible also and would come into general use if the price of sulfur should rise from its present level of about $35 per ton to about $50 per ton. Thus, there is no likelihood that sulfur shortages will do more than cause temporary dislocations and a modest increase in the cost of the finished product.

TABLE 6-4.—*Estimated free world reserves of phosphate*[1]

| Continent: | *Reserves of $P_2O_5$ (millions of metric tons)* |
|---|---|
| North America | 2,000 |
| Europe | Negligible[2] |
| Asia | 1,000 |
| South America | 200 |
| Africa | 4,000 |

[1] (Estimated mineable reserves under present economic conditions, allowing for mining and refinery losses.)
[2] Exclusive of Union of Soviet Socialist Republics.

TABLE 6-5.—*Estimated free world reserves of potash*[1]

| Continent: | *Reserves of $K_2O$ (millions of metric tons)* |
|---|---|
| North America | 8,000 |
| Europe | 1,000–10,000 |
| Asia | 1,000 |
| South America | 25 |
| Africa | 50 |

[1] (Estimated mineable reserves under present economic conditions, allowing for mining and refinery losses.)

### *6.3.6 The Economics of Fertilizer Production*

The economics of large-scale operation are highly important in the manufacture of fertilizer. Potash and phosphate mines and nitrogen plants must be quite large in order to be efficient. Mines should have an annual capacity of at least 500 thousand metric tons of $K_2O$ or $P_2O_5$ to achieve the lowest cost. Modern, highly efficient, nitrogen plants have capacities of 1,000 metric tons per day or more, but undoubtedly many less efficient smaller plants will be built to achieve compensating efficiencies in distribution within local areas or national boundaries. There is already a tendency toward relatively small operations where liquid formulation is used. This procedure may have an influence on the present method of marketing and distributing fertilizer.

The uneven distribution of natural gas, potash, and phosphate and the requirement for large plants and mines will pose major problems in international trade if the projected needs for fertilizer are to be met. In particular, the major need is a mechanism by means of which the fertilizer-deficit countries, such as India, can buy the fertilizer, since most of these countries in the developing world are perennially short of foreign exchange.

## *6.4.0 Seeds*

### *6.4.1 Recognition of Requirement for Good Seeds*

There is ample evidence that good seeds are required for a highly productive agriculture. The importance of this input is illustrated by the fact that the Food and Agriculture Organization of the United

Nations has given a "seed rating" to characterize nations on their development, production, distribution, and proper use of better seeds. In a survey using rice, wheat, and maize as indicators, the most advanced nations were given a rating of "1" while those nations rating the lowest were given a rating of "4." In the "1" category are Japan, Taiwan, the Netherlands, and Mexico; while Pakistan, Iran, and Jordan are in the "4" category. It is interesting to note that the yields for the nations with a "1" rating averaged 3,250 kilograms per hectare during the period from 1960 to 1962, while those rated "4" averaged 1,400 kilograms per hectare for the same period. Nations rating "1" had almost 100 percent of their grain cropland in improved varieties, while those rated "4" had less than 10 percent in improved varieties.[8]

The importance of good seeds is evident from the improvement in yields of selected crops in certain nations from 1948 to 1962. The N:Co 310 strain of sugar cane introduced into Taiwan in 1951 was being grown on 91 percent of the sugar cane cropland by 1957, with a consequent increase in yield exceeding 50 percent. In contrast, the unimproved varieties of jute and chickpeas grown in Pakistan, and of coffee and maize grown in Venezuela, were not replaced with improved varieties during the period from 1948 to 1962, and there was no increase in yields.[9] In the state of Illinois, hybrid corn was introduced in 1933 and by 1945 was planted almost exclusively. During this period, yields increased 65 percent.

It has been estimated that if 50 percent of the cropland in any given area is properly planted with an improved seed, it is reasonable to expect a 100 percent increase in yields for the entire area. It must, however, be emphasized again that this yield improvement does not result solely from the use of an improved seed, but is dependent upon the adoption and use of improved practices of all kinds, including the use of more and better fertilizer, more pesticides, more and better machinery, and better water management in the case of irrigated areas.

### *6.4.2 Processing Plant Requirements*

Empirical evidence indicates that the required 50 percent of the cropland will be sown in improved seed if 25 percent of the seed for the area flows through commercial channels. Table 6–6 gives an estimate of the number of plants, their cost, and the value of their output if 25 percent of the total seed requirement were to be provided commercially in Asia, Africa, and Latin America. Table 6–7 gives data on the number of plants, capital required, and costs to increase productivity by various percentages.

It will be noted that by 1985, almost 1,000 seed processing plants will be needed, with each plant having an annual capacity of 3,000 metric tons. Approximately $200 million will be required to construct

[8] Statistics Division, FAO, Rome, and Special FAO "Seed Status" Inquiry.
[9] Statistics Division, FAO, Rome, and Special FAO "Seed Status" Inquiry.

TABLE 6–6.—*Number of plants, capital required for construction and annual operating cost to supply 25 percent of the seed requirements of the developing free world by areas* [1]

| Area | Number plants [2] | Millions of United States dollars | |
|---|---|---|---|
| | | Capital needed | Annual operating costs to farmers |
| Latin America | 225 | 40 | 260 |
| Asia | 1,075 | 225 | 1,170 |
| Africa | 175 | 40 | 180 |
| Total | 1,475 | 305 | 1,610 |

[1] Cereals, oilseeds, and pulses. These account for more than 95 percent of all seed requirements.
[2] 3,000 metric tons annual capacity.

TABLE 6–7.—*Seed requirements for increasing food production on acreage now in cultivation in Asia,*[1] *Africa, and Latin America by the percentages indicated* [2]

| Percent increase in agricultural production | Number of plants [3] | Millions of United States dollars | |
|---|---|---|---|
| | | Capital needed | Annual operating cost to farmers |
| 10 | 148 | 30 | 160 |
| 20 | 300 | 60 | 330 |
| 30 | 440 | 90 | 480 |
| 40 | 590 | 120 | 640 |
| 50 | 740 | 150 | 810 |
| 60 | 885 | 180 | 970 |
| 70 | 1,030 | 210 | 1,120 |
| 80 | 1,180 | 240 | 1,290 |
| 90 | 1,325 | 270 | 1,440 |
| 100 | 1,475 | 300 | 1,610 |

[1] Except Mainland China and Japan.
[2] Cereals, oilseeds, and pulses. These account for more than 95 percent of all seed requirements.
[3] 3,000 metric tons annual capacity.

these plants, and the annual value of the output will be approximately $1 billion. While this capacity is in addition to that now in existence, the difference between additional capacity and total capacity is small, since only a small percentage of the cropland in the area is now in improved varieties, and an even smaller percentage of the seed requirement flows through commercial channels.

### *6.4.3 Nature and Subtleties of the Seed Business*

There are several special problems involved in providing seed which must be taken into account as programs are developed. These problems may be generally categorized under the headings of long-range planning, critical timing, and marketing.

The production of seed is characterized by an inflexible time lag, at least four years in the case of hybrid corn production (one year each for increase of inbred lines, making single-cross parents, producing final-cross, and distribution to the farmer), and two years or more for increase of seed of open-pollinated varieties where field-crossing is not required. Careful judgment must be exercised as to the amount and pedigree of a particular variety or hybrid chosen for increase of seed, as there is relatively little a seed producer can do to increase the volume after the program has been started.

A second important feature of seed production is the necessity of performing technical tasks, such as detasseling of corn, roguing of cereals, and pruning of vegetables, at definite times during the growing season. The timing of these critical steps is dependent upon uncontrollable environmental conditions, but they must be done regardless of rain, cold, or holidays. Seed is produced by growing plants, and there is no second chance for any particular generation.

Marketing of seed has several unique features. Farmers develop a preference for particular varieties through knowledge gained from public and private extension efforts. These educational efforts may take the form of test plantings in the area or by publicizing unique resistance to prevalent disease and insect pests. The farmer, however, has no way of knowing when he purchases the seed whether the seed producer did a professional job in critical production practices and avoided mixtures with other varieties in the cleaning and bagging operations. Most countries have seed labeling laws to protect the consumer against fraud.

In addition to the above general factors there are unique and exacting demands for successful seed production of every crop species. Most vegetable seed, for example, must be produced under specific day-length and temperature conditions. If these conditions are not met, the plant will not flower. Harvesting procedures frequently present special problems in small seeded crops, such as the grasses. Special machines have been developed to permit mechanized harvesting of many of these species. In tuberous crops, the storage conditions for seed tubers are critical; light, temperature, and humidity must be controlled. These examples indicate that the seed producer must be familiar with the pecularities of each species that he handles.

Governmental agencies have not been successful in producing and selling seed due to the critical timing involved in performing necessary roguing, detasseling, or inspection functions. The seasonal nature of the job, with the corresponding necessity of long hours and solid work peaks during these periods, is not compatible with the operations of a typical public agency. Also, it is difficult for a governmental agency to commit its facilities for the necessary long-range plans. Public administrators are reluctant to commit resources for the time peri-

ods necessary to build a solid base for a thriving seed enterprise. Marketing of seed can be handled by public agencies through government banks or other public institutions, but the farmer has very limited choice of varieties in such a scheme.

### 6.4.4 *Technology for Seed Production and Distribution*

The provision of superior seed requires a continuing research program, not only for constant improvement in yields and quality, but also for genetic resistance to plant pathogens, such as wheat rust. A general rule is that the expenditure for research should be about 10 percent of the value of the seed. If so, $100 million would be required for research on seed for use in the developing countries by 1985, although this figure may be somewhat reduced by the importation of seed technology from the developed nations. The costs given in Table 6–7 allow for this research cost.

The development of hybrid seed is generally done by the private companies selling the seed. On the other hand, open-pollinated varieties are generally developed by public agencies. This difference arises because hybrid seed cannot be saved by the farmer, but must be purchased from a commercial supplier. The hybrid seed producer can thus absorb his development cost into his selling price, which is difficult for the producer of an open-pollinated variety. This problem has led some nations to enact laws on "breeders' rights" to encourage seed firms to undertake their own research by protecting them from competition from seed producers and distributors who do no research.

The production and distribution of seed requires technical manpower—college graduates or equivalent. Requirements have been estimated to be about nine technical men for each 3,000-metric-ton plant, or almost 10,000 such individuals by 1985. This estimate does not include the highly trained manpower required for research. After basic training in agronomy, the specialized knowledge needed to produce and distribute seed can be acquired rather quickly and easily. Seed companies in the developed nations could train technicians in a relatively short time in the basic operations involved in producing and handling both hybrid and open-pollinated seed. This training would be used most effectively if it were conducted where the seed is produced. Possibly private seed companies could be encouraged to place pilot seed installations in some of the developing nations with arrangements that as many people as possible be trained by the firm.

No particular difficulty in providing the necessary equipment is anticipated if planning is adequate and sufficient lead time is allowed.

## *6.5.0 Pesticides*

### *6.5.1 Importance of Pest Control for Crop Production*

A large complex of pest species share man's requisite for food. These include viruses, bacteria, fungi, protozoa, nematodes, insects, birds, and rodents. Weeds do not consume food directly, but reduce food production through competition with plants for nutrients, water, and sunlight. The direct loss of food as a result of pests has been impossible to determine accurately, but is known to be large, and the minimum estimates of world losses range from 20 to 30 percent of the total food produced. Highly germane in planning for increased agricultural production is the extensive and convincing evidence that pest problems are intensified as yields are increased through the use of more fertilizer, better seed, better water management, and other modern production practices. If the maximum benefits are to be obtained from a system employing these production inputs, effective crop protection methods must be a part of the system.

An example of the importance of crop protection comes from rice production in California. Formerly, weed control was obtained by maintaining a six-to-eight-inch depth of water. However, the development of selective herbicides has made it possible to control weeds effectively without the use of expensive water management techniques. When herbicides came into use, it was possible to reduce the water level in rice fields to approximately two inches, and shorter stemmed rice varieties could then be used which respond effectively to higher levels of fertilization. In this case, better methods of weed control enabled rice growers to realize greater benefits from fertilizer because an improved seed type could be grown.

### *6.5.2 Chemical Pesticide Requirements*

Pests can be controlled either by biological or chemical methods. Numerous examples of spectacular successes have been obtained from the use of biological methods. The success of the plant breeders in developing rust-resistant wheat has been a major factor in increasing wheat yields in this country, even though the resistance effect is soon lost due to changes in the rust organism. This requires that there be a continuous search for new varieties. The elimination of the screw worm in the southern United States was accomplished by male sterilization techniques, a remarkable achievement. In spite of these successes, however, chemical agents remain the main weapons for pest control in most crops, and this will undoubtedly continue for the forseeable future in spite of the increasing and very desirable exploration for germ plasm with biological resistance to insects.

The use of chemical pesticides increases very rapidly as plant production is intensified. Table 6–8 shows pesticide use and the yields of major crops for seven areas or nations. Two important observations

are the excellent correlation between pesticide use and yields, and the extremely rapid rate at which pesticide usage increases as agriculture is intensified. The amounts of pesticides applied in Africa and India, where yields are generally low, amount to only slightly more than 1 percent of the quantities used in Japan, with its intensive agriculture and high yields. Examination of available data also shows that pesticide and fertilizer usages are closely correlated. There are linear relationships between pesticide usage and yields, fertilizer usage and yields, and pesticide usage and fertilizer usage on log-log plots.[10] These relationships were used in predicting pesticide requirements for the various percentage increases in yields shown in Table 6–9.

TABLE 6–8.—*Areas and nations ranked in order of pesticide usage per hectare and in order of yields of major crops* [1]

| Area or nation | Pesticide use | | Yields | |
|---|---|---|---|---|
| | Grams/hectare | Rank | Kilograms/hectare | Rank |
| Japan | 10,790 | 1 | 5,480 | 1 |
| Europe | 1,870 | 2 | 3,430 | 2 |
| United States | 1,490 | 3 | 2,600 | 3 |
| Latin America | 220 | 4 | 1,970 | 4 |
| Oceania | 198 | 5 | 1,570 | 5 |
| India | 149 | 6 | 820 | 7 |
| Africa | 127 | 7 | 1,210 | 6 |

[1] Food and Agriculture Organization of the United Nations. Production Yearbook, Vol. 17, 1963.

TABLE 6–9.—*Pesticides needed to increase food production on acreage now under cultivation in Asia,*[1] *Africa, and Latin America by the percentages indicated*

| Percent increase in agricultural production | Tonnage needed (metric tons) | Millions of United States dollars | | |
|---|---|---|---|---|
| | | Capital | | Total annual cost to farmers |
| | | Manufacturing | Formulation and distribution | |
| ---------- | 120,000 | ---------- | ---------- | 580 |
| 10 | 150,000 | 60 | 40 | 730 |
| 20 | 195,000 | 160 | 80 | 950 |
| 30 | 240,000 | 250 | 130 | 1,070 |
| 40 | 285,000 | 350 | 190 | 1,390 |
| 50 | 342,000 | 470 | 240 | 1,670 |
| 60 | 402,000 | 590 | 320 | 1,960 |
| 70 | 475,000 | 750 | 400 | 2,310 |
| 80 | 558,000 | 920 | 490 | 2,720 |
| 90 | 640,000 | 1,090 | 580 | 3,120 |
| 100 | 720,000 | 1,240 | 670 | 3,500 |

[1] Except Mainland China and Japan.

[10] L. L. Jansen, and W. B. Ennis, Jr., to be published.

Linear regression relationships were calculated between pesticide usage and yields, fertilizer usage and yields, and pesticide and fertilizer usage for Japan, India, and the United States for the years 1952, 1957–58, and 1962–63, using data from the FAO Yearbooks. The regression equations were slightly adjusted to coincide with the 1963 usages of the United States. Predictions of the quantities of pesticides required to meet requirements of developing countries were calculated from the equation

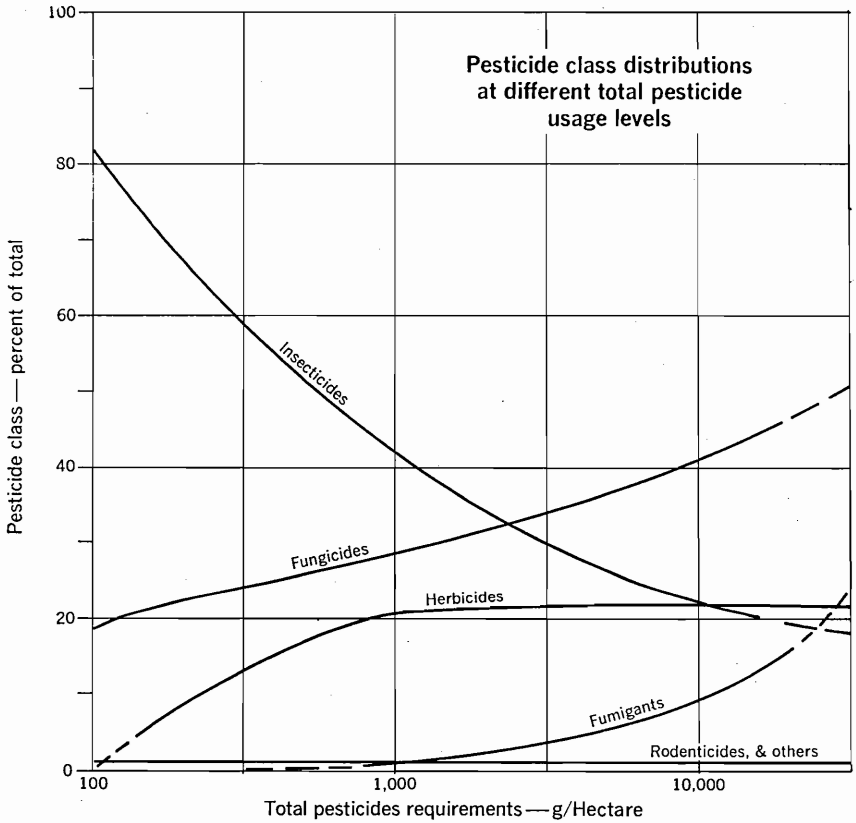
$$\log \mathrm{P} = 2.575 \log Y - 5.620$$

in which P is the pesticide usage rate in grams per hectare and Y is the desired average aggregate yield in kg per hectare of principal food crops (cereals, pulses, oilseeds, raw sugar, potatoes, sweet potatoes, yams, cassava, onions, and tomatoes). Quantities of pesticides to meet the requirements for the various percentage increases in yields (Table 6–9) are cumulative totals of the required pesticide usage rate multiplied by the number of arable hectares for each of the developing geographical areas specified.

Significant correlations were also found for each of the types of pesticides—insecticides, fungicides, herbicides, fumigants, and rodenticides—as functions of the total pesticide requirement. The proportional amounts of the various types change as the total requirement increases. These relationships are shown in Figure 6–4. When pesticides are used in small quantities, they are mostly insecticides with a small percentage of fungicides. As the level of usage increases, fungicides, herbicides, and fumigants become increasingly important, and insecticides are used relatively less, even though the absolute amount being applied increases.

The use of herbicides is often regarded as only a labor-saving measure intended to reduce the cost of production in high-labor-cost areas such as the United States. Recent evidence indicates that the use of modern and highly selective herbicides may increase yields much more than can be achieved by manual or mechanical weeding methods. In the Philippines, when conventional mechanical weed control practices were followed by farmers, the average yield of rice was 2,600 kilograms per hectare. When propanil, a modern selective herbicide especially adapted for use on rice, was used for weed control, the average yield rose to 3,800 kilograms per hectare, an increase of 43 percent. Similar results have been obtained in West Pakistan and Brazil. If these favorable results can be duplicated in other areas, selective herbicides are likely to be adopted extensively for rice production, even in areas having sufficient labor at low wages.

Figure 6-4




Approximate percentage contributions of different pesticide classes to the total pesticides requirement as the total requirement changes from approximately 100 to 10,000 g/hectare. Based on data for India, the United States, and Japan, 1963.

### *6.5.3 Capital and Personnel Requirements*

The production and distribution of pesticides will require a large capital investment and substantial increases in annual operating costs of farms. It is estimated that by 1985 a billion dollars or more will be required for manufacturing, formulation, and distribution facilities, and that the farmers' annual bill for purchased pesticides will be over $2 billion (Table 6–9).

In addition to increased capital, an increase in technical manpower, estimated at 5,000 men plus a supporting staff, will be required for the manufacture, formulation, distribution, and regulation of pesticides in the developing free world by the year 1985.

### *6.5.4 Research and Other Technological Requirements*

It is essential that both adaptive and pioneering research in the field of pesticides be carried out locally by interdisciplinary re-

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search teams. In some cases, pesticides originally developed for use in the temperate zone will be effective.

However, many pest problems of tropical areas are quite different from those of temperate zones, and these will require a substantial research effort intended to lead to entirely new crop protection materials and techniques.

The problems of regulation and other aspects of the safe usage of pesticides require special attention. In the developed countries, sufficient experience and background knowledge have been accumulated to provide a base upon which to establish guidelines for safe practices in the manufacture and use of potent pesticides. Even so, there are many hazards associated with the handling and use of those pesticides which are highly toxic to man, animals, and wildlife. Extensive educational programs will be necessary in the developing nations, and some of the more toxic pesticides, such as parathion, should be handled by specially trained personnel until safety education is widespread, effective, and accepted. The potent power of pesticides to contribute to world food production must be balanced by their intelligent and safe use, if they are to be widely accepted.

It will undoubtedly be much more efficient to manufacture pesticides in the developed nations where trained manpower, raw materials, and utilities are readily available than to manufacture them in the developing nations where these requisities are not available generally. Restrictions on international trade and currency limitations may control the extent to which this can be done. The capital requirements summarized in Table 6–9 are based on the assumption that the manufacturing plants will be built in the developed nations. If, instead, they are built in the developing nations, the total cost might be twice as much.

If pesticides are manufactured in developed nations, the formulation can generally be carried out efficiently on a local basis. With this system, pesticides can be shipped in a concentrated form and then be formulated locally to meet special local requirements.

## *6.6.0 Machinery*

### *6.6.1 Importance of Machinery for Improved Crop Production*

Agricultural machinery is generally thought of in connection with the more efficient use of labor rather than as a yield-raising input. However, the low levels of mechanization in the developing areas of the world seriously handicap the farmers, and more power and better equipment are an essential part of any program for increasing productivity in these areas. Table 6–10 shows data on the available horsepower per hectare of available land in Asia, Africa, Latin America, Europe, and the United States. Figure 6–5 shows the relationship of crop yields and horsepower per hectare for a number of nations and

areas. Although this is a preliminary analysis, the data support the thesis that at least 0.5 horsepower per hectare is needed to achieve high yields. On this scale, it is apparent that the developing free world is far short of the power required for agricultural efficiency.

TABLE 6-10.—*Available horsepower per hectare of arable land and land under permanent crops*

| | Asia [1] | Africa | Latin America | United States | Europe |
|---|---|---|---|---|---|
| Tractor (riding) | 0.02 | 0.03 | 0.18 | 1.00 | 0.78 |
| Garden tractor | .03 | ---------- | ---------- | .014 | .02 |
| Animal | .09 | .01 | .05 | ---------- | .08 |
| Human | .05 | .01 | .04 | .003 | .05 |
| Total | .19 | .05 | .27 | 1.02 | .93 |

[1] Except Mainland China and Japan.

There are a number of ways in which increased power and more efficient machinery can contribute to better yields. One of the most important of these is seedbed preparation, which requires a higher energy input than any other operation. This is, in part, a question of good preparation, generally consisting of mouldboard or disc plowing, with secondary tillage by discing and harrowing. At the present time even animal drawn mouldboard ploughs are hardly used in Asia, Africa, and Latin America. Instead, the far less efficient wooden plough is used. Adaptive research on minimum tillage should be conducted concurrently with efforts to increase power to determine ways to reduce the minimum power requirements.

Another way in which power can improve yields is in timely seedbed preparation. It has been estimated by A. A. Swamy Rao [11] that there is, in general, a loss in yield for many crops in India of about 1 percent per day if seeding is delayed beyond the optimum period of 10 to 15 days. If all of the bullocks in the Raipur district of India were put to work preparing the unirrigated paddy land with a wooden plough, it would require about 50 days. If the mouldboard plough were substituted, it would take about 27 days. These unirrigated fields cannot be ploughed until enough rain falls at the start of the monsoon season to soften the earth. Because ploughing cannot be completed quickly, seedbed preparation is inadequate or delayed in most fields in the district, and there is a consequent loss in yields.

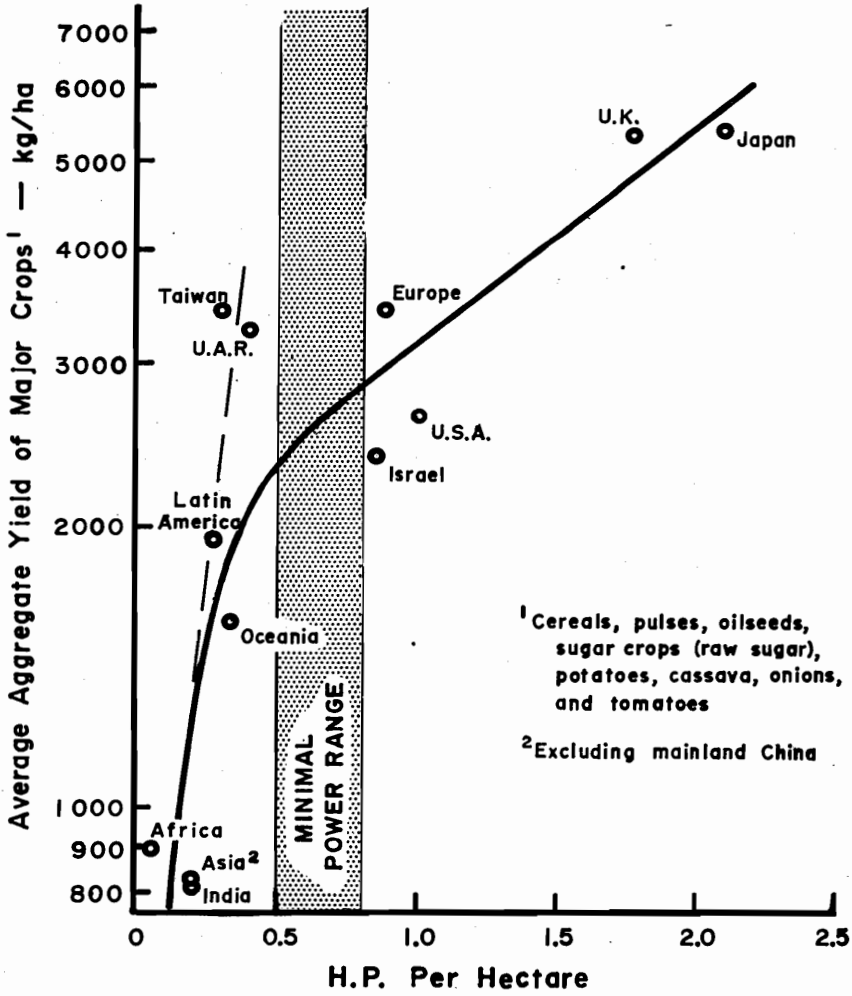
In many cases, rapid seedbed preparation by mechanical methods makes double or triple cropping feasible, where it otherwise would not be possible.

[11] Agricultural Improvements and Power Development Center, Allahabad Agricultural Institute, Allahabad, U.P., India, unpublished report.

# Figure 6-5

## RELATIONSHIP BETWEEN YIELDS IN KG/HECTARE AND POWER IN HORSE POWER PER HECTARE

### Major Food Crops



Timeliness in seedbed preparation is less critical on irrigated lands unless there is a pressure to achieve double or triple cropping. This is perhaps one of the main reasons why Taiwan and Egypt, with only 0.3 and 0.4 horsepower per hectare respectively, are able to maintain high yields. In Taiwan, over 60 percent of the cultivated land is irrigated, while 100 percent is irrigated in Egypt. This contrasts with only 20 percent in India, where, in addition, many of the soils are particularly difficult to plough, requiring high power levels for seedbed preparation.

The extent to which accuracy in the placement of seed and fertilizer can increase yields is not generally realized. Tests conducted in India showed yields of maize increased 40 percent over conventional practices through the use of an efficient machine which placed the seed at the right depth in properly spaced rows and simultaneously added fertilizer.[12] Sixty trials with grain drills averaged a 12.5 percent increase.[13] These machines were operated by farmers for the first time.

With increasing use of pesticides, it becomes important to provide equipment for uniform spraying and dusting. An operator with a single-nozzle sprayer activated by a foot-operated pump cannot distribute pesticides uniformly. But a simple knapsack duster or sprayer powered with a two-horsepower engine can be used to distribute pesticides efficiently over twenty hectares per day.

Increased power can also improve yields by facilitating more efficient and timely harvesting and threshing. The Agricultural Research Institute of Gyogen, near Rangoon, Burma, has shown that a yield of long-grain paddy decreases 2 percent for every day the harvest is postponed after the grain is ripe.

### *6.6.2 Kinds of Machinery Needed*

The basic machinery units needed include tractors, ploughs, disc harrows, peg harrows, grain drills, planters, distributors, cultivators, sprayers, and threshing equipment. Substantial gains in efficiency could be made by providing more efficient machines to be drawn by animals. Reference has already been made to the substitution of the steel mouldboard plough for the wooden plough. Improved animal-drawn seeders, harrows, and cultivators are also needed.

The number of tractors manufactured in Asia (excluding Japan and Mainland China), Africa, and Latin America has been increasing in recent years, and this, of course, has led to their increased use. Some tractors were imported from developed countries. The number of tractors in use increased from approximately 400,000 [14] in 1955

[12] Allahabad Agricultural Institute. Agricultural Implements and Power Development Center. Progress report No. 2. Allahabad, March 1966.

[13] On-the-Farm Evaluation Cum Demonstration of a Seed-Fertilizer Drill 1964–65, I.A.D.P., New Delhi, India, July 1965.

[14] Wheel and crawler tractors, estimated average of 30 horsepower each.

to approximately 900,000 in 1965, an average compound growth rate of more than 8 percent per year. It is reasonable to assume, based upon past trends, that Latin America can achieve the minimum level of 0.5 horsepower per hectare by 1986; Asia can go from the present 0.19 horsepower per hectare to 0.33 horsepower per hectare by 1998; and Africa can move from 0.05 horsepower per hectare to 0.20 horsepower per hectare by 1998. It is evident that the farmers of the developing world are "power minded". There is a natural and universal human desire to escape from the drudgery of hand-labor. In addition, the capital cost of a tractor is actually less per horsepower than that of animals, as are the operating costs. In India, it is becoming common practice for one affluent farmer to buy a four-wheel tractor and gain full utilization of it by ploughing not only his own fields, but also his neighbors' fields for a fee.

### *6.6.3 Estimated Machinery Costs*

The cost of agricultural machinery is surprisingly low relative to the cost of other inputs, such as fertilizer, as compared to experience in the United States, both in terms of capital and in terms of the cost to the farmer. Table 6–11 shows that the capital cost required to provide manufacturing plants for the tractors, power tillers, power sprayers, power harvesting and threshing equipment, and animal equipment needed to achieve the levels of power suggested in section 6.6.2 is approximately $1.8 billion. A more difficult problem will be the recruitment of approximately 10,000 college-trained engineers, or equivalent, who will be required by 1985 to develop, produce and provide for the distribution of the machinery. A much larger number of technicians to assist with the proper use and maintenance of farm machinery will also be needed. No estimate has been made of the requirement for

TABLE 6–11.—*Capital costs for the manufacture and distribution of agricultural machinery for the developing free world*

[Millions of United States dollars]

| | Latin America (20 years) | Asia (32 years) | Africa (32 years) |
|---|---|---|---|
| Total sales | 10,600 | 29,900 | 12,300 |
| Sales per year | 530 | 930 | 380 |
| Capital requirements [1] | 530 | 930 | 380 |
| Total capital | | | $1,800 |

[1] Calculated at 100 percent of annual sales. This includes ancillary plants producing such components as tires, batteries, radiators, etc.

maintenance and repair facilities. Table 6–12 gives a detailed breakdown of projected costs to the farmer of the machinery. It is estimated that the annual cost to farmers will approximate $1.5 billion per year for the next few years and will increase to about $2 billion by the year 1985.

The large contribution to improved yields which can be obtained by use of agricultural machinery, along with the modest cost of these inputs, surely dictates their inclusion in any balanced attack on the hunger problem in the developing nations.

TABLE 6–12.—*A summary of retail costs by type of equipment, area, and period*

[Millions of United States dollars]

| | Latin America | Asia [1] | Africa |
|---|---|---|---|
| 4-year period ending 1970: | | | |
| Tractors | 550 | 470 | 450 |
| Power tillers | 50 | 220 | 20 |
| Power equipment | 950 | 1,060 | 300 |
| Animal equipment | 200 | 1,240 | 50 |
| Total for 4-year period | 1,750 | 2,990 | 820 |
| 6-year period ending 1976: | | | |
| Tractors | 1,110 | 940 | 910 |
| Power tillers | 70 | 340 | 20 |
| Power equipment | 1,420 | 1,580 | 440 |
| Animal equipment | 300 | 1,860 | 80 |
| Total for 6-year period | 2,900 | 4,720 | 1,450 |
| 10-year period ending 1986: | | | |
| Tractors | 2,890 | 2,530 | 2,440 |
| Power tillers | 120 | 560 | 40 |
| Power equipment | 2,380 | 2,630 | 740 |
| Animal equipment | 510 | 3,100 | 130 |
| Total for 10-year period | 5,900 | 8,820 | 3,350 |
| 12-year period ending 1998: | | | |
| Tractors | ---------- | 5,790 | 5,580 |
| Power tillers | ---------- | 670 | 50 |
| Power equipment | ---------- | 3,160 | 890 |
| Animal equipment | ---------- | 3,720 | 150 |
| Total for 12-year period | ---------- | 13,340 | 6,670 |
| Total for the period | 10,550 | 29,870 | 12,290 |
| Investment: | | | |
| Per hectare | 110 | 85 | 50 |
| Per acre | 44 | 34 | 20 |

[1] Except Mainland China and Japan.

### *6.7.0 Interrelationships of Inputs*

There has been emphasis throughout this report on the necessity to use all the production inputs in proper proportion in order to maximize yields of agricultural crops. While some physical inputs are more expensive to provide than others, this does not suggest that these are relatively more important. The proper amount of each of the inputs will vary depending upon the conditions of each situation under which plants and animals are grown. Furthermore, it is not possible to accurately generalize as to the total annual cost of the inputs that will be required to reach various levels of food production throughout the world.

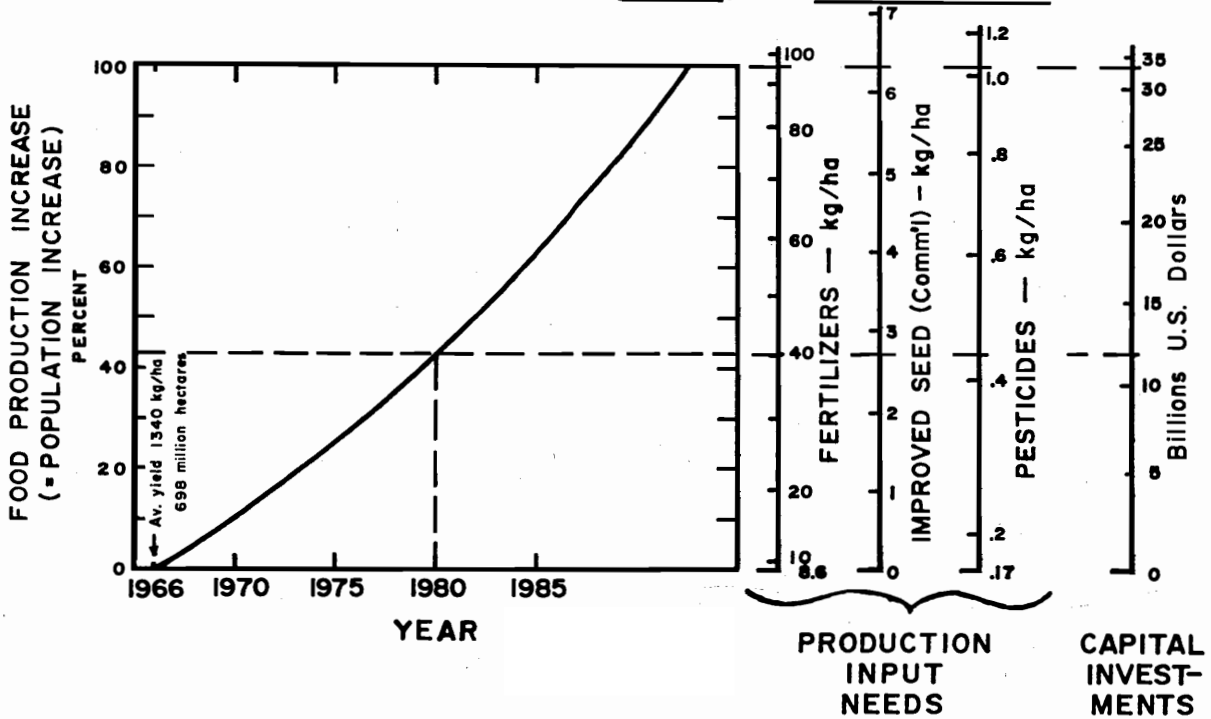
Some attempt has been made to interrelate the input needs and their cost for fertilizer, seed, and pesticides in Asia, Africa, and Latin America. This interrelationship is shown in Figure 6–6.

It is emphasized that the data provided from this graph, can at best, only approximate the true situation. It does indicate the relative magnitudes of the input components that need to be used in production and gives some idea of the costs of achieving the desired level of crop performance. Requirements in terms of amounts and costs of these three inputs have already been given separately and will not be reported here. The combined cost of fertilizer, seed, and pesticides at the level indicated and considered necessary in these countries by 1980 will require a capital investment of approximately $12 billion. By 1985 the cost will have moved to about $18 billion. As indicated earlier, the major portion of these costs are in providing the needed fertilizer.

Figure 6-6

**Interrelations of 3 Production Inputs and Investments in Food Production**

ASIA (except mainland CHINA and JAPAN), AFRICA, and LATIN AMERICA



# CHAPTER 7

# WATER AND LAND

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## Contents

| | | Page |
|---|---|---|
| 7.1.0 | Summary | 407 |
| 7.2.0 | Introduction | 409 |
| 7.3.0 | The World's Potentially Arable Land | 411 |
| 7.3.1 | Methods of Analysis | 411 |
| 7.3.2 | Soils of the World | 412 |
| 7.3.3 | Major Climates of the World | 418 |
| 7.3.4 | The Agroclimatic Regions of the World | 421 |
| 7.3.5 | Possible Increase in Cultivated Areas | 422 |
| 7.3.6 | Costs of Increasing Net Cultivated Areas | 435 |
| 7.4.0 | Water Supplies for Irrigation | 439 |
| 7.4.1 | Presently Irrigated Lands | 440 |
| 7.4.2 | Estimates of Irrigation Development | 443 |
| 7.4.3 | Ground Water | 446 |
| 7.4.4 | Costs of Irrigation Potential | 449 |
| 7.4.5 | Problems of Irrigation Development | 450 |
| 7.4.5.1 | Resource Surveys | 451 |
| 7.4.5.2 | Salinity and Drainage | 451 |
| 7.4.5.3 | Human Factors Must Be Considered | 451 |
| 7.4.5.4 | Irrigation Research | 452 |
| 7.4.5.5 | Irrigation Is Capital—Intensive | 452 |
| 7.4.5.6 | Integrated Planning and Management | 452 |
| 7.4.5.7 | Increased Knowledge of Weather and Climate | 453 |
| 7.5.0 | Water Management | 454 |
| 7.5.1 | Water Alone is not Enough | 454 |
| 7.5.2 | Efficiency of Water Use | 457 |



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# 7.0 WATER AND LAND

## *7.1.0 Summary*

1. The area of potentially arable land on the earth is much larger than anyone has previously supposed, being 24 percent of the total ice-free area and considerably more than twice the land that has been cultivated at some time during the last few decades. It is more than three times the area actually harvested in any given year.

2. More than half the potentially arable land, over 4 billion acres, lies in the tropics. Thirty percent of these tropical arable lands are in the humid tropics; 36 percent in the subhumid tropics where a season of abundant rainfall alternates with a relatively dry season; and 34 percent in the semiarid or arid tropics.

3. Outside the tropics there are large areas of potentially arable land in temperate parts of North America and in Australia.

4. In contrast to the principal areas of potentially arable land, most of the presently cultivated land is in the cool-temperate zone.

5. The largest areas of potentially arable land lie in Africa and South America which, outside the relatively small continents of Europe and Australia, have the smallest cultivated areas.

6. The potential for increasing net cultivated area is very small in Europe and Asia and relatively small in the Soviet Union.

7. In Asia, if we subtract the potentially arable land area in which water is so short that one 4-month growing season is impossible, there is essentially no excess of potentially arable land over that actually cultivated.

8. To increase food supplies in Asia, therefore, it will be necessary either to increase yields per acre or to increase the gross harvested area through double or triple cropping, often, but by no means always, based on irrigation development. We estimate that the potential increase in irrigated area in the Indian sub-continent and Southeast and Southwest Asia is over 200 million acres. The total cost of such development would probably be around $80 billion.

9. In South America and Africa, we can be optimistic about the potential land and water resources. The limiting factors in agricultural development are not natural resources, but economic, institutional, and social problems.

10. The very large disparity between population size and potentially arable land in Asia, on the one hand, and South America, North America, and Africa on the other, suggests that very large-scale inter-



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continental migrations, such as characterized most of the 19th century, might well become important again in times to come.

11. Human migrations within different countries will almost certainly be required in the crowded agricultural lands of Asia. The marginal productivity of agricultural labor is approaching zero in these countries. It will be quite difficult to apply modern technology to raise agricultural production without moving large numbers of people off the land into the cities. For this, as well as other reasons, agricultural development must be accompanied by general economic improvement and particularly by large-scale urbanization.

12. The present technology for agricultural production is inadequate for the humid tropics and for most of the sub-humid tropics. New plant varieties must be developed and new methods of fertilization, pest control, soil conditioning, and water management must be found. Even the basic data on soil properties and climatic conditions are scanty or lacking for most of this region. Hence, major emphasis should be given to research and development of agricultural technology.

13. The need to develop the agricultural potential of the humid and subhumid tropics is a long-range need. This suggests that in this problem we should concentrate on the development of research and teaching institutions. It will also be important to increase communication and coordination between different workers and to attempt to recapture what was learned from previous experiences.

14. Problems of water management and the use of water in combination with other inputs in the arid and semi-arid regions should also be given high priority and may have a more immediate pay-off.

15. In irrigation development, much more attention needs to be paid to ground water resources and their use, particularly in the Indian subcontinent. A test of the effectiveness of ground water development in the Gangetic plain of northern India should be given high priority

16. Problems of water management and the interaction of water with other factors of production must be given special emphasis. Whenever irrigation removes the moisture ceiling on crop yield, other management practices such as fertilization, liming, use of improved varieties, and insect and disease control become more critical. Failure to follow through with all required practices can easily offset the advantages of irrigation.

17. Most major irrigation projects are concerned with only a small part of the total picture. Such projects normally are limited to storage dams, diversion structures, canals and laterals, and in some cases to tubewells. All involved in project planning, project authorization, and project operation should recognize the vital necessity of providing adequately not only for water but for all the inputs and processes that are required if an irrigation scheme is to make a major contribu-

tion to the increased agricultural productivity of the nation. Only by providing in a timely manner all of the inputs required to make an irrigation project fully productive can the high cost of such projects be really justified. The information required for making intelligent decisions on location and magnitude of irrigation projects is generally inadequate in the developing nations. Training of personnel and providing of organizational capability for planning and implementation of projects within the concerned nations needs more attention. It is likely that these requirements may be more difficult to provide than the capital for construction.

18. While large amounts of investment capital are urgently needed for irrigation projects in the developing countries, even more pressing are the needs for hydrologic and engineering data and for highly-trained specialists who can analyze and plan such projects. The training and organization of these specialists should be an important component of technical assistance from the developed countries to the developing ones.

19. Agriculture, wherever it is practiced, is greatly affected by weather fluctuations from year-to-year. In the monsoon regions of South and Southeast Asia, improvement in long-range forecasting of the time of onset and intensity of the monsoon rains would be of great value to farmers. Much research is needed on the air-ocean interactions that drive the monsoons and this will require training of many meteorologists and oceanographers.

### *7.2.0 Introduction*

The Amazon and Congo basins together contain nearly a billion acres of potentially arable soils under a climate with abundant rainfall and little or no dry season. About the same area of potentially arable soils exists in peripheral belts around these basins with a dry season six or less months long. Other sizeable acreages of potentially arable but presently uncultivated soils in the humid Tropics occur in Sumatra, some other Pacific Islands and in Australia.

Thus, we have close to 2 billion well-watered acres today largely unused, except locally for shifting cultivation, with deep, friable soils on smooth terrain that would be easy to till. The principal soils in these vast areas unfortunately are low in fertility for crop plants; the fertility of some of them, especially in South America, is so low that we do not know how to bring them to a sustained high level of productivity. Neither did we know 50 years ago how to do this with the very sandy soils in Florida. Today we do know how to manage these soils. It seems reasonable to assume that through research, ways can be found to make the infertile but otherwise favorable tropical soils acceptably productive. It was through research that the infertile sandy soils of Florida

and, for that matter, many other soils in the southeastern United States, were made productive. At the outset, they were as low in fertility as many of the soils of the humid tropics.

The available evidence, especially from the impressive research in Central Africa, supports the prospect that the humid tropics have a tremendous potential for food production. The Belgians, for example, before suspending their research in the Congo, had developed an oil palm which when properly grown yielded about 4,000 kg per hectare whereas the ordinary palm yielded only about 500 kg per hectare. In the humid Amazon Valley, peppers have been grown successfully by several colonies of Japanese immigrants for at least 20 years. These peppers were grown on Yellow Latosols, which are indeed low in fertility by temperate zone standards. If peppers can be grown successfully, cannot several other crops be grown?

Potentially arable land unused today for crop production is not limited to the tropical and subtropical areas of the world. In the United States and Canada, the soils on at least several hundred million unused acres are suitable for cropping and there are additional millions in southern South America and Australia. Moreover, with breeding of food plants that will mature in shorter and shorter periods and a persistent search for the best combination of cultural practices, cropping could be pushed farther north than it is today, and many more millions of acres thereby would become potentially arable.

On a world-wide basis, therefore, soils capable, under good management, of producing food are not yet in short supply. They may not be for a long time. Unfortunately, the large acreages of such soils are not where population densities are high, also lacking are transport, industries, and the institutions essential for successful, sustained agriculture.

Stated in reverse, scarcities of arable soils in relation to population densities are regional in distribution rather than world-wide. Even within many Latin American countries, unused potentially arable soils are scarce in some localities in relation to population while substantial areas of potentially arable soils still remain unused in other regions. But the principal shortage of arable land relative to population size and growth rate is in Asia. Here multiple cropping and increases in yields must be the principal means for increasing food production to meet human needs. This will require irrigation development and improved water management as well as vigorous and sustained application of all other factors of agricultural production. The capital and operative costs will be high, and the required levels of technology and skill will need to be greatly raised.

It is the chief purpose of this report to put these general statements on a more quantitative basis.

## 7.3.0 *The World's Potentially Arable Land*

One of the basic kinds of information needed to consider problems of food and agriculture on a global basis is the quantity and geographic distribution of potentially arable land, and its ratio in different regions to the area of land already under cultivation. The agricultural potential of any land area depends on three factors: (a) the physical, chemical, and biological properties of the soil; (b) the annual range and seasonality of temperature; and (c) the annual amount and seasonal distribution of precipitation relative to potential evapotranspiration. Several order-of-magnitude estimates have been made of the total world area that could be used for food production, but much previously unavailable data on soils and climate have been compiled during the last few years. Consequently, we have attempted to make more quantitative and detailed estimates than have hitherto been possible.

### *7.3.1 Methods of Analysis*

The climatic classification used was that published by Landsberg, et al.[1] Information on the geographic distribution of soils was taken from a world soil map,[2] scale 1:15 million, prepared by the World Soil Geography Unit of the Soil Conservation Service. On this map, the soils of the world have been aggregated into 13 broad geographic groups, and the distribution of each group has been delineated. Boundaries from the climatic map were superimposed onto the soil map and the acreages of the resulting soil-climate combinations, some 200, were measured. Drawing upon substantial amounts of additional information on file in the World Soil Geography Unit, additional acreage estimates for each combination were made of soils (1) potentially arable, (2) nonarable but with grazing potential, and (3) nonarable and without grazing potential. These estimates were tabulated for each of 22 regions, for seven continental land masses (Union of Soviet Socialist Republics was treated as a separate "continent"), and for the world as a whole, excluding Antarctica and Greenland.

The ecological interpretation of the climatic classification was augmented with data on precipitation and evapotranspiration by C. W. Thornthwaite Associates.[3]

Finally, and highly important to the analysis in this report, the 33 climatic types were consolidated into 17 agroclimatic regions.

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[1] Rodenwalt, E. (ed). World maps of climatology, by H. E. Landsberg and others. Berlin, Springer, 1963.

[2] U.S. Defense Intelligence Agency General guide for estimating significant soil characteristics for predicting the gamma hazard from neutron inducted activity. U.S. Dep. Defense, 1963.

[3] C. W. Thornthwaite Associates, Average climatic water balance data of the continents—Part I, Africa; Part II, Asia; Part III, USSR; Part IV, Australia; Part V, Europe; Part VI, North America (excluding United States); Part VII, United States; Part VIII, South America. Publications in Climatology, Vol. 15–18, C. W. Thornthwaite Associates, Laboratory of Climatology, Elmer, New Jersey, 1962, 1963, 1964, 1965.

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*Potentially arable land* includes soils considered to be cultivatable and acceptably productive of food crops adapted to the environment. All arable land has potential for grazing and, where not too dry, for forestry too. Agricultural technology equivalent to average United States agricultural technology is assumed. Soils already under cultivation are included as well as others not now cultivated. Some soils will need irrigation, drainage, stone removal, clearing of trees, or other measures, the cost of which would not be excessive in relation to anticipated returns.

*Non-arable land with grazing potential* includes soils with severe limitations for growing crops requiring tillage but with at least some potential for grazing. Where not too dry, all of these soils have potential for forestry too.

*Non-arable land without grazing potential* includes land (roads, cities, etc.) not available for cropping or grazing, and soils which without extreme reclamation measures have insignificant potentials for crop production and grazing.

It must be recognized that at the level of generalization used in the soil, climate, and agroclimate classification schemes, rather wide ranges of temperature, rainfall, soil properties and growing conditions exist. Much further refinement of the analysis here reported is possible for those parts of the world where more detailed quantitative data on both soil and climate are available.

Unfortunately for large areas of the world the existing data are insufficient to permit the kind of detailed and refined analysis of agricultural and food production potentialities needed to guide national or international development policies. The lack of information is greatest for those parts of the world which, from this analysis, are believed to have the greatest long-range potentialities for greatly expanding world food production. Consequently the major conclusions stemming from this study are highly conditioned by interpretations based on the least adequate data. Further refinements that might result from a longer and more detailed study of data from the more highly developed temperate regions of the world would not alter in any major sense the total world picture because the latter is dominated by the potentialities of the humid and sub-humid tropics for which the existing data are least adequate.

### *7.3.2 Soils of the World*

The soils of the world are arranged and discussed according to 13 broad geographic groups. Most of these are made up of several classes of soils known as great soil groups. Many of the great soil groups are minor components of several of the 13 broad geographic groups, although the acreage is too small to deserve mention in some of them. At least a few areas of alluvial soils and Lithosols can be found in each of the 13 geographic groups. Similarly, some areas of ground-

water podzol, half bog, humic gley, and low-humic gley occur in all areas with humid climates. At least some areas of solonchak, solonetz, and calcisol are to be found among most soils of dry areas. Table 7–3 sets forth a brief description of each great soil group. In the other tables, the soil areas are identified by the numbers 1 to 13; these refer to the broad geographic groups discussed below.

1. *Tundra, Subarctic Brown Forest.* Soils of this group occur mainly in the Arctic. They cover about 1,277 million acres, or nearly 4 percent of the ice-free surface of the world. Coldness alone is a limitation so severe that these soils are unimportant for food production in the world as a whole. They are little used except for providing browse for Arctic animals, some of which serve as food for the sparse human populations of the far North.

2. *Desert, Red Desert, Sierozem, Brown, Reddish Brown, Solonchak, Solonetz, Soloth, Calcisol.* Soils of this widespread group cover about 5,261 million acres or about 16 percent of the land surface and 15 percent of the arable land of the world. They extend across vast, dry areas in Africa, Asia, Australia, and smaller areas in North and South America. The most arid of these soils, as those in the Sahara, are totally devoid of vegetation, but between 50 and 75 percent of total area of these soils does provide some browse. The least arid soils (Brown, Reddish Brown) are suitable for dry farming, but the yields tend to be low and the risks of failure high. Significant food production is limited to areas that can be irrigated.

Most soils of this group are well supplied with plant nutrients, but they are low in organic matter and nitrogen and often the mineral nutrients are poorly balanced. With technically sound irrigation, nitrogen fertilizers are needed almost without exception. Potassium is usually abundant, but phosphorus is commonly low. Deficiencies of micronutrients—for example iron and zinc—are common.

Soluble salts in detrimental amounts or excessive alkalinity, common to soils in many places in arid regions, are limitations that must be overcome and subsequently prevented if sustained high production under irrigation is to be realized.

3. *Chernozem, Chestnut, Reddish Chestnut, Brunizem, Reddish Prairie, and Humic Gley.* This group of about 2,030 million acres or 6 percent of the land surface of the world contains nearly 15 percent of the arable land and includes the great wheat-producing soils (Chernozems) of the world and the great maize-producing soils (Brunizems) of the United States. Nearly all soils of this group occur chiefly in temperate, semiarid to subhumid regions and are used for farming and ranching.

The physical condition of these soils commonly is favorable for plant roots and the nutrient supply generally is high and well-balanced. Yet, favorable responses are obtained from fertilizers containing

nitrogen and phosphorus especially under the more humid climatic conditions. Yields generally are not high as moisture, while sufficient for moderate yields, is insufficient for high yields except in the more humid areas. Yields, of course, can be increased substantially by supplemental irrigation, but research is pointing the way to increased yields without irrigation as well.

In this group, mainly under subhumid climates, some soils are naturally wet. These need artifical drainage for the production of crops such as maize and wheat, but once drained they are highly responsive to good management and are highly productive.

4. *Noncalcic Brown.* Of relatively small total extent, 717 million acres or slightly more than 2 percent of the total and 3.5 percent of the arable land of the world, the soils of this group are common in those warm temperate and subtropical parts of the world with a long dry season. A hardpan, while not everywhere present, is a common subsoil feature that restricts root penetration to 1½ to 2 feet; and, in many places, the surface soil tends to become hard and massive following prolonged drying.

The soils are medium to relatively high in plant nutrients. They are moderately responsive to management, especially where they are free of a restrictive pan in the subsoil. Maintenance of good tilth is a problem. Moderately high yields are possible where irrigation is combined with other good management practices.

5. *Podzol, Gray-Brown Podzolic, Brown Podzolic, Gray Wooded, Soils Brun Acides, Ground-Water Podzol, Low-Humic Gley, and Half Bog.* This group, one of the more extensive, covers about 4,847 million acres or nearly 15 percent of the total and 10 percent of the arable land of the world. Soils of this group form a broad belt across the northern part of Asia, Europe, and North America, and they also occur near the tip of South America.

They are leached of most of the readily available plant nutrients and are acid in reaction. The dominant soils are sandy. For sustained production of common food crops, lime as well as nitrogen, phosphorus, and potash are needed, and some minor elements, such as boron, may be needed too.

All but a small proportion of the total area of soils in this group is still in forest. Coolness is a serious limitation for food crop production, and in many places the soils are excessively wet. Nevertheless, crop production is feasible in many places; the famous potato-growing section of Maine is an example.

Along the southern fringe of the vast areas of this group of soils, particularly in Europe and North America, are some that are only moderately leached and are loamy or clayey (gray-brown podzolic, gray wooded). These also, being in a warmer climate, are highly

responsive to good management and with proper liming and fertilizing give high yields of forage and a variety of crops.

6. *Red-Yellow Podzolic.* Soils of this group cover about 965 million acres or nearly 3 percent of the total and 4 percent of the arable land of the world. The largest areas are in southeastern United States and southeastern mainland China. The soils of this group are highly leached and consequently are quite low in plant nutrients. Commonly the soils are deep and are penetrable by roots to a considerable depth, although the subsoil in numerous localities has a pan that restricts root penetration to about 2 feet.

Without liming and fertilization with nitrogen, phosphorus, potash, and perhaps some minor elements, the productivity of these soils is low; but, with good management, including appropriate application of lime and fertilizers, herbicides, insecticides, etc., the productivity of a wide variety of crops is high. In fact, it can be very high.

7. *Latosol, Ground-Water Laterite, Reddish-Brown Lateritic, Yellowish-Brown Lateritic.* This extensive group covers about 6,177 million acres or about 19 percent of the total but includes one-third of the arable land of the world. It includes the principal soils of the humid and seasonally wet-dry tropics where temperatures are always favorable for plant growth and rainfall is adequate to abundant from about 5 to 12 months of the year.

This group of soils, extensive under savannah as well as under forest, contains the most severely weathered and leached soils of the world. Their meager supply of plant nutrients is barely enough to support cropping for 2, 3, or 4 years, after which long periods—6 to 12 years or more—of fallow are necessary to restore their limited productivity. The soils are almost universally low in phosphorus, and they have the unfavorable tendency of "fixing" phosphorus fertilizer and thereby making it unavailable to plants. On the other hand, most of these soils are permeable to both air and water, easily penetrated by roots to great depths, easy to keep in good tilth, and have at least moderate water-holding capacity. Perhaps at least 75 percent of the total area has smooth topography suitable for the use of farm machinery.

Many, perhaps most, of these soils are highly responsive and under substantially improved management can be made highly productive of a wide variety of food crops. While practical ways have not yet been found for bringing the most infertile soils of this group to a high level of productivity, research can be expected to find ways.

Scattered throughout most areas where the soils of this group occur are some that contain laterite. This is iron-rich material which already has hardened into sheets of gravels or will harden irreversibly into such forms under drying. Commonly, soils with laterite have severe limitations for crop production. Such soils, while conspicuous and

widespread make up less than 10 percent of the total area of this extensive group.

8. *Grumusol, Terra Rossa.* Only about 809 million acres, 2.5 percent of the world, is covered by the soils of this group, but they constitute 5.5 percent of the arable land. The black soils (grumusols) are the more extensive. They occur chiefly in southern Asia, Africa, and Australia with lesser areas in the Mediterranean region and United States.

The black soils of this group are high in clay, are plastic, and shrink and swell with the formation of vertical cracks that extend downward 2 to 3 feet. While these soils are moderate to high in fertility, they are heavy to work, and maintenance of good tilth is a major problem, particularly without modern machinery.

Because of their low permeability, these black soils are difficult to irrigate. Most areas are either flat or gently sloping, and many of the flat areas are wet for several months each year. Yields of food crops under primitive management are commonly low, but moderate to high yields are possible with improved management including the use of power machinery.

The red soils (terra rossa) which also are moderate to high in fertility are moderately friable and hence easier to maintain in good tilth. In some places these red soils are only a foot or two deep over limestone, a condition which restricts the soil volume available to plant roots.

9. *Brown Forest, Rendzina.* The total extent of these soils is slightly less than 0.8 percent of the world soil-covered area, about 253 million acres. They contain a similar percentage of the arable land of the world. They occur mainly in Europe and United States. They have limestone or basic igneous rock at rather shallow depths, and a high proportion of the total area is hilly to mountainous. While these soils are high in fertility, their steepness and their shallowness are serious limitations to their use for crops requiring cultivation. They are, however, productive of pasture.

10. *Ando.* This group covers only about 0.2 percent of the world, about 65 million acres, one-fourth of which is arable. It is important in Japan, New Zealand, Chile, and on many islands. These soils, having formed in volcanic ash, are light; they weigh only about half as much per cubic foot as most other soils of the world. They are dark in color, quite acid in reaction, and have a high water-holding capacity. Even though high in organic matter, they usually need nitrogen fertilizers for the production of crops, and they commonly have a high requirement for phosphorus too. A high proportion of the soils of this group are on forested mountains, but there are important exceptions. Where the climate is suitable, they, under good management can be made pro-

ductive of pastures, and where their topography is suitable of a variety of food crops.

11. *Lithosols.* The soils of this group cover about 6,732 million acres, nearly 21 percent of the world land surface, but comprise only about 2.5 percent of the arable land. While they occur chiefly in the rather cold or arid mountainous areas of the world and hence are steep, they also occur in deserts, particularly in the Sahara, where the topography is smooth.

Lithosols are shallow over bedrock, commonly too shallow and stony for cultivation. They have an insignificant potential for the production of food crops, although where the climate is favorable they have some potential for pasture or forestry. (Within areas delineated as lithosols on small scale maps, there may be inclusions of other soils which are arable.)

12. *Regosols.* Regosols, unlike lithosols, are deep, and, unlike most other soils of the world, lack the usual horizonation (genetically related layers) in the topmost few feet. They occupy nearly 6 percent of the total land but contain only about 2 percent of the arable land of the world. Regosols are uniform in soil characteristics from the surface downward to a depth of about 5 feet or more, generally much more. Most are sands and most are in the arid parts of the world where sand dunes are common.

The water-holding capacity of sandy regosols is so low that it is a very serious limitation to their use for crop production. Moreover, as most regosols are highly susceptible to blowing, the control of drifting sand is a problem in many places especially in deserts. The food production potential of regosols as a group is low although locally they can be made productive by carefully controlled irrigation, fertilization, etc.

13. *Alluvial soils.* Perhaps a third of the world's population gets its food supply from this important group of soils, which is conservatively estimated to cover about 1,468 million acres or between 4 and 5 percent of the total ice-free land area. Alluvial soils constitute 10 percent of the arable land supply. They occur mainly in relatively narrow, elongated areas widely dispersed throughout the world. This group includes soils that are still subject to flooding or were subject to flooding until rather recent channel deepening or shifting occurred. It does not include soils in old alluvium that now reflect strongly the influence of climate and vegetation.

The fertility of different kinds of alluvial soils is directly related to the sources of the alluvium. For example, alluvial soils from erosion products of sandstones, shales, and other detrital sedimentary rocks tend to be relatively low in fertility; whereas those from limestone, basalt, and other nutrient-rich rocks tend to be high.

Most of the large areas of alluvial soils along large streams are of mixed origin and well supplied with plant nutrients. The foremost management problem of such soils is water control, including drainage, irrigation in dry seasons and protection from flooding.

Alluvial soils vary widely in texture. The clayey ones are apt to be difficult to drain and to till.

Especially in dry regions, low areas are likely to be highly saline or alkaline; these limitations must be removed before the soils can be made productive under irrigation.

Even though alluvial soils are unleached and therefore relatively fertile, high yields usually require nitrogen fertilizer and some phosphorus and potassium, or both. The alluvial soils in arid regions are also likely to have deficiencies in zinc and iron that need correction.

### *7.3.3 Major Climates of the World*

The means and annual range of temperature and the total quantity and seasonal distribution of precipitation are the primary factors that determine the climate types used in this report. The 33 types identified in the tables are subdivisions of the five climate zones. These zones are based largely on annual mean temperatures and seasonal temperature ranges. Certain generalizations concerning their agricultural production characteristics and potentialities are given in the following paragraphs.

*Climate Zone I. Polar and Subpolar climate* occurs at high altitudes and at high elevations in other parts of the world. Temperature conditions in this zone, which covers 4.3 percent of the land surface of the world, are so severe as to prevent plant growth except for sparse lichens, mosses and tussock grasses which provide forage for caribou and musk oxen. The land in this zone contributes virtually nothing to the world's food supply and will not in the foreseeable future.

*Climate Zone II. The Cold-Temperate Boreal Zone* extends northward to the Polar zone from approximately 50° north latitude in North America and from 55° north latitude in Europe and Asia. It represents 15 percent of the world's land area but contains only about 1.5 percent of the total inventory of arable land. Except for small coastal areas where oceanic effects modify the temperature, the length of the growing season is too short for the production of most cultivated crops. Some forage crops and cool season food crops can be produced during the summer months when the days are long and the intensity of solar radiation is high. No extensive increase in the productivity of this region is likely because of the severe temperature constraints placed on vegetative growth. According to Landsberg, et al.,[4] three different climatic types can be distinguished in

[4] Rodenwalt, E. (ed). World maps of climatology, by H. E. Landsberg and others. Berlin, Springer, 1963.

the boreal climatic zone. These are designated as II 1 through II 3 in our tables.

*Climate Zone III. The Cool-Temperate Zone* includes approximately 22 percent of the total land area and nearly 30 percent of the arable land of the world. Most of this land is in the northern hemisphere where it occurs largely in a band lying between 35° and 55° north latitude. The amplitude of the seasonal variation in temperature and the amount and seasonal distribution of precipitation are the major climatic factors that determine the agricultural productivity of regions in this important zone. Temperature conditions throughout the zone provide a growing season sufficiently long for the production of a wide range of annual and frost-resistant perennial crops. In some areas multiple cropping is feasible by growing in sequence a warm season and a cool season crop. Natural precipitation is adequate for full season crop production in roughly half the area of this zone. In the other half the lack of sufficient moisture during the growing season restricts the choice of crops produced or limits land use to grazing purposes or to areas where irrigation can be practiced. Considerable increases in food production are feasible from the land in this climatic zone by improving production technology on land now under cultivation, by increasing the cultivated acreage, and by irrigation in the moisture deficient areas. The cool temperate zone contains the major food surplus regions of the world at the present time. In our tables this zone is subdivided into 15 climatic types, listed as III 1 through III 12a, in accordance with the definitions given by Landsberg, et al.[5]

*Climate Zone IV. The Warm-Temperate Sub-Tropical Zone* represents about 21 percent of the total land area and roughly 17 percent of the world supply of arable land. This zone dominates the two areas lying between 20° and 35° latitude in both the northern and southern hemispheres. Temperatures are sufficiently high to permit vegetative growth throughout the entire year in all but the high-latitude margins of this zone. The amount and seasonal distribution of precipitation in the various parts of this zone are the dominant climatic factors that determine its agricultural productivity. The great deserts of both the northern and southern hemispheres lie wholly or in part in it. In the more humid parts of the zone multiple cropping is feasible particularly in areas where the surface or underground water supply will permit supplementary irrigation to reduce the hazard of a water deficit during the low rainfall months. In the drier parts of the zone, agriculture is limited to a single crop grown during the rainy season or to irrigated areas supplied with water from watersheds often far removed from the area to be cultivated.

[5] Rodenwalt, E. (ed). World maps of climatology, by H. E. Landsberg and others. Berlin, Springer, 1963.

Food production in this part of the world can be substantially increased by raising yields per acre through improved production practices, by expansion of multiple cropping with supplementary irrigation, by increasing the area under cultivation through improved moisture conservation, and by full irrigation. Climate zone IV contains 7 climatic types, listed as IV 1 through IV 7.

*Climate Zone V. The Tropical Climate Zone* represents nearly 38 percent of the land surface of the world and contains slightly more than one-half of the arable land. It is largely found in the region lying between 20° north and 20° south latitude. Temperatures show little or no seasonal variation and are sufficiently above the threshhold for vegetative growth to permit continuous production of food crops. The agricultural productivity of this zone is determined not by any temperature constraints but by moisture supply and soil characteristics. Near the equator large areas exist where the amount and seasonal distribution of precipitation are adequate for crop production in all months of the year. Both the annual amount and the seasonality of rainfall become less favorable in areas farther removed from the equator, and annual crop production based on rainfall becomes restricted to a progressively smaller number of months.

Although the principal areas of current food deficit occur in the tropical zone there also exist in this zone the greatest potentialities for increasing world food production. The humid tropics contain nearly 16 percent of the arable land of the world. Although proven production technology is not presently available, this vast land resource is ecologically suitable for food production on a year-round basis. A somewhat larger area in the subhumid tropics containing nearly 20 percent of the arable land supply has the ecological potentialities for at least 6 months of crop production each year. Because the total annual precipitation of this large region is on the average greater than the annual evapotranspiration, sufficient water reserves normally exist throughout the area to permit supplementary irrigation that would extend the cropping season to a full 12 months. The remaining parts of the tropical zone contain 17 percent of the arable land of the world. Both the amount and seasonal distribution of rainfall in this large region usually limit food production to a single rainy season crop. An additional short-season crop dependent on soil-stored moisture or supplementary irrigation from indigenous seasonal water supplies can often be produced. Year-round crop production in this region is dependent on irrigation based usually on water supplied to one area from another area. Extensive areas of grazing land particularly in the drier part of the tropical and sub-tropical zones have the potentiality of increasing the world food supply if animal and range management production technologies suitable for the region can be

developed. Six climatic types, V 1 through V 5, are contained in the tropical climate zone.

*7.3.4 The Agroclimatic Regions of the World*

Temperature and available moisture are the two principal climatic factors that determine the agricultural and food production characteristics of the nearly 8 billion acres of arable land of the world. They determine either singly or in combination the number of months of the year during which food crops can be grown with reasonable certainty at acceptable levels of production. When temperature and moisture conditions are adequate for vegetative growth throughout the year, the ecological requirements for maximum food production are available. If low temperature or moisture deficit or both prevent or render plant growth very hazardous in an area, say for 4 months each year, the area would be classified as an 8-month agroclimatic region and designated as 8M if the constraint is caused by moisture deficit or 8T if low temperature is the limiting factor during the remaining 4 months.

Using the above system the 33 climate types from the 5 climate zones were grouped into 17 agroclimate regions. These are identified in the tabular sections of the report by numbers from 0 to 12 representing the length of the growing season in months. A postscript T or M indicates whether the constraint is caused by temperature or moisture. When all or part of the dry season is also cold, this is shown by a number followed by T in parenthesis, which gives the total number of months during the year when temperature is not a limiting factor and thereby indicates the potential for double-cropping. Thus in the agroclimatic region designated 4M (8T), two crops could be grown during the year if water were available for irrigation.

The analysis reveals that 1.2 billion acres or nearly one-sixth of the arable land is found in an agroclimatic region which without irrigation will permit year-round food crop production. An additional 0.43 billion acres representing 6 percent of the arable land is found in an 8M agroclimatic region. In such areas two food crops per year are normally feasible and where sufficient water is available for irrigation, and the temperature during the remaining 4 months is warm enough, crop production on a 12-month basis is possible.

For an estimated 1.8 billion acres or 23 percent of the arable land, insufficient moisture limits crop production to 6 months each year. For this 6M agroclimatic region a full-season crop during the rainy season can normally be followed by a short-season food crop produced largely on the residual soil moisture. The yield level and certainty of the dry season crop are improved by selecting early maturing drought-tolerant crops and by the availability of even small quantities of supplementary irrigation water. As in the 8M region full 12-month production is

possible if an irrigation system has been developed and year around temperatures are sufficiently high.

More severe and prolonged moisture deficits exist for the 4M and 2M regions which contain 1.5 and 0.5 billion acres of arable land respectively. The 4M regions will produce one full-season food crop under normal conditions, but yields may vary widely from year to year because of variations in the amount and timing of rainfall. In the 2M regions the annual moisture supply and the year-to-year variations are large enough to render crop production very hazardous. Short-season, drought-tolerant crops may be produced annually or alternate-year cropping with intervening fallow for moisture conservation may be practiced.

For 0.35 billion acres of arable land the moisture supply is so low that no food crop production is possible without irrigation. In this region which contains about 4.5 percent of the arable land, indigenous water supply is so limited that irrigation must be based on water imported into the area.

For 26 percent of the arable land of the world, crop production is limited by low temperatures alone. This constraint varies from a total year-round restriction in agroclimatic region 0T to the 4-month limitation in region 8T. The intermediate categories of 2T, 4T, and 6T represent 0.11, 0.98, and 0.94 billion acres respectively. At present no remedial technology can be applied extensively to counteract the low-temperature constraint that characterizes these agroclimatic regions. Increases in food production from the arable soils of those regions depends on (a) the selection of short season varieties, (b) the production of crops that grow rapidly under cool conditions, and (c) the development of frost tolerant plants.

### *7.3.5 Possible Increases in Cultivated Areas*

Tables 7–1, 7–2, and 7–4 show on a worldwide basis the number of acres of potentially arable land, the non-arable area that has some grazing potential, and the remaining area that can be used neither for crops nor grazing. In Table 7–1 these different quantities are given for each of the 13 great soil groups described in Section 7.3.2.; Table 7–2 shows a similar breakdown by climatic zones; and Table 7–4 by agroclimatic regions. The quantity of potentially arable land in each continent and each soil group is shown in Table 7–6. Tables 7–7 and 7–8 give a similar breakdown for the different continents by climatic zones and agroclimatic regions, respectively. (The Union of Soviet Socialist Republics is counted as a separate "continent" in these tables.)

TABLE 7–1.—*World land area in different soil groups*

[In billions of acres]

| Soil group[1] | Potentially arable | | Grazing | | Nonarable | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Acres | Percent | Acres | Percent | Acres | Percent | Acres | Percent |
| 1. Tundra | 0 | 0 | 0 | 0 | 1.28 | 3.9 | 1.28 | 3.9 |
| 2. Desert | 1.07 | 3.3 | 2.26 | 7.0 | 1.93 | 5.9 | 5.26 | 16.2 |
| 3. Chernozem and brunizem | 1.15 | 3.5 | .70 | 2.2 | .18 | .5 | 2.03 | 6.2 |
| 4. Noncalcic brown | .27 | .8 | .34 | 1.1 | .10 | .3 | .72 | 2.2 |
| 5. Podzol | .79 | 2.4 | 1.24 | 3.8 | 2.82 | 8.7 | 4.85 | 14.9 |
| 6. Red-yellow podzolic | .32 | 1.0 | .49 | 1.5 | .16 | .5 | .96 | 3.0 |
| 7. Latosol | .62 | 8.1 | 1.76 | 5.4 | 1.80 | 5.5 | 6.18 | 19.0 |
| 8. Grumusol, terra rossa | .43 | 1.3 | .27 | .8 | .11 | .3 | .81 | 2.5 |
| 9. Brown forest, rendzina | .06 | .2 | .13 | .4 | .06 | .2 | .25 | .8 |
| 10. Ando | .02 | .1 | .03 | .1 | .02 | .1 | .06 | .2 |
| 11. Lithosol | .19 | .6 | 1.02 | 3.1 | 5.52 | 17.0 | 6.73 | 20.7 |
| 12. Regosol | .15 | .5 | .36 | 1.1 | 1.39 | 4.3 | 1.90 | 5.8 |
| 13. Alluvial | .79 | 2.4 | .43 | 1.3 | .25 | .8 | 1.47 | 4.5 |
| Total | 7.86 | 24.2 | 9.02 | 27.8 | 15.60 | 48.0 | 32.50 | 100.0 |

[1] For a complete listing of components of each group, see sec. 7.3.2.

TABLE 7–2.—*World land area in different climatic zones* [1]

[In billions of acres]

| Climatic zone | Potentially arable | | Grazing | | Nonarable | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Acres | Percent | Acres | Percent | Acres | Percent | Acres | Percent |
| I Polar and subpolar | 0 | 0 | 0 | 0 | 1.38 | 4.2 | 1.38 | 4.2 |
| II Cold-temperate boreal | .12 | .4 | .47 | 1.4 | 4.28 | 13.2 | 4.87 | 15.0 |
| III Cool-temperate | 2.24 | 6.9 | 2.46 | 7.6 | 2.48 | 7.6 | 7.18 | 22.1 |
| IV Warm-temperate subtropical | 1.37 | 4.2 | 2.08 | 6.4 | 3.38 | 10.3 | 6.83 | 21.0 |
| V Tropical | 4.13 | 12.7 | 4.02 | 12.3 | 4.08 | 12.7 | 12.23 | 37.7 |
| Total | 7.86 | 24.2 | 9.02 | 27.8 | 15.60 | 48.0 | 32.50 | 100.0 |

[1] Excluding ice-covered areas.

TABLE 7–3.—*Brief Definitions of the Great Soil Groups* [1]

*Alluvial:* Soils developing from recently deposited alluvium with little modification except for small accumulation of organic matter near the surface. With favorable climates and flood control, many of these soils have high potential for crops.

*Ando:* Dark colored acid soils dominated by volcanic ash. Many areas are hilly and forested; smooth areas if well managed, are moderately to highly productive for farm crops.

[1] More complete definitions may be found in the following references:

*a.* U.S. Department of Agriculture. *Soils and Men.* U.S. Department of Agriculture Yearbook for 1938. 1232 pp. Illus. Washington.

*b.* Kellogg, Charles E. Tropical Soils. Trans. 4th International Congress of Soil Science. 1 : 266–276, 1950. Amsterdam. (For Latosol)

*c.* *McGraw-Hill Encyclopedia of Science and Technology.* McGraw-Hill Book Co., 12: 433–441. 1960. New York.

TABLE 7–3.—*Brief Definitions of the Great Soil Groups* [1]—Continued

*Brown:* Brown soil, grading through light brown prismatic soil into a gray calcareous layer at one to three feet in areas of cool to temperate semi-arid grassland. The strongly sloping areas are used for grazing and the smooth areas can be used for cereal grains. Yields are moderate in moist years and very low in drought years. Many are responsive to irrigation.

*Brown Forest:* Dark brown, humus-rich soils grading through lighter colored soil to the parent material at 2 to 4 feet, developed under forest in cool and temperate regions. Where neither steep nor stony, they are highly productive for a wide variety of crops.

*Brown Podzolic:* These are similar to Podzol, but have brown acid surface soils rather than gray. They are developed under forests in cool temperate and temperate climates. Where not too stony and hilly, with adequate fertilization and water control, they are suitable for a wide range of fruits and other cool-season crops.

*Brunizem:* Very dark brown soils in cool and temperate humid grassland areas that are a little more humid than Chernozem. They are highly productive of maize, other cereals, and forages.

*Calcisol:* Soils of semi-arid and arid regions with so much powdery calcium carbonate in them that rooting zones are relatively shallow. They are used mainly for grazing but smooth areas lacking hardpans respond to irrigation.

*Chernozem:* Deep, black, granular, organic-rich soils with calcium carbonate at 2 to 4 feet in subhumid temperate grasslands. They are naturally productive of the cereals, including maize, and several other crops. Yields can be improved with supplemental irrigation.

*Chestnut:* Dark-brown soils with calcium carbonate at 2 to 4 feet in subhumid to semi-arid temperate grasslands, intermediate between the Brown and Chernozem. Except in dry years they are productive of cereals, and smooth areas respond well to irrigation.

*Desert:* Light gray or brownish-gray soils low in organic matter developed under thin desert vegetation. Part of them have meager pasture; some smooth areas respond to irrigation. Many have hardpans or are too stony and rough for farming.

*Gray-Brown Podzolic:* Pale brown, acid, leached surface soils with clayey subsoils, developed under deciduous forests in temperate areas. They are highly responsive to management, including fertilizers, for a wide variety of crops.

*Ground-Water Laterite:* Gray or light brown leached surface soils underlain in depth with doughy laterite, which hardens irreversibly if exposed, and developed under present or earlier wet-dry tropical climates. Although highly distinctive, the total area is not large. Many areas are moderately productive for selected crops if kept in continuous cover to avoid erosion. Once the laterite hardens they are useless for cropping.

*Gray Wooded:* Generally similar to Gray-Brown Podzolic but in cool-temperate forested areas. They are adapted to short-season varieties of cereals and other crops if properly fertilized.

*Ground-Water Podzol:* Leached sandy surface horizons over dark brown sandy subsoils with water tables fluctuating between about 1 and 4 feet beneath the surface, in humid climates from near the Arctic to the Tropics, usually under forest or palms. With drainage, and fertilization that includes the secondary elements, they are moderately productive for crops.

*Grumusol:* Black to brown, cracking clays, which mulch naturally at the very surface when dry, in warm to tropical climates with wet-dry seasons.

[1] See footnote on page 423.

TABLE 7-3.—*Brief Definitions of the Great Soil Groups* [1]—Continued

The characteristic low micro-relief is called "gilgai". With water control and heavy tillage machinery they respond to good management, especially for cotton and sorghum.

*Half Bog:* Dark brown peaty material, 6 to 18 inches, over gray mineral soil, mainly under swamp forest in cool to tropical humid areas. With water control, including drainage, and good management they are responsive to locally adapted crops.

*Humic Gley:* Dark colored, organic-rich surface soil over gray or mottled mineral soil, developed under grass or forests in cool to warm-temperate, humid or subhumid areas. With drainage they can be made into highly productive arable soils.

*Latosol:* Deep, reddish tropical soils from moderately to highly weathered minerals, and highly permeable because of the low activity of the weathered clays, developed under tropical forest or woodland. (Many of them now have a cover of anthropic savanna.) Except for the very strongly sloping areas, many of these soils are highly responsive to good management, including fertilization and water control, for oil palm, sugarcane, rubber, maize, banana, and a wide variety of other crops. Now some are used under shifting cultivation that depends on the return of the forest for rejuvenation between short cycles of cropping.

*Lithosol:* Thin, usually stony, soils over rock. They are found under a wide variety of climates and generally scrubby vegetation. Some are useful for grazing or forestry; a few spots have been developed for cropping with stone terraces and hand labor.

*Low-Humic Gley:* Light colored clayey or sandy soils developed under conditions of high water tables part of the year, in humid temperate to tropical areas, mainly under forest or anthropic savanna. With drainage and fertilization, crops may be grown successfully.

*Noncalcic Brown:* Light colored surface soils over brown or red clay-rich subsoils developed under thin forest in temperate to warm wet-dry subhumid areas. The sloping areas are used mainly for pasture but smooth areas are responsive to irrigation under good management.

*Podzol:* Light colored acid surface soil over dark brown subsoil, developed under forest in cool or cool-temperate areas. Where strongly sloping, thin, or stony, the soils are used for forest; where not too cold, smooth areas can be used for potatoes, forages, and a wide variety of cool-season crops.

*Reddish Brown:* Reddish-brown surface soils with accumulations of calcium carbonate at 18 to 30 inches, developed in subhumid and warm to warm-temperate areas. Smooth areas are used for cereals, including wheat and grain sorghum. They are responsive to irrigation. Sloping and irregular areas are used for grazing.

*Reddish-Brown Lateritic:* Thick dark-red or brown surface soils with clayey red subsoils of warm-temperate to subtropical humid areas under hardwood forests. The strongly sloping ones are used for forests or pasture. Smooth areas can be used for a wide variety of crops under good management that includes water control and fertilization.

*Red Desert:* Light reddish-brown surface soil with red clayey soil beneath, commonly calcareous, under desert vegetation in warm temperate to tropical areas. Smooth areas lacking thick hardpans are highly responsive to irrigation.

*Reddish Chestnut:* Reddish-brown soils with calcium carbonate at 2 to 5 feet in warm subhumid grassland areas. The smooth soils are used for cereals and

[1] See footnote on page 423.

TABLE 7-3.—*Brief Definitions of the Great Soil Groups*[1]—Continued

cotton and the irregular sloping ones for grazing. With irrigation and water control they are highly responsive to a wide range of additional crops.

*Reddish Prairie:* These reddish soils of warm to warm-temperate grassland or savanna are intermediate between Brunizems and Reddish Chestnut. They are used for cotton, maize, and other cereals mainly.

*Red-Yellow Podzolic:* Light-colored acid surface soils with more clayey, acid subsoils to a considerable depth, in warm-temperate to tropical forested areas. Except for the hilly soils used for forest, the others are highly responsive to management, which includes water control and fertilization, for a wide range of crops, such as fruits, cotton, tobacco, maize, vegetables, and forages.

*Regosol:* Generally sloping young soils from unconsolidated sand, silt, glacial drift, and the like. They occur widely over the world under many conditions of temperature, rainfall, and vegetation. With water control the smoothest areas can be used for crops.

*Rendzina:* Gray to nearly black surface soil overlying soft limestone or marl under grass or mixed grasses and trees in humid to subhumid cool-temperate to warm areas. Except for hilly and stony areas, with good management they can be used for a wide variety of forages, cereals, and vegetable crops. In humid areas many are used for intensive grazing, especially by sheep and goats.

*Solonchak:* Soils with characteristics dominated by the presence of soluble salts at the surface or within the soil, in subhumid to arid areas under sparse, salt-tolerant vegetation. With abundant water and good drainage many of the soils can be prepared for intensive farming under irrigation.

*Solonetz:* Soils with light or dark-colored surface layers underlain by hard, highly alkaline prismatic clayey soil, in subhumid and semi-arid areas from cool-temperate to tropical areas. Commonly the soils are found as small areas of less than an acre to 10 acres in bodies of Brown, Chestnut, and similar soils. With good drainage and proper chemical treatment they can be reclaimed for the uses of the associated soils.

*Soloth:* Thin, light-colored friable soil over dark-brown more clayey subsoils, under grasses or mixed grasses and trees in subhumid cool to warm-temperate areas. Commonly the soils are found in small areas of 2 to 10 acres within bodies of Chernozem, Gray Wooded, or other soils. With proper fertilization and tillage they can be made productive for the use of crops grown on the associated soils.

*Sierozem:* Light-gray or brownish-gray soils grading into calcareous materials at 1 to 2 feet in cool to warm areas under thin grass and desert shrub. They are intermediate between the Desert and the Brown soils. Smooth, deep salt-free areas are used intensively under irrigation where water is abundant.

*Sols Bruns Acides:* Brown-colored acid soils of nearly uniform texture for 2 to 3 feet in forested cool-temperate climates. Large areas are in forests but smooth areas are responsive to intensive management with fertilization for pasture, forage, and a wide variety of cereals and vegetable crops.

*Subarctic Brown Forest:* Forested soils with acid organic surface layers underlain with dark-gray or brown mellow acid soil, which is cool below 18 inches. Some have erratic permafrost. Smooth areas can be used for short-season forage and food crops and for cereals in the most favored places.

*Terra Rossa:* Reddish-brown calcareous friable clayey loams, usually over hard limestone under Mediterranean climate and vegetation. Except for thin, stony, and eroded areas, the soils are well adapted to olives, vines, and a wide variety of food crops.

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[1] See footnote on page 423.

TABLE 7-3.—*Brief Definitions of the Great Soil Groups* [1]—Continued

*Tundra:* Dark-brown peaty material over gley horizons that are cold. These soils support mosses and very low shrubs in cold humid areas. Most Tundra soils are underlain with permafrost, and are too cold for food crops; but in highly favored places where the soils slope toward the sun, grasses and a few short-season food crops can be grown.

*Yellowish-Brown Lateritic:* Yellowish-brown friable clayey forested soils in humid temperate to tropical areas. Except for hilly and stony areas, these soils are productive under intensive management that includes fertilizers and water control. Many are used under shifting cultivation.

TABLE 7-4.—*World land area in different agroclimatic regions and climatic types*

[In billions of acres]

| Agroclimatic region | Climatic type | Potentially arable | | Grazing | | Nonarable | | Total | |
|---|---|---|---|---|---|---|---|---|---|
| | | Acres | Percent | Acres | Percent | Acres | Percent | Acres | Percent |
| 0T | I1 | 0 | 0 | 0 | 0 | 1.38 | 4.3 | 1.38 | 4.3 |
| 2T | II2 | .11 | .3 | .38 | 1.2 | 1.73 | 5.3 | 2.22 | 6.8 |
| | II3 | -------- | 0 | .06 | .2 | 2.52 | 7.8 | 2.59 | 8.0 |
| Total | ---------- | .11 | .3 | .44 | 1.4 | 4.25 | 13.1 | 4.81 | 14.8 |
| 4T | II1 | .01 | 0 | .03 | .1 | .02 | .1 | .06 | .2 |
| | III5 | .08 | .3 | .12 | .4 | .07 | .2 | .27 | .8 |
| | III6 | .09 | .3 | .14 | .4 | .09 | .3 | .31 | 1.0 |
| | III9 | .38 | 1.2 | .15 | .5 | .02 | .1 | .56 | 1.7 |
| | III10 | .33 | 1.0 | .45 | 1.4 | .18 | .6 | .96 | 3.0 |
| | III11 | .09 | .3 | .24 | .8 | .73 | 2.2 | 1.06 | 3.3 |
| Total | ---------- | .98 | 3.1 | 1.13 | 3.6 | 1.11 | 3.5 | 3.22 | 10.0 |
| 6T | III3 | .20 | .6 | .16 | .5 | .14 | .4 | .50 | 1.5 |
| | III4 | .37 | 1.1 | .27 | .8 | .19 | .6 | .83 | 2.5 |
| | III7 | .26 | .8 | .10 | .3 | .11 | .3 | .48 | 1.5 |
| | III8 | .10 | .3 | .16 | .5 | .04 | .1 | .30 | .9 |
| | III9a | .01 | 0 | .01 | 0 | 0 | 0 | .02 | .1 |
| Total | ---------- | .94 | 2.8 | .70 | 2.2 | .48 | 1.4 | 2.13 | 6.5 |
| 8T | III1 | 0 | 0 | .05 | .1 | .08 | .2 | .13 | .4 |
| OM(4T) | III10a | .07 | .2 | .10 | .3 | .02 | .1 | .19 | .6 |
| | III12 | .07 | .2 | .20 | .6 | .59 | 2.0 | .86 | 3.0 |
| Total | ---------- | .14 | .4 | .30 | .9 | .61 | 2.1 | 1.05 | 3.6 |
| OM(6T) | III12a | .03 | .1 | .05 | .1 | .06 | .2 | .14 | .4 |
| OM(8T) | IV5 | .11 | .3 | .35 | 1.1 | 2.56 | 7.9 | 3.01 | 9.3 |
| OM | V5 | .07 | .2 | .18 | .5 | 1.14 | 3.5 | 1.38 | 4.3 |
| 2M | V4 | .50 | 1.5 | .99 | 3.0 | .42 | 1.3 | 1.91 | 5.9 |
| 4M(6T) | IV7a | .03 | .1 | .09 | .3 | .06 | .2 | .17 | .5 |

[1] See footnote on page 423.

263-888 O—67——29

TABLE 7-4.—*World land area in different agroclimatic regions and climatic types*—Continued

| Agroclimatic region | Climatic type | Potentially arable | | Grazing | | Nonarable | | Total | |
|---|---|---|---|---|---|---|---|---|---|
| | | Acres | Percent | Acres | Percent | Acres | Percent | Acres | Percent |
| 4M(8T) | IV1 | 0.20 | 0.6 | 0.30 | 0.9 | 0.17 | 0.5 | 0.66 | 2.0 |
| | IV2 | .28 | .9 | .39 | 1.2 | .27 | .8 | .93 | 2.9 |
| | IV3 | .17 | .5 | .35 | 1.1 | .11 | .3 | .64 | 2.0 |
| Total | | .65 | 2.0 | 1.04 | 3.2 | .55 | 1.6 | 2.23 | 6.9 |
| 4M | V3 | .81 | 2.5 | 1.13 | 3.5 | .58 | 1.8 | 2.52 | 7.8 |
| 6M(8T) | III2 | .12 | .4 | .18 | .6 | .11 | .3 | .41 | 1.3 |
| | IV4 | .19 | .6 | .20 | .6 | .09 | .3 | .48 | 1.5 |
| Total | | .31 | 1.0 | .38 | 1.2 | .20 | .6 | .89 | 2.8 |
| 6M | V2 | 1.50 | 4.6 | .91 | 2.8 | 1.06 | 3.3 | 3.47 | 10.7 |
| | V2a | 0 | 0 | 0 | 0 | 0 | 0 | .01 | 0 |
| Total | | 1.50 | 4.6 | .91 | 2.8 | 1.06 | 3.3 | 3.48 | 10.7 |
| 8M(8T) | IV6 | .09 | .3 | .07 | .2 | .02 | .1 | .18 | .5 |
| 8M | IV7 | .34 | 1.1 | .43 | 1.3 | .16 | .5 | .94 | 3.0 |
| 12 | V1 | 1.24 | 3.8 | .81 | 2.5 | .88 | 2.7 | 2.94 | 9.0 |
| Total temperature limited | | 2.03 | 6.2 | 2.32 | 7.3 | 7.30 | 22.5 | 11.67 | 36.0 |
| Total moisture limited | | 3.22 | 9.9 | 3.64 | 11.1 | 3.36 | 10.4 | 10.23 | 31.4 |
| Total moisture and temperature limited | | 1.36 | 4.2 | 2.28 | 7.0 | 4.06 | 12.7 | 7.67 | 23.9 |
| Total not climate limited | | 1.24 | 3.8 | .81 | 2.5 | .88 | 2.7 | 2.94 | 9.0 |
| Grand Total | | 7.85 | 24.1 | 9.05 | 27.9 | 15.60 | 48.3 | 32.51 | 100.3 |

In Table 7-9, the quantity of potentially arable land on each continent is compared with the presently cultivated area. By "cultivated" area we mean the lands designated by the Food and Agriculture Organization of the United Nations as "arable land and land under permanent crops . . . including land under crops, temporary fallow, temporary meadows for mowing and pastures, market and kitchen gardens, fruit trees, vines, shrubs and rubber plantations." Within this designation there are said to be wide variations within reporting countries. The area actually harvested during any particular year is about one-half to two-thirds of the total cultivated land.

Potentially arable land makes up 24 percent of the total ice-free land surface of the earth and considerably more than twice the land area that has been cultivated at some time during the last few decades.

TABLE 7-5.—*Estimated carrying capacity of nonarable but potential grazing lands*

| Agroclimatic region | Grazing area (billions of acres) | Estimated carrying capacity acres per animal unit | Production (millions of tons) [1] |
|---|---|---|---|
| 2T | 0.44 | 50 | 0.88 |
| 4T | 1.13 | 20 | 5.65 |
| 6T | .70 | 10 | 7.00 |
| 8T | .05 | 15 | .33 |
| 0M(4T) | .30 | 350 | .09 |
| 0M(6T) | .05 | 350 | .01 |
| 0M(8T) | .35 | 350 | .10 |
| 0M | .18 | 350 | .05 |
| 2M | .99 | 100 | .99 |
| 4M(6T) | .09 | 30 | .30 |
| 4M(8T) | 1.04 | 30 | .35 |
| 4M | 1.13 | 30 | .38 |
| 6M(8T) | .38 | 25 | 1.52 |
| 6M | .91 | [2] 40(4) | [2] 2.28(22.75) |
| 8M(8T) | .07 | 25 | .28 |
| 8M | .43 | 40(3) | 1.08(14.33) |
| 12 | .81 | 25(2) | 3.24(40.50) |
| Total | 9.05 | ---------- | 24.53(95.51) |

[1] Assuming 1 animal unit is equivalent to 200 pounds of live weight production per year.
[2] Numbers in parenthesis give estimated carrying capacities and production under high-level technology involving fertilization and improved plant varieties.

It is more than three times the area actually harvested in any given year. Several previous estimates of the worldwide quantity of potentially arable land have been made. Kellogg in 1951 estimated 4.5 billion acres, but by 1964 he had increased his estimate to 6.6 billion.[6] The figures given by other authors lie between these two values. Thus our estimate of nearly 7.9 billion acres is over 20 percent larger than any previous figure.

The largest areas of potentially arable land are in Africa and South America which, outside the relatively small continents of Europe and Australia, have the smallest cultivated acreage. In these two continents there are nearly 3 billion acres of potentially arable uncultivated land (not much less than the total presently cultivated area of the earth) and fewer than 600 million cultivated acres. In addition, nearly a billion potentially arable, but not cultivated, acres exist in North America, Australia, and New Zealand.

The potential for increasing net cultivated area is very small in Europe and Asia and relatively small in the Soviet Union. In Asia, if we subtract the potentially arable area in which water is so short that one 4-month growing season is impossible without irrigation, there is very little excess of potentially arable land over that actually cultivated.

[6] Kellogg, C. E., Potentials for food production. U.S. Dep. Agr. Yearbook. 1964. pp. 57–68.

TABLE 7-6.—*Potentially arable land, by continents and soil groups*

[In $10^3$ acres and percent of total land area on that continent]

| Soil group | Africa | | Asia [1] | | Australia | | Europe [1] | | North America | | South America | | U.S.S.R. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | Percent | Acres | Percent | Acres | Percent | Acres | Percent | Acres | Percent | Acres | Percent | Acres | Percent |
| 1. Tundra | (2) | | | | | | 0 | 0 | 0 | 0 | | | 0 | 0 |
| 2. Desert | 3.4 | 4.5 | 2.5 | 3.7 | 1.1 | 5.6 | .3 | 2.1 | .5 | 1.0 | 0.9 | 2.0 | 2.1 | 3.7 |
| 3. Chernozem and Brunizem | [3] 0 | 0 | 1.2 | 1.8 | .3 | 1.6 | .3 | 2.7 | 4.0 | 7.6 | 1.8 | 4.1 | 3.9 | 7.1 |
| 4. Noncalcic brown | .2 | .3 | 1.6 | 2.4 | .2 | 1.1 | .4 | 3.1 | .2 | .4 | .1 | .2 | | |
| 5. Podzol | | | .5 | .7 | .02 | .1 | 2.8 | 23.3 | 2.5 | 4.8 | | | 2.2 | 3.9 |
| 6. Red-yellow podzolic | .2 | .2 | .9 | 1.4 | .1 | .6 | | | 1.9 | 3.6 | .1 | .2 | | |
| 7. Latosol | 10.3 | 13.9 | 2.5 | 3.7 | .3 | 1.4 | | | .4 | .8 | 12.7 | 29.3 | | |
| 8. Grumusol, Terra Rossa | 1.3 | 1.7 | .6 | .8 | 1.4 | 7.0 | .2 | 1.3 | .7 | 1.4 | .2 | .5 | | |
| 9. Brown Forest Rendzina | .1 | .1 | .1 | .1 | 0 | 0 | .2 | 1.6 | .2 | .3 | .1 | .1 | .1 | .1 |
| 10. Ando | 0 | 0 | .1 | .1 | 0 | 0 | | | 0 | 0 | .1 | .2 | | |
| 11. Lithosol | .2 | .3 | .7 | 1.1 | .1 | .7 | .1 | .6 | .3 | .5 | .4 | .9 | .1 | .2 |
| 12. Regosol | 1.2 | 1.6 | .1 | .1 | .1 | .4 | .1 | .5 | .1 | .1 | | | .1 | .2 |
| 13. Alluvial | 1.3 | 1.7 | 4.8 | 7.1 | 0 | 0 | .1 | .8 | .8 | 1.5 | .6 | 1.5 | .3 | .6 |
| Total | 18.2 | 24.3 | 15.6 | 23.0 | 3.6 | 18.5 | 4.5 | 36.0 | 11.6 | 22.0 | 17.0 | 39.0 | 8.8 | 15.8 |

[1] Omitting U.S.S.R.
[2] Blank space indicates soil group is not represented on the continent.
[3] 0 indicates there is no potentially arable land in this soil group on the continent.

TABLE 7-7.—*Potentially arable land, by continents and climatic zones*

[in $10^8$ acres and percent of total land area on that continent]

| Climatic zone | Africa | | Asia [1] | | Australia | | Europe [1] | | North America | | South America | | U.S.S.R. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | Percent | Acres | Percent | Acres | Percent | Acres | Percent | Acres | Percent | Acres | Percent | Acres | Percent |
| Polar and subpolar | (2) | | | | | | [3] 0 | 0 | 0 | 0 | | | 0 | 0 |
| Cold-temperate boreal | | | 0.04 | 0.1 | | | .1 | .4 | .6 | 1.1 | | | .6 | 1.1 |
| Cool-temperate | | | 3.5 | 5.2 | 0.04 | 0.1 | 3.4 | 28.4 | 6.8 | 13.1 | 0.5 | 1.2 | 8.2 | 14.9 |
| Warm-temperate subtropical | 1.7 | 2.3 | 3.7 | 5.4 | 2.6 | 13.0 | .9 | 7.3 | 2.8 | 5.3 | 2.1 | 4.9 | 0 | 0 |
| Tropical | 16.4 | 22.0 | 8.3 | 12.3 | 1.1 | 5.3 | | | 1.3 | 2.5 | 14.2 | 32.7 | | |
| Total | 18.1 | 24.3 | 15.5 | 23.0 | 3.7 | 18.4 | 4.4 | 36.1 | 11.5 | 22.0 | 16.8 | 38.8 | 8.8 | 16.0 |

[1] Omitting U.S.S.R.
[2] Blank space indicates climatic zone is not represented on the continent.
[3] 0 indicates there is no potentially arable land in the climatic zone on the continent.

TABLE 7-8.—*Potentially arable land in different continents and agroclimatic regions*

[In $10^3$ acres and percent of total land area on that continent]

| Agroclimatic region | Climatic number | Climatic type | Africa | | Asia [1] | | Australia | | Europe [1] | | North America | | South America | | U.S.S.R. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Acres | Percent | Acres | Percent | Acres | Percent | Acres | Percent | Acres | Percent | Acres | Percent | Acres | Percent |
| 0T | 1 | I1 | | | | | | | 0 | 0 | 0 | 0 | | | 0 | 0 |
| 2T | 32 | II2 | | | | | | | .05 | .4 | .5 | .9 | | | .6 | 1.0 |
| | 33 | II3 | | | 0.04 | 0.1 | | | | | 0 | 0 | | | 0 | 0 |
| Total | | | | | .04 | .1 | | | .05 | .4 | .5 | .9 | | | .6 | 1.0 |
| 4T | 2 | II1 | | | | | | | | | .1 | .2 | | | | |
| | 7 | III5 | | | | | | | | | .4 | .9 | | | .4 | .4 |
| | 8 | III6 | | | .7 | 1.1 | | | | | | | | | .2 | .3 |
| | 12 | III9 | | | .0 | 0 | | | .05 | .4 | .8 | 1.5 | | | 3.0 | 5.5 |
| | 14 | III10 | | | .4 | .5 | | | | | 1.7 | 3.2 | | | 1.2 | 2.3 |
| | 16 | III11 | | | .9 | 1.3 | | | | | | | | | 0 | 0 |
| Total | | | | | 2.0 | 2.9 | | | .05 | .4 | 3.0 | 5.8 | | | 4.8 | 8.5 |
| 6T | 5 | III3 | | | .0 | 0 | | | 1.9 | 16.4 | 0 | 0 | | | .1 | .1 |
| | 6 | III4 | | | .0 | 0 | | | .5 | 4.1 | .8 | 1.5 | | | 2.4 | 4.4 |
| | 9 | III7 | | | .9 | 1.3 | | | | | 1.7 | 3.3 | | | | |
| | 11 | III8 | | | .2 | .3 | | | | | .8 | 1.6 | | | 0 | 0 |
| | 13 | III9a | | | | | 0 | 0 | | | .1 | .2 | | | | |
| Total | | | | | 1.1 | 1.6 | 0 | 0 | 2.4 | 20.5 | 3.4 | 6.6 | | | 2.5 | 4.5 |
| 8T | 3 | III1 | | | | | 0 | 0 | | | .02 | .04 | 0.01 | 0 | | |
| 0M(4T) | 15 | III10a | | | .05 | .1 | | | | | .3 | .6 | .2 | .4 | .2 | .3 |
| | 17 | III12 | | | .2 | .4 | | | | | .04 | 0.1 | | | .4 | .7 |
| Total | | | | | .25 | .5 | | | | | .34 | .07 | .2 | .4 | .6 | 1.0 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0M(6T) | 18 | III12a | | | | | | | | | | | .1 | .3 | .2 | .3 |
| 0M(8T) | 23 | IV5 | 0.1 | 0.1 | .7 | 1.0 | .1 | .7 | | | .1 | .1 | .1 | .2 | | |
| 0M | 31 | V5 | .4 | .5 | .2 | .2 | .1 | .4 | | | .01 | 0 | .04 | .1 | | |
| 2M | 30 | V4 | 2.8 | 3.7 | 1.2 | 1.7 | .6 | 3.2 | | | .1 | .1 | .3 | .8 | | |
| 4M(6T) | 10 | IV7a | | | .1 | .2 | | | | | .1 | .2 | | | .1 | .2 |
| 4M(8T) | 19 | IV1 | .2 | .3 | .5 | .7 | .2 | 1.1 | .8 | 6.9 | .2 | .3 | .05 | .1 | 0 | 0 |
| | 20 | IV2 | 1.0 | 1.3 | .8 | 1.1 | .9 | 4.3 | .05 | .4 | .1 | .2 | .01 | 0 | | |
| | 21 | IV3 | .1 | .2 | .2 | .3 | .4 | 1.8 | | | .4 | .7 | .6 | 1.4 | | |
| Total | | | 1.3 | 1.8 | 1.5 | 2.1 | 1.5 | 7.2 | .85 | 7.3 | .7 | 1.2 | .66 | 1.5 | 0 | 0 |
| 4M | 29 | V3 | 5.1 | 6.8 | 1.9 | 2.8 | .3 | 1.4 | | | .5 | 1.0 | .3 | .7 | | |
| 6M(8T) | 4 | III2 | | | | | .03 | .1 | .9 | 7.4 | .06 | .1 | .2 | .5 | | |
| | 22 | IV4 | .3 | .3 | .2 | .3 | .9 | 4.5 | | | .1 | .2 | .4 | .9 | | |
| Total | | | .3 | .3 | .2 | .3 | .93 | 4.6 | .9 | 7.4 | .16 | .3 | .6 | 1.4 | | |
| 6M | 27 | V2 | 5.5 | 7.3 | 3.1 | 4.6 | .1 | .3 | | | .4 | .8 | 4.0 | 13.7 | | |
| | 28 | V2a | | | | | | | | | | | .04 | .1 | | |
| Total | | | 5.5 | 7.3 | 3.1 | 4.6 | .1 | .3 | | | .4 | .8 | 6.04 | 13.8 | | |
| 8M(8T) | 24 | IV6 | | | | | | | | | | | .9 | 2.0 | | |
| 8M | 25 | IV7 | 0 | 0 | 1.3 | 1.9 | .1 | .5 | | | 2.0 | 3.8 | .1 | .2 | 0 | 0 |
| 12 | 26 | V1 | 2.7 | 3.6 | 2.0 | 3.0 | | | | | .3 | .6 | 7.5 | 17.2 | | |
| Total | | | 18.1 | 24.3 | 15.5 | 23.0 | 3.8 | 18.4 | 4.3 | 36.1 | 11.5 | 22.1 | 16.8 | 38.8 | 8.8 | 15.9 |
| Less than 4-month growing season | | | 3.3 | 4.3 | 2.4 | 3.4 | .8 | 4.3 | .05 | .4 | 1.0 | 1.8 | .7 | 1.8 | 1.4 | 2.3 |
| No climate restraint for one 4-month crop | | | 14.8 | 20.0 | 13.1 | 19.6 | 3.0 | 14.1 | 4.25 | 35.7 | 10.5 | 20.3 | 16.1 | 37.0 | 7.4 | 13.6 |

[1] Omitting U.S.S.R.

TABLE 7–9.—*Present population and cultivated* [1] *land on each continent, compared with potentially arable land*

| Continent | Population in 1965 (millions of persons) | Area in billions of acres | | | Acres of cultivated [1] land per person | Ratio of cultivated [1] to potentially arable land (percent) |
|---|---|---|---|---|---|---|
| | | Total | Potentially arable | Cultivated [1] | | |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Africa | 310 | 7.46 | 1.81 | 0.39 | 1.3 | 22 |
| Asia | 1,855 | 6.76 | 1.55 | 1.28 | .7 | 83 |
| Australia and New Zealand | 14 | 2.03 | .38 | .04 | 2.9 | 2 |
| Europe | 445 | 1.18 | .43 | .38 | .9 | 88 |
| North America | 255 | 5.21 | 1.15 | .59 | 2.3 | 51 |
| South America | 197 | 4.33 | 1.68 | .19 | 1.0 | 11 |
| U.S.S.R. | 234 | 5.52 | .88 | .56 | 2.4 | 64 |
| Total | 3,310 | 32.49 | 7.88 | 3.43 | 1.0 | 44 |

[1] Our cultivated area is called by FAO "Arable land and land under permanent crops." It includes land under crops, temporary fallow, temporary meadows, for mowing or pasture, market and kitchen gardens, fruit trees, vines, shrubs, and rubber plantations. Within this definition there are said to be wide variations among reporting countries. The land actually harvested during any particular year is about one-half to two-thirds of the total cultivated land.

SOURCES

Column (1): Revelle, R., Population and food supplies: the edge of the knife. Nat. Acad. Sci. Proc. 56(2): 328–351. August 1966, and United Nations. Demographic Yearbook, 1964. New York, 1965.

Column (2): U.S. Defense Intelligence Agency General Guide for estimating significant soil characteristics for predicting the gamma hazard from neutron-induced activity. U.S. Dep. Defense, 1963.

Column (3): See Tables 7–6, 7–7, 7–8 of this chapter.

Column (4): Table 1 in: Food and Agriculture Organization of the United Nations. Production Yearbook, 1964. Rome, 1965.

Of the total potentially arable land in the world, about 850 million acres or 11 percent of the total requires irrigation for even one crop. In the remaining nearly seven billion acres, at least one crop could be grown without irrigation, and over a considerable region, multiple-cropping is possible. Without irrigation, multiple-cropping could increase the gross cropped-area (the cultivated area times the number of crops) to 9.8 billion acres annually, about 2 billion acres more than the total arable land and about 3 times the presently "cultivated" land. The gross cropped-area could be increased an additional 6.5 billion acres if irrigation water could be made available for double- or triple-cropping. The maximum gross cropped-area on the earth is thus 16.3 billion acres.

All potentially arable land is also potential grazing land, and all that is not too dry can also be used for economically productive forestry. An additional 28 percent of the land area of the earth has some grazing potential, even though it is not potentially arable. Without high level technology, however, we estimate (See Table 7–5) that the total potential annual production of this grazing land is only about 24 million tons of live animal weight per year, a relatively small proportion of present livestock production.

During the first ten years after World War II, the net harvested acreage in Asia (outside of China) increased about 2 percent per year. Since 1957–58, however, the rate of increase has been only about 1.4 percent per year. While the rate of population increase has been accelerating, the rate of increase of harvested areas has been declining. This is probably related to the very low level of expenditure on water resources development, less than $2 per year per person, as well as to the relative scarcity of uncultivated land that could be cultivated. At this expenditure level, at least one hundred years would be required to bring an additional acre per capita under cultivation. In the same time span at present rates of population growth, there would be 16 persons for every one now alive. If population is to be matched by increases in cultivated area, annual per capita expenditures on water and land development must be increased more than fourfold.

The rate of increase of cultivated areas is even lower in Africa than in Asia, but it is considerably higher in South America, averaging 3 percent annually during the last 15 years and nearly 4 percent during the last seven years.

### *7.3.6 Costs of Increasing Net Cultivated Areas*

The costs of agricultural development in a new area are widely variable. Comparative data for several rather different projects are shown in Tables 7–10 and 7–14. The range in cost estimates is between $973 per acre in Kenya for irrigation development excluding associated infrastructure costs, and $91 per acre for a resettlement scheme in Guatemala including infrastructure. This latter project even included costs of building urban centers and settling 1,000 merchants and their families. In two apparently similar irrigation projects in Kenya and Sudan, the unit cost in Kenya was more than four times higher, in spite of the fact that infrastructure costs were included only in the Sudan project.

Besides illustrating the spread of costs between development projects, Table 7–10 emphasizes the necessity to distinguish various components of cost in making the land productive and the substantial infrastructure costs associated with establishing a viable farming community.

Some of the factors that prevent cost estimates from showing much uniformity are:

(*a*) *Physical factors.* The condition of the land will determine the need for irrigation, drainage, land clearing and similar measures. The proximity of an available water supply and the difficulty of providing drainage have a major influence on unit costs. The productivity of the land determines the optimum size of an economic farm unit affecting unit costs.

(*b*) *Political and social factors.* Overcrowding of newly settled areas may reduce unit family costs and accommodate more

people, but will ultimately lead to uneconomic management to the detriment of the settlers. Criteria for project feasibility and preferred location are often influenced by other factors than maximum return on investment dollars from agricultural enterprises.

(c) *Economic factors.* Allocation of costs in multipurpose projects often is arbitrary. Also, the choice between various proportions of capital-intensive and labor-intensive development, depending on the level of employment and the capital available, will greatly affect monetary cost estimates.

TABLE 7–10.—*Sample total project costs*

| Country | Acreage | Cost per acre | Cost per family | Total cost in millions of dollars |
|---|---|---|---|---|
| Kenya [1] | 30,000 | $973 | | $29.2 |
| Morocco [2] | | 572 | | |
| Ceylon [3] | | 307 | | |
| Sudan [4] | 90,000 | 218 | $3,270 | 19.6 |
| Nigeria [5] | | 118 | 8,400 | |
| Guatemala I [6] | 247,000 | 91 | 4,527 | 22.2 |
| Guatemala II [7] | 247,000 | 32 | 1,617 | 8.1 |
| United States [8] | 1,007,000 | 612 | | |

[1] Kano Plain Irrigation Project. Includes dams, reservoirs, canals, flood control, land preparation, Power distribution, Source: Preliminary draft of Kano Plain Reconnaissance Study, U.S. Bureau of Reclamation, April and May 1966.

[2] Lower Moulouya Irrigation Project. Includes dams, canals, power, pumps, distribution, drainage, land prepraration. Source: Preliminary Project Lower Moulouya Irrigation Project, AID, Washington, D.C.

[3] Project unknown. Irrigation $196 per acre, clearing $111 per acre. Excludes domestic water, sanitation, fencing, homes. Source: Farmer, B. H. Pioneer peasant colonization in Ceylon; a study in Asian agrarian problems. London, Oxford University Press, 1957. 387 p.

[4] Kasha-el-Guba Settlement. Includes dams, canals, laterals, infrastructure. Source: Sudan Desk File, AID, Washington, D.C.

[5] Source: Okediji, O. O., entitled "Some Socio-Cultural Problems in the Western Nigeria Land Settlement Scheme: A Case Study." Nigerian J. Econ. and Social Studies 7(3): 301–310. November 1965.

[6] Sebol-Chinaja. Includes surveying, drainage, roads, houses, population nuclei, family transportation. Source: United Nations draft document, based on Government of Guatemala estimates.

[7] Same as footnote 6. Includes surveying, drainage, roads.

[8] Garrison Diversion, Missouri River. Includes storage, canals, drainage, roads for providing irrigation water to currently cultivated land. Source: U.S. Bureau of Reclamation.

Some of the components of development schemes that must be considered separately are resource surveys, roads, land clearing, irrigation, drainage, and settlement.

*Resource Inventory.*—A first requirement of any project is an adequate inventory of the natural resources. Whereas this statement appears superfluous, an example may illustrate that such a requirement, while obvious, is often overlooked.

The expansion of the Riverton Project in Wyoming, built in the late 1940's and early 1950's, was to bring irrigation water to approximately 100,000 acres. Included in this acreage were some 23,000 acres of flat topography of the Cottonwood Bench Section. Upon completion

of the irrigation distribution system to Cottonwood Bench, it was found that this area consisted of an extremely sandy soil which made agriculture economically untenable. Furthermore, the geologic structure restricted drainage and would have resulted in a serious salinity problem had irrigation agriculture been introduced. Fortunately, the difficulties were discovered prior to bringing in settlers, so that personal hardships to a new population were avoided. Much of the remainder of the land area was found to consist of sodic soils that were not economically reclaimable. A land reclassification made in the late 1950's showed that about one-third of the land was not suitable for irrigation. As a result, some 75 families were moved to suitable homesteads on other projects in the west.

The need for a soil survey before construction of irrigation works or other capital improvements is clearcut. Equally important is an inventory of water resources and an estimate of the adequacy of the available water supply, both in quantity and in quality. The water resources of the world are discussed in general terms in Section 7.4, but any specific project proposal will require an evaluation of the pertinent local conditions.

Although pertinent surveys of soil and water resources are primary requirements at the initiation of any reclamation project, it is apparent that an adequate resource inventory must include as well an evaluation of other resources, such as the availability of capital, trained manpower, and the technology needed to make the project successful.

It is difficult to make meaningful estimates of the costs involved in surveys, especially when the range of conditions covered is as wide as in the present report. The average cost of soil surveys made in the United States by the Soil Conservation Service varies from 30 to 70 cents per acre.[7] Reconnaissance costs are as low as 15 cents an acre and detailed pre-engineering surveys cost about $1.00 per acre.

*Roads.*—The need for access to farming communities, farm houses, and farm fields is self-evident. The cost of the roads may vary widely depending on topography and soil characteristics. Klingebiel [8] quotes an example of a saving of $81,000 per mile in the construction of a highway resulting from relocation following a soil survey. From the data on development projects in foreign countries, it appears that road costs can vary from 10 to over 30 percent of the project costs. In Guatemala (see Table 7–10), interior road costs accounted for $13 per acre, and access roads for $17 per acre of the $91 per acre total project cost; thus also, $30 of the $32 shown for land development cost

[7] Klingebiel, A. A., Costs and returns of soil surveys. Soil Conservation 32(1): 3–6. Aug. 1966.

[8] Klingebiel, A. A., Costs and returns of soil surveys. Soil Conservation 32(1): 3–6. Aug. 1966.

is due to roads. In Turkey [9] roads between farms accounted for $12 out of a total of $107 per acre for tertiary land development (irrigation).

In general, road costs are given in terms of cost per unit length. Data from five Latin American countries indicated a range from $37,000 to $133,000 per kilometer for paved roads and from $3,000 to $60,000 for gravel feeder roads.

*Land Clearing.*—The costs for land clearing again vary widely depending on the original topography and vegetation as well as on local economic conditions. Records from Brazil indicate costs as low as $5.50 per acre. In Argentina (Rio Dulce study) costs were $61 per acre, and in Venezuela they ranged from $220 to $360 per acre.

*Irrigation.*—In discussing irrigation costs, a clear distinction must be made between the costs of developing a water supply, of distributing the water to the land and of applying it to the land. The most variable of these cost components probably is the first one. But within a single project, the unit costs of applying the water may cover a wide range as is shown by an example from Israel.[10]

The project, initiated in 1949 and completed in 1961, contains about 1,700 acres of land of which 1,250 acres are irrigated. Water is supplied from a canal to a 10,000 acre-foot reservoir built for the project. The cost for the irrigation system includes the cost of the reservoir but not that of bringing the water to the reservoir. The cost is broken down into three categories: the reservoir and main pipeline, the submains or pumping plant, and the field application system.

On this one project, the cost of the field application system varied from $20 to $216 per acre, and the total cost from $52 to $233 per acre. This illustrates the need for a detailed design before the cost of irrigation can be estimated with any degree of certainty.

*Drainage.*—In discussing drainage a distinction must be made between drainage of irrigated land to prevent waterlogging and salinization and drainage in humid areas to improve aeration of the root zone. The difference is not so much associated with the investment per acre, but with the fact that on an irrigated area drainage is a requirement for continued agricultural production, whereas in the humid area it is an optimal practice available for increasing production. As an example, one may recall that lack of adequate drainage on the irrigated lands in West Pakistan has resulted in a significant reduction of the total irrigated area over time, with over half of the area affected to some degree by a build-up of salinity.

As in irrigation, one must distinguish between the main water disposal system and the farm drainage system. Costs of the main outlet

[9] U.S. International Cooperation Administration. Regional irrigation practices leadership seminar, NESA region. Proc. 4 : 118–120. 1962.

[10] Zimmerman, J. D. Irrigation. New York, Wiley, 1966. 516 pp.

system vary drastically from one situation to the other. In the farm drainage system, one must consider the need for drainage or its required intensity, the crops to be grown, the general topography, the soil characteristics and the type of system to be used—closed subsurface or open ditch, gravity or pump, horizontal or well-type.

Experience in the United States would indicate that where drainage is needed, costs from $100 to $300 per acre for gravity drains are common at the farm level. Main outlet costs generally run less than $12 per acre. Pump drainage often is more expensive. In irrigated areas, it is well established that drainage systems installed simultaneously with the irrigation system are less expensive than those that are installed at a later date after difficulties have arisen.

*Settlement.*—Whatever capital investment is necessary to provide for roads, land clearing, irrigation, drainage and similar land appurtenances, the total cost of any development also must include the cost of providing homes for the settlers, as well as schools, services and market facilities. It is difficult to quote meaningful figures for settlement costs because of the lack of precise definition, in most cases, of what is included. It is clear, however, that cost figures will be strongly influenced by factors such as the extent of government subsidies, the involvement of the military, the use of government-owned or expropriated land as opposed to purchased land, the distances from which settlers are moved, and the extent to which the settlers help themselves.

From the last two entries under cost per family in Table 7–10, one may deduce that the settlement cost, made up of providing homes, population centers and family transportation, was $2,910 per family in Guatemala. Similar costs amounted to $600 per family in Peru and Columbia, $1,173 in Argentina and $1,777 in Venezuela, according to one set of sources.[11] Another source records a cost of $1,080 per family for Ecuador, $2,520 for Colombia and $3,560 for Venezuela.[12]

*Administration.*—Another important item that must be considered is the overhead cost of administering an extensive development project. South American experience indicates that these costs are about 20 to 25 percent of the total project costs although the variation is large. The Colombian project, for example, had an administrative overhead of only 15 percent, whereas in Chile it was 33 percent.

### *7.4.0 Water Supplies for Irrigation*

Wherever there is arable land which experiences periods during the growing season in which evapotranspiration exceeds precipitation

[11] International Bank for Reconstruction and Development. Economic development of Venezuela. Baltimore, Johns Hopkins Press, 1961. 494 pp.

[12] Carroll, Thomas F. "Issues of Financing Agrarian Reform: The Latin American Experience", World Agrarian Reform Meeting, Rome, Italy, June, 1966. p. 26.

by an amount greater than soil moisture storage, the opportunity to increase production by irrigation exists. Irrigation may be applied to the desert, where rainfall is totally inadequate for any agriculture, as in Egypt or Southern Iraq; it may replace or supplement rainfall agriculture as in the dry farming regions of the United States; it may make possible multiple-cropping in areas where only single-cropping is possible because of wet and dry seasons as in Bengal; or it may serve as insurance against damaging, short-time sporadic droughts, as in the eastern United States.

Adequacy of irrigation in terms of providing a full water supply for evapotranspiration potential is highly variable, ranging from sporadic spreading of meager spring flood waters in the deserts of the Middle East to sprout a thin crop of wheat, to carefully controlled, optimal applications under the sophisticated technology of the southwestern United States. Besides the temperate and subtropical deserts, large areas of subtropical and tropical lands experience long, dry seasons where rainfall is nonexistent or exceedingly short. It is in these areas that the use of irrigation could provide the basis for rapid expansion of food supply through intensive, year-round cropping and could make attractive the use of increased fertilizer, pest control, and the other inputs of modern agricultural technology.

### *7.4.1 Presently Irrigated Lands*

The origins of irrigation are buried in antiquity. History makes many references to the practice of irrigation. It is well-established that several once-flourishing civilizations were based upon the practice. Remnants of irrigation systems built hundreds and even thousands of years ago are present today. However, until about the beginning of the 19th century, irrigation systems were small and most failed eventually because they did not provide for salinity control. Gulhati estimates that the area of irrigated land in the world was about 20 million acres in 1880. During the 19th century, larger and more sophisticated irrigation projects were constructed mainly in India, Russia, the United States, and Egypt, increasing the total area of irrigated land in the world to about 100 million acres by 1900. Experience gained during the latter part of the 19th century in the planning, construction, and operation of irrigation projects together with continuing advances in civil engineering and in the agricultural sciences has led to a nearly fourfold increase in the world's irrigated area during the first two-thirds of this century.

Of the approximately 3.43 billion acres of cultivated land in the world, about 0.38 billion acres or 11 percent are presently irrigated. Table 7–11 shows the acreages under irrigation in 44 countries. The small percentage of the world's arable land under irrigation suggests that irrigation agriculture plays only a minor role in the world

food budget. However, when the distribution of irrigated and arable land over the world is related to the distribution of world population, it becomes apparent that a large fraction of the earth's people, living mainly in diet-deficient countries, are heavily dependent upon irrigation for food. In these areas, increasing the food supply will require extensive irrigation development. On the Indian subcontinent, with one-fifth of the population of the world, water supply seriously limits agricultural production on 65 percent of the arable land and prevents

TABLE 7–11.—*Land areas under irrigation in various countries compared with cultivated and total areas*

| Continent and country | Population in 1965 in millions of persons | Area in millions of acres | | | Ratio of irrigated to cultivated (×100) |
|---|---|---|---|---|---|
| | | Total | Cultivated | Irrigated | |
| | (1) | (2) | (3) | (4) | (5) |
| Africa: | | | | | |
| Sudan | 14 | 620 | 18 | [b] 4 | 22 |
| Tunisia | 5 | 31 | 12 | [c] .2 | 1.7 |
| United Arab Republic | 30 | 247 | 7 | [c] 7 | 100 |
| Total | 49 | 898 | 37 | 11.2 | 30 |
| Asia: | | | | | |
| Afghanistan | (15) | 163 | (37) | [b] 9 | 24 |
| China (Mainland) | (730) | 2,360 | (500) | [b] 132 | 27 |
| Cyprus | 1 | 2 | 1 | [f] .2 | 20 |
| India | 483 | 810 | 402 | [a] 69 | 17 |
| Indonesia | 105 | 369 | 44 | [a] 14 | 32 |
| Iran | 23 | 407 | 42 | [a] 12 | 29 |
| Iraq | 8 | 111 | 20 | [a] 9 | 45 |
| Israel | 3 | 5 | 1 | [f] .3 | 30 |
| Japan | 98 | 92 | 15 | [d] 9 | 60 |
| Jordan | 2 | 24 | 3 | [f] .2 | 7 |
| Lebanon | (2) | 2 | 1 | [f] .2 | 20 |
| Nepal | 10 | 35 | 10 | [a] 3 | 30 |
| Pakistan | 115 | 234 | 71 | [c] 27 | 38 |
| Philippines | 32 | 74 | 28 | [d] 1 | 4 |
| Syria | 6 | 45 | 22 | [f] 1 | 5 |
| China (Taiwan) | 12 | 9 | 3 | [d] 1 | 33 |
| Thailand | 31 | 127 | 25 | [a] 4 | 16 |
| Turkey | 32 | 193 | 64 | [a] 5 | 8 |
| Total | 1,708 | 5,062 | 1,289 | 296.9 | 23 |
| Australia | 11 | 1,900 | 38 | [a] 3 | 8 |
| Europe: | | | | | |
| Greece | 9 | 33 | 10 | [c] 1 | 10 |
| Poland | 32 | 77 | 40 | [c] .5 | 1 |
| Spain | 32 | 125 | 52 | [a] 4 | 8 |
| Yugoslavia | 20 | 63 | 20 | [c] .3 | 2 |
| Total | 93 | 288 | 122 | 5.8 | 5 |
| North America: | | | | | |
| Mexico | 41 | 489 | 27 | [c] 11 | 41 |
| United States | 195 | 2,320 | 458 | [a] 38 | 8 |
| Total | 236 | 2,809 | 485 | 49 | 10 |

TABLE 7–11.—*Land areas under irrigation in various countries compared with cultivated and total areas*—Continued

| Continent and country | Population in 1965 in millions of persons (1) | Area in millions of acres | | | Ratio of irrigated to cultivated (×100) (5) |
|---|---|---|---|---|---|
| | | Total (2) | Cultivated (3) | Irrigated (4) | |
| South America: | | | | | |
| Argentina | 22 | 585 | 74 | [a] 4.0 | 5 |
| Bolivia | 4 | 272 | 2 | [e] 0.03 | 2 |
| Brazil | 81 | 2,105 | 47 | [c] .9 | 2 |
| Chile | 9 | 184 | 14 | [a] 3.0 | 21 |
| Colombia | 16 | 293 | 6 | [e] .6 | 10 |
| Costa Rica | 1 | 13 | .7 | [e] .04 | 6 |
| Cuba | 8 | 28 | 5 | [e] .15 | 3 |
| Dominican Republic | 4 | 12 | 2 | [e] .2 | 10 |
| El Salvador | 3 | 5 | 1 | [e] .01 | 1 |
| Equador | 5 | 67 | 5 | [e] .3 | 6 |
| Guatemala | 4 | 27 | 4 | [e] .02 | .5 |
| Haiti | 5 | 7 | 1 | [e] .1 | 10 |
| Honduras | 2 | 28 | 2 | [e] .05 | 2 |
| Nicaragua | 2 | 37 | 4 | [e] .01 | .2 |
| Panama | 1 | 19 | 2 | [e] .02 | 1 |
| Paraguay | 2 | 101 | 2 | [e] .03 | 1 |
| Peru | 12 | 318 | 4 | [a] 3.0 | 75 |
| Uruguay | 3 | 293 | 6 | [e] .2 | 3 |
| Venezuela | 9 | 226 | 6 | [c] .6 | 10 |
| Total | 193 | 4,620 | 187 | 13 | 7 |
| U.S.S.R. | 234 | 5,540 | 568 | [a] 23 | 4 |
| Grand total | 2,521 | 21,113 | 2,724 | 401.8 | 15 |

SOURCES

Column (1) Revelle, R., Population and food supplies: the edge of the knife. Nat. Acad. Sci. Proc. 56(2): 328–351. August 1966. Numbers in parentheses are our estimates based on data given in United Nations Demographic Yearbook, 1964. New York, 1965, and on other sources.

Columns (2) and (3) and reference (*a*) in column (4): Food and Agriculture Organization of the United Nations. Production yearbook, 1964. Rome, 1965. Numbers in parentheses are our estimates.

Column (4), reference (*b*): Israelsen, O. W., and Hansen, V. E. Irrigation principles and practices. 3d ed. New York, John Wiley, 1962. 447 pp.

Column (4), reference (*c*): Greenshields, E. L. Water has a key role. U.S. Dep. Agr. Yearbook, 1964. pp. 75–96.

Column (4), reference (*d*): International Commission on Irrigation and Drainage. Irrigation in the world, a global review. 1st ed. New Delhi, 1955. 130 pp.

Column (4), reference (*e*): United Nations Economic Commission for Latin America. Water resources and their utilization in Latin America. United Nations Document E/CN 12/501, May 1959.

Column (4), reference (*f*): U.S. Agency for International Development. Regional irrigation practices leadership seminar, NESA region. 6th, Amman, Jordan, 1966. Country reports.

year-round production on another 29 percent. Nearly two-thirds of the world population lives in diet-deficient countries having less than half of the arable land but about three-fourths of the irrigated land. It has been estimated that by 1975 the total irrigated area in the world may exceed 500 million acres and that by the year 2,000 the area may

well approach 750 million acres.[13] [14] If, as predicted, the world population is over 6 billion in the year 2,000, then the ratio of world population to world area of irrigated land will be approximately the same as at present.

### 7.4.2 *Estimates of Irrigation Potential*

Attempts to estimate the world potential for irrigation development, or even regional potentials, are highly speculative. Each irrigation project, if it is to have any chance for success, must be based on fairly intensive study of available resources of land and water and should involve careful strategic planning for providing necessary infrastructure, settlement, and other inputs to production besides water. Since World War II, hundreds of millions of dollars have been invested in irrigation projects which have been highly disappointing, if not outright failures, because lands or water were unsuitable or inadequate attention was given to development strategy.

Some very rough estimates of irrigation potential can be made by considering the amounts of potentially arable land in different geographic areas under climatic classifications which have deficiencies of precipitation during all or part of the year, and comparing the estimated water needs with estimated river runoff in the same regions. River runoff (except for ground water flow to the sea) represents the equilibrium excess of rainfall less effective evapotranspiration; hence, the location of rivers in an area of climatic and soil potential for irrigation can provide at least an index of water supply availability. The combined total runoff of the 40 largest rivers has been estimated to be about 11,000 million acre feet per year.

*India-Pakistan.* The land area (1,043 million acres) of the Indian subcontinent is subjected to extreme variation of rainfall ranging from a few inches in the north and west to more than 100 in Assam and Bengal and along the west coast of the peninsula. Almost invariably there is both a wet and a dry season with from 60 to 95 percent of the precipitation falling during the summer monsoon, June to September.

The five large rivers of the subcontinent: Brahmaputra, Ganges, Indus, Godaveri, and Kristna produce an estimated 1,233 million acre feet annually.

India[15] reports 337 million acres net (368 million acres gross) actually cultivated in 1962–63 with 63.5 million acres net (72.6 million gross) irrigated, an increase from 29 million acres in 1895 and 51.5 million acres in 1951.[16]

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[13] Gulhati, N. D., Worldwide view of irrigation developments. Amer. Soc. Civil Eng. Proc. Irrigation & Drainage 84 (IR3—Part 1): Paper 1751, 14 pp. Sept. 1958.

[14] Gulhati, N. D., Introduction chapter of FAO/UNESCO International Sourcebook on Irrigation and Drainage in Relation to Salinity and Alkalinity, Draft, May 1965.

[15] U.S. Agency for International Development. Regional irrigation practices leadership seminar, NESA region. 6th, Amman, Jordan. 1966. Country Reports.

[16] Indian Council of Agricultural Research. Agriculture and animal husbandry in India. New Delhi, 1958. 364 pp.

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Our calculations indicate that 403 million acres are potentially arable, of which 266 million acres are under climatic types IV3, V3, and V4, and 116 million acres under type V2. The estimated ultimate irrigation potential is 187 million acres of which 142 million would be watered from surface sources and the remainder from ground water.

Pakistan reported a potential for irrigation of 21.4 million acres [17] in West Pakistan with perennial water supply and an additional 11.4 million acres to be irrigated during high flow only. The White House, Interior Report [18] indicates that, with a planned program of ground water mining, first level development of irrigation supplies in West Pakistan would be available for 26.4 million acres, and, at the second development level, when the surface reservoirs are available, 29.7 million acres. The irrigation potential of East Pakistan is difficult to estimate. Plans were underway to irrigate 0.6 million acres with portable pumps by 1964.[19] About 11.3 million acres of agricultural land in East Pakistan are "normally" flooded each year. A 1959 recommendation of FAO [20] recommended 41 million acres for eventual irrigation in the Lower Ganges and Brahmaputra basins, but some of this would be in India. Allocating this in proportion to arable land (70 million in the basin; 22.2 million in East Pakistan) would assign about 13 million acres to East Pakistan. Adding 187 million acres for India, 30 million acres for West Pakistan, and 13 million acres for East Pakistan, gives 230 million acres as an ultimate estimate of irrigated land for the subcontinent. Our studies show 48.4 million arable acres in climatic zones IV2, IV3, IV5, and V5 in Pakistan and 25.2 million acres in zone V2. Adding these acres to the corresponding ones in India gives for the subcontinent 314 million acres arable in climatic zones IV2, IV3, IV5, V3, V4, and V5, and 141 million acres in zone V2.

Eventual irrigation water use for West Pakistan is estimated at 106 million acre feet; [21] it might be 40 million for East Pakistan. Jain [22] reports 450 million acre feet eventually for India of which 150 million was being used in 1966. In summary, for the subcontinent:

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[17] U.S.C. Agency for International Development. Regional irrigation practices leadership seminar, NESA region. 6th, Amman, Jordan. 1966. Country Reports.

[18] White House-Department of the Interior Panel on Waterlogging and Salinity in West Pakistan. Report on land and water development in the Indus plain. Washington, U.S. Govt. Printing Office, 1964. 454 pp.

[19] U.S. Agency for International Development. Regional irrigation practices leadership seminar, NESA region. 4th, Ankara, Turkey, 1962. 318 pp.

[20] Agricultural, fisheries, and forestry resources of the Lower Ganges-Brahmaputra Basin in relation to human needs. Food & Agr. Org. United Nations Conf. Proc. 10th Session, Oct. 31, 1959. Document C59/20.

[21] Agricultural, fisheries, and forestry resources of the Lower Ganges-Brahmaputra Basin in relation to human needs. Food & Agr. Org. United Nations Conf. Proc. 10th Session, Oct. 31, 1959. Document C59/20.

[22] U.S. Agency for International Development. Regional irrigation practices leadership seminar, NESA region. 6th, Amman, Jordan, 1966. Country Reports.

| | Million acres |
|---|---|
| Total land area | 1,043 |
| Total arable area | 489 |
| Land in irrigable classes except V2 | 314 |
| Land in class V2 | 141 |
| Ultimate irrigation potential | 230 |
| Presently irrigated | 90 |

| | Million acre feet per year |
|---|---|
| Annual runoff of major rivers | 1,233 |
| Present water use | 224 |
| Eventual water use | 596 |

*Southwestern Asia.* This region includes Afghanistan, Cyprus, Iran, Iraq, Israel, Jordan, Lebanon, Syria, Turkey, and the Arabian Peninsula, containing a total of 1,704 million acres with a population of about 107 million people. Estimates of total "cultivated" [23] and presently irrigated area are available for all the countries except those in the Arabian Peninsula (see Table 7–11).

There is considerable irrigation in Yemen, probably accounting for at least half of that in the Arabian Peninsula. Of the countries for which we have estimates of irrigation potential [24] nearly half of the total area, "cultivated" lands cover 154 million acres; irrigated lands, 28 million acres; irrigation potential is estimated at 71 million acres. These countries would account for the largest part of the irrigation in the region. Considering that some of the irrigation presently practiced is quite sporadic and that the potential of the Euphrates-Tigris valley [25] is probably less than presently planned by Syria, Iraq, and Turkey, the three countries concerned, perhaps estimates of 40 million acres and 80 million acres for present and potential irrigation in the region would be reasonable.

*Irrigation Potential in Southeast Asia, South America, and Tropical Africa.* The two cases studied, our climatic classifications, and the surface water supply as indicated by the runoff from large rivers, provide a base of confidence for making very rough estimates of the possibilities for irrigation development in other areas. While the estimates of our two case studies may be somewhat optimistic, they do not appear

[23] In several countries about two-thirds of the "cultivated" land is left fallow each year.

[24] Information on irrigation potential in Cyprus, Iran, Iraq, Israel, Jordan, Lebanon, Syria, and Turkey, is contained in the following reports.

Regional irrigation practices leadership seminar, NESA region. Proceedings. 3d–6th 1960–1966.

Third—Lahore, Pakistan, 1960. 198 pp.

Fourth—Ankara, Turkey, 1962. 318 pp.

Fifth—New Delhi, India, 1964. 500 pp.

Sixth—Amman, Jordan, 1966.

Proceedings of 3d issued by U.S. International Cooperation Administration; 4th–6th by U.S. Agency for International Development.

[25] Annual runoff of the Tigris-Euphrates system is about 50 million acre feet.

impossible. Israel, for example, has developed an extremely efficient irrigation system and proposes to utilize 95 percent of surface and ground water within the decade.

In Southeast Asia, South America and Tropical Africa, we have considered the potentially arable areas for those climates where irrigation would appear to be effective. Climate types selected for irrigation in these regions included III 10a, III 12a, IV2, IV3, IV4, IV5, V3, V4, and V5. This does not mean there are no other climatic zones for which irrigation is desirable. Although in India, consideration of climatic records, evapotranspiration, and soil moisture storage indicates that V 2 areas need irrigation during the dry season, this does not seem to be true in South America, where soil moisture storage appears generally adequate except possibly for V 2a climates. These latter climates are relatively limited (4 million acres in Brazil, none in the other regions). The 25 million acre irrigation potential assigned to Southeast Asia is based on the gross area in zone V 3. The irrigated area could probably be doubled if irrigation in zone V 2 would also be profitable. Results of tabulations of land area, together with annual discharge of the major rivers, are tabulated in Table 7–12, where the data for India, Pakistan, and Southwest Asia are also shown. Out of a total potentially arable area of more than 3.2 billion acres, over 1.1 billion are in climatic zones where irrigation is necessary or desirable for effective agricultural development. The potential irrigated area is 0.640 billion acres, probably about half the size of the area in which irrigation is necessary or desirable.

Irrigation would be necessary or desirable in most of India, Pakistan, and Southern South America, probably in most of Southwest Asia, and probably in about half of the mainland of Southeast Asia. It is needed only in about one fourth of Tropical Africa and only in about 2 percent of Tropical South America. These figures should be compared with those given earlier in Section 7.3.5 where it was shown that on a worldwide basis irrigation was necessary even to grow a single crop on about 0.85 billion acres, and that a gross cropped area of 6.52 billion acres could be obtained by irrigation in addition to 9.8 billion acres without irrigation. Of course, any projection of irrigation potential without detailed survey information is speculative and estimates should be regarded as gross projections.

### *7.4.3 Ground Water*

In general, ground water reservoirs are integral with the continuous river system and are in dynamic balance with precipitation, evaporation, and drainage to the sea. Even so the amount in storage is relatively large. The volume of ground water stored at depths of less than one-half mile is estimated to be 3,000 times as large as that contained in all rivers. There are also extensive ground water deposits

which are not in dynamic equilibrium with the current surface hydrology but which have been stored from past ages. In the first instance, allowing for the impedance of the system, use of ground water for irrigation is reflected eventually in a reduction of the surface or the underground flow to the sea or in reduction of non-economic vegetation drawing on the water table; in the second instance, the water, in essence, is "mined" and is not replaced by nature within non-geological time spans.

TABLE 7–12.—*Estimates of irrigation potential in parts of Asia, Africa, and South America*

| Region | Climatic types benefiting from irrigation | Major river basins and annual runoff (million acre-feet per year) | Arable area ($10^6$ acres) | Arable area in irrigable climate zones (in $10^6$ acres) | Potential irrigation ($10^6$ acres) |
|---|---|---|---|---|---|
| India (810 million acres) | IV3, V3, V4, V2 | Indus, Brahmaputra, Ganges Godaveri, Kristna 1,233 | 403 | 266, 116 | 187 |
| Pakistan (234 million acres). | IV2, IV3, IV5, V5, V2 | Indus, Brahmaputra, Ganges 1,127 | 86 | 48, 25 | 43 |
| Southwest Asia (1,704 million acres). | IV1, IV2, IV5, V3, V4 | Tigris, Euphrates 50 | (1) | (1) | 80 |
| Continental Southeast Asia (511 million acres). | V3 | Irrawaddy, Mekong Salween 690 | -------- | 2 (102) | 25 |
| Brazil (2,102 million acres). | V3, V4 | Amazon, San Francisco, Parana 2,679 | 966 | 10 | 10 |
| Tropical South America less Brazil (945 million acres). | IV5, V3, V4, V5 | Orinoco, Magdalena 549 | 312 | 14 | 10 |
| Middle South America (372 million acres). | V3, V4, V5 | Parana 378 | 125 | 24 | 10 |
| Southern South America (913 million acres). | III 10a, III 12a, IV2, IV3, IV4, IV5, V3, V4, V5 | Parana, Uruguay, Bueno, Valderia, Bio Bio, Negro 574 | 266 | 246 | 125 |
| Tropical Africa (2,359 million acres). | V3, V4, V5 | Congo, Niger, Zambezi 1,520 | 967 | 250 | 150 |
| Total | ---------- | 7,673 | 3,225 | 1,101 | 640 |

[1] Not available. Our calculations of potentially arable land were not programed to give this information.
[2] Gross area rather than area of V3 climatic zone is indicated.

Ground water supplies frequently may provide relatively fast and inexpensive development in contrast to surface supplies, as in the Central Valley of California, in southern Arizona, and in West Pakistan. If the supply is to be permanent, the draft over a period of time must not exceed the replenishment. However, overdraft of ground water supplies may well be justified as a means of providing rapid development, especially if these are to be replaced by eventual development of permanent surface supplies. This will occur, unplanned, in southern Arizona if the Central Arizona project or some other long distance

transfer is completed, and, in Israel, where ground water overdrafts since about 1960, by deliberate action, have sustained a growing agricultural activity during the period of construction of the diversion from Lake Tiberias to the coastal valleys of Palestine. Ground water development, as in West Pakistan, may make extensive electrification feasible also, with consequent additional benefits to agriculture and industry. In West Pakistan,[26] cost of well development and electrification in former Punjab and Bahalwalpur was $41 per acre; capital costs of drainage, fertilizer, pest control and educational facilities raised this to $81 per acre.

It is probable that extensive ground water supplies exist within those heavily populated areas of the sub-arid world where surface supplies have been exploited already or where their rapid development is inhibited by the magnitude of the task or by international complication; for example, in the Ganges Basin, other Indian subcontinental coastal basins, and Southeast Asia. *An intensive effort should be made to identify potential areas of available ground water, particularly in these areas of the world, and to assess their economic potentials.*

Ground water development should be planned conjunctively with surface water. The use of underground reservoirs by artificial recharge methods saves the cost of expensive surface reservoir development and avoids evaporation losses.

Development of ground water reserves *could* provide the quickest, easiest and least expensive means to enhance water supply and develop food supplies in large areas of the world. Overdraft or mining in the earlier stages of comprehensive development can provide the economic impetus on which later, more comprehensive development might be founded but there must be foreseeable replacement from surface supplies. *Emphasis should be placed on initiating development in those areas or in nearby heavily populated regions where ground water resources are reasonably available.*

*A critical prototype for ground water development.*—Priority consideration should be given to attempting to implement a critical size agricultural development prototype in northern India based on ground water. Recent success in West Pakistan in utilizing ground water which can be developed relatively quickly and inexpensively as a means for rapidly increasing food production provides the basic guidelines for such an attempt. The probability of the existence of relatively large ground water supplies and the relatively high level of education and commerce suggest northern India, possibly in Utta Pradesh or Punjab, as the most favorable spot, probably in the whole world, to conduct such an effort. Based on the Pakistan experience the area should be of the order of one million acres.

[26] White House-Department of the Interior Panel on Waterlogging and Salinity in West Pakistan. Report on land and water development in the Indus plain. Washington, U.S. Govt. Printing Office, 1964. 454 pp.

Introduction of relatively low-cost power for pumping into the developmental area will be essential; hence, one of the important considerations will be electrification, including availability of fuel resources or, possibly, nuclear energy. Success would require a definite commitment on the part of both the Indian central government and the concerned state. There is a great deal of talent in India and foreign technical assistance, while essential, might be kept to a relatively low amount. Based on the Pakistan experience, capital investment would be of the order of one hundred million dollars for the first prototype.

Once confidence in the success of such an effort is established, additional areas could be developed and a fairly large area of northeast Indian and possibly East Pakistan might become involved. Success in agriculture, water resources, and electrification, possibly using nuclear energy sources, could generate effort toward a coordinated plan for the development of the surface supplies of the Ganges-Brahmaputra basin before excessive ground water mining occurs.

While the short-range objective would be to establish at least one region of economic criticality in agriculture, the long-range objective would also include the development of other sectors of the economy.

*7.4.4 Costs of Irrigation Development* (see Table 7–14)

Comprehensive cost data from Southwest Asia are scarce. Two projects in Iraq, not including storage, provided diversion and canal facilities for $127 per acre (Greater Mussaib) and $217 per acre (Kirkuk). Recent costs of developing lands for sugar beet production in Iran and Iraq have been reported at $1,230 per acre and $975 per acre respectively. The cost of developing sugar refining facilities was about $1,000 per acre. In Greece, for a recent project, costs, including farm systems are reported at $362 per acre, and if sprinkling is used, $590 per acre. Annual costs are $38 per acre and $68 per acre respectively. Cost data from modern projects in other similar areas of the world indicate that complete development at costs of less than $400 per acre is unlikely, thus an increase of 40 million irrigated acres would cost about *$16 billion.*

In this arid region, it appears that about 2.4 percent of the total land area is now irrigated, but this could be raised to nearly 5 percent; about one-fourth of which would be supplied by the Tigris and Euphrates if their flows were utilized to the maximum possible extent.

India [27] reports that the 19 million acres being placed under irrigation under the three 5–year plans beginning in 1951–52 cost Rs 13,100 million ($146 per acre). The estimated cost of irrigating 13.8 million acres now planned is Rs 5,800 million ($89 per acre). In 1956, costs for the 2 million acre Nagajunasagar project were estimated at $151 per acre net. Costs for the Rajasthan project are estimated by

[27] U.S. Agency for International Depelopment. Regional irrigation practices leadership seminar, NESA region. 6th Amman, Jordan, 1966. Country reports.

the Central Water and Power Commission at $134 per acre net. These costs include only reservoirs and distribution canals. Costs for well development and electrification were estimated at $41 per acre [28] in former Punjab and Bahawalpur, West Pakistan. Capital costs for fertilizer, drainage, pest control, and education, research, and management raised these to $81 per acre; comparable costs were $100 per acre to $110 per acre in the Sind. The estimated cost of coastal flood protection works in East Pakistan is given by AID sources as $84 per acre for a 2.4 million acre project.

Including lateral distribution works and other investments, costs in India may well exceed $250 per acre for irrigation development. In many areas of the world, costs are commonly higher than this, but the Indian projects are large in size. Assuming $250 to $300 per acre, the capital investment costs for additional irrigation on the subcontinent would be 35 to 40 billion dollars.

In the Indian subcontinent, 47 percent of the land is classified as arable and potentially 22 percent may be irrigated. Presently 8.5 percent is irrigated. Present water use is about 18 percent of major river flow, and this would be increased eventually to 48 percent.

### *7.4.5 Problems of Irrigation Development*

An inadequate water supply places inherent limitations on the productivity of all other agricultural inputs. Once a full water supply is provided, production increases resulting from the interaction of other inputs can be dramatic. Consequently, the development of additional supplies of water by the construction of dams and canals and/or by drilling large-capacity wells can provide the basis for a greatly increased agricultural production. On the other hand, such projects can create many problems which, if unsolved, may ultimately hold crop yields far below potential levels or may actually cause yields to decline. It must be recognized by water engineers, agricultural scientists, development planners, and government policy-makers that developing a water supply is but a small part of the total input required for agriculture if it is to become productive and permanently successful.

Recent studies by the National Committee on Water for Peace show that capital for investment in water resource development in the developing countries is relatively available, but manpower and organizational capability within these countries for investigating and planning at acceptable loan standards greatly limits progress. Increased attention needs to be given both to the training of qualified personnel and to establishing planning and generating institutions within the countries with which we are concerned. The organization of regional inter-

[28] White House-Department of the Interior Panel on Waterlogging and Salinity in West Pakistan. Report on land and water development in the Indus plain. Washington, U.S. Govt. Printing Office, 1964. 454 pp.

national land and water resource institutes has been suggested as a means of alleviating this difficulty.

*7.4.5.1 Resource Surveys.* Irrigation project planning should be backed by an adequate inventory of the physical, economic, and human resources available. Resources, of course, are not constant, but change with technological change and with the scope, timing, and policy of development. Past irrigation developments in the developing countries have on the whole been disappointing. In part, this has been due to inadequate evaluation of resources. Most frequent mistakes have involved miscalculations of the soil capacity, water supply, drainage, or capital requirements.

*7.4.5.2 Salinity and Drainage.* Drainage and salinity problems have caused disastrous difficulties, and particular care needs to be given to these factors. Plans which contemplate the diversion and consumptive use of large proportions of the flow of major rivers should be approached with care because water quality deterioration is inherent as dilution supplies are reduced and more saline drainage water is returned. Use of ground water may complicate salinity considerations also. Climate and water supply are highly variable and it is important that the effects of variations, as well as averages, be included in calculations.

*7.4.5.3 Human Factors Must Be Considered.* Human resources are particularly important and many projects have been severely handicapped because inadequate attention has been given to them. The availability of opportunities and incentives to farmers has been demonstrated to be a necessary element for success. In Israel, a highly successful agricultural development strategy has assured farmers of a reasonable income with the aid of a subsidy and price fixing program used to readjust income in their favor. Too frequently, irrigation investment has been looked upon solely to increase the profit to the landlord or the state with no increased share to the producer. This will not work.

To obtain the most efficient use of water, it is necessary to know—both in project planning and in operation—the existing conditions of soil, crops, climate, and farm management. There must also be communication and understanding between personnel of water supply organizations and agriculturalists if water is to be delivered in amounts and at a frequency which conforms to crop needs. Water agencies should inform farmers as far in advance as possible of the expected seasonal water supply and of probable water delivery schedules so that farmers can make plans and obtain seeds, fertilizers, and other inputs required to achieve efficient use of the delivered water.

At the farm level, irrigation facilities must be properly selected, designed, and operated if good use is to be made of the delivered water.

The right amount of water applied for the proper length of time and at a frequency which conforms to crop needs requires the attention of an informed farmer and those who advise him. Governments should develop specific programs to improve the utilization of existing irrigation schemes and to train farmers in improved irrigation methods. There are many areas where water could be used much more efficiently. Where water is scarce, farmers should be encouraged to obtain the highest yields per unit of water applied rather than use excessive water in the hope of achieving somewhat greater yield. This will require in most cases some control of water use if the farmer is to forego possible yield gain to achieve maximum water-use economy.

Development is constrained at present by the problem of large numbers of people on the land. This cannot be changed rapidly, but the target should be intensification and advancement of technology as rapidly as is reasonable. A high density of rural population poses difficult problems in utilizing modern technology which is based, in part, on economies of scale in farming operations. Utilizing cooperatives and arranging farm units in such a way that modern implements can be operated should be considered; farm implement size can be scaled down also, as in Japan.

*7.4.5.4 Irrigation Research.* A great deal is known about irrigation and agriculture and some countries have spent too much of their limited manpower resources on "basic" research which is irrelevant or of remote long-range usefulness to the problems at hand. In developing countries, irrigation research programs should meet the practical needs of development. This does not exclude basic programs designed to solve future problems, but these should be consistent with long-term strategy.

*7.4.5.5. Irrigation Is Capital-Intensive.* Irrigation is very definitely a capital-intensive endeavor. It will not pay unless other inputs are also used intensively and the level of technology rises rapidly. This means that the economic success of irrigation development is tied in some measure to the development of other elements of the national or regional economy. Normally, projects will continue to require subsidy until some level of regional economic viability is reached. Therefore, the effort needs to be of critical size and scope. Under conditions in West Pakistan, project elements of about 1 million acres were considered to be the minimum critical size.

*7.4.5.6 Integrated Planning and Management.* Why is it that after an irrigation dam and main canal facilities have been constructed, measures to use this costly water with high efficiency are often overlooked or minimized? There are several reasons. One stems from the fact that large dams and canals are impressive and create visible monuments to the accomplishments of governments and assistance programs. On the other hand, the extensive network of small distribu-

taries, head ditches, properly graded farm fields, simple water control devices, irrigations scheduled in accordance with the crop needs, and drainage systems are far less spectacular and may not even be visible at all to the traveler or to the political leaders of a country. As a result, those measures necessary to achieve efficient utilization of developed water supplies seldom receive the financial support necessary to carry them out thoroughly enough to permit maximum crop production from the irrigation scheme.

A second reason is that in the basic plans for irrigation projects, consideration is seldom given to the problems in the catchment or watershed area above the storage or diversion point or to the problems of water utilization and drainage beyond the lateral canals. Management of forest and range lands in the upper catchments of river basins plays an important part in the success of water development schemes. Public agencies should therefore provide for appropriate coordination of watershed management and flood control measures with water development schemes downstream. While, fortunately, there is now a growing recognition of the need to look upstream and solve the watershed problems and to look beyond the canal laterals and deal with problems of drainage, most projects still fail to give enough attention to the other basic inputs required for a productive and permanently successful agriculture.

In developing countries, the irrigation engineer is usually concerned with storage, diversion and conveyance of water. He is rarely involved even in the distribution of water to user associations, let alone to the farmer's fields. A fundamental part of engineering education for agriculture in these countries needs to be full recognition that an irrigation project is not complete until water has reached the last row of the last farm on a schedule in accordance with the needs of the crop, and any surplus has been taken care of by a suitable drainage system. Not only the project engineers but government officials, legislators, and other policy makers need to recognize that sound water management is as essential as water development if costly irrigation schemes are to contribute substantially to agricultural production.

The sequence of processes required to achieve a productive and permanent irrigation agriculture is outlined in the chart on page 454.

*7.4.5.7 Increased Knowledge of Weather and Climate.* The practice of agriculture everywhere is highly dependent upon the weather. The farmer suffers extensive crop damage due to premature or late planting or harvesting because of drought or flooding, especially in regions of dramatic wet and dry seasonal changes common in many heavily populated areas. Weather and climate need to have increased study with the view to improving prediction in specific years and possibly some eventual modification. Increased studies of the monsoon weather

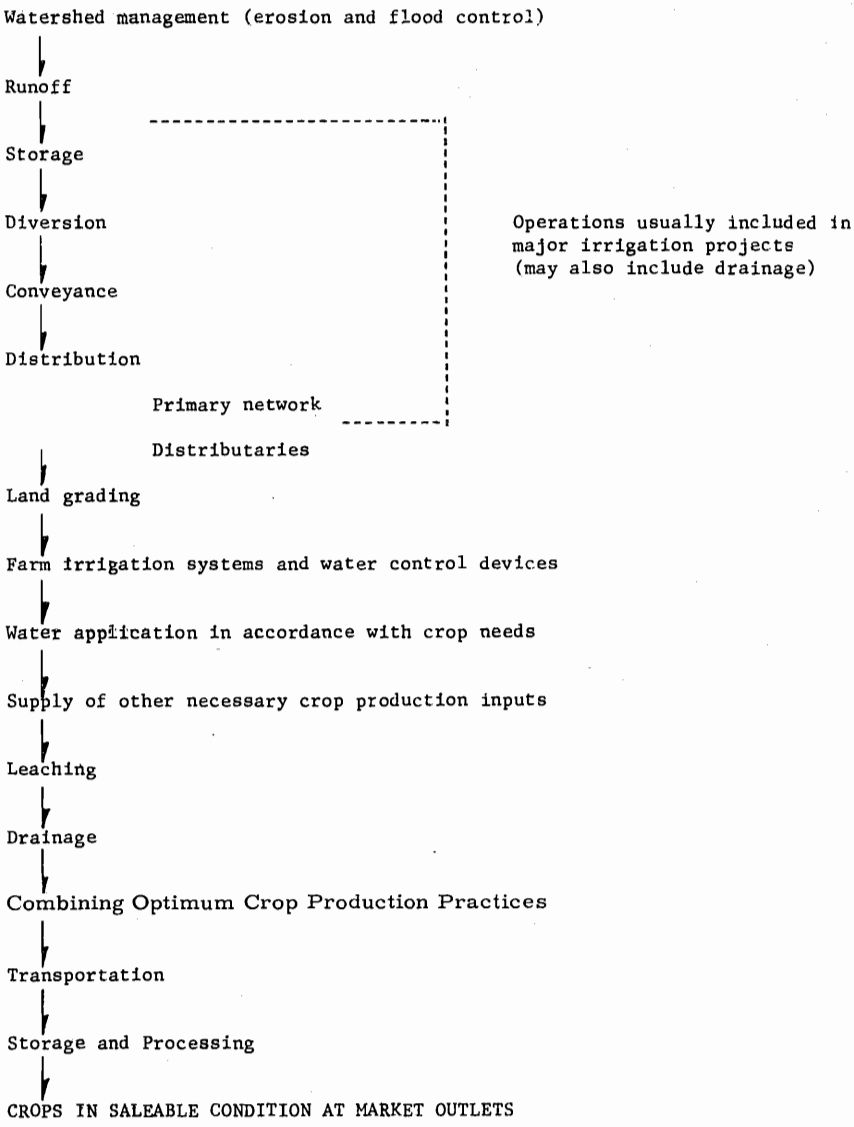
of south and southeast Asia would appear to be important and promising.

## 7.5.0 Water Management

### 7.5.1 *Water Alone is not Enough*

In many developing countries, the bringing of costly irrigation water has failed to increase crop production and in some cases, has actually decreased it, because of failure to recognize that water is but *one* of the essential inputs for successful agriculture. After the lack

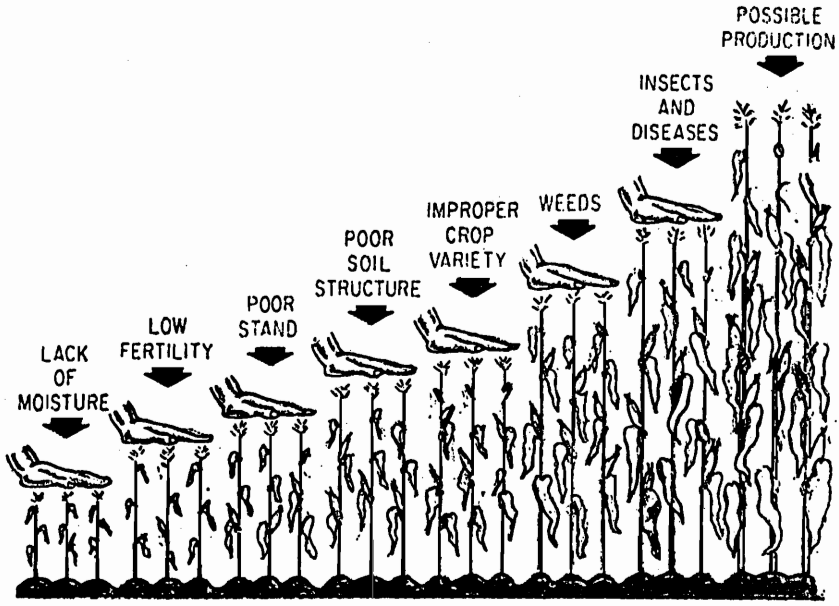
Chart 7-1



of adequate water is eliminated by irrigation, many other factors may then limit yields. For example, it has been found in Thailand that irrigation alone, without fertilizers, will often result at first in a striking improvement in yields. But then, unless the supply of plant nutrients is soon increased, yields are liable to fall back to previous levels or to decline below them as the hitherto unused reserves of nutrients in the soil are exhausted by the increased crops made possible by the irrigation. Inadequate water is often made a convenient scapegoat for which to blame any poorly growing crop, even though nutrient deficiency, pests, and other problems were concurrent or possibly dominant limiting factors.

Figure 7–1 summarizes some of the inputs and processes required to achieve maximum crop yield in irrigation agriculture. Obviously, the quantity and quality of the water supply must be adequate, and the water should be supplied to farms in the amounts, and on a schedule which permits irrigation to be applied in accordance with actual crop needs. But it is equally important that the introduction of irrigation or the improvement of irrigation and drainage should be accompanied by a complete program of better cropping practices. All are essential if the full production potentials of the land and of the irrigation water are to be achieved and if serious disappointments and even ultimate failure of irrigated agriculture are to be avoided.

Figure 7-1




[1] (Irrigation on western farms. U.S. Dep. Agr. Agr. Info. Bull. 199, 53pp. July 1959. Reference on p. 49).

If crop yields are doubled or tripled by irrigation, the removal of plant nutrients from the soil is correspondingly doubled or tripled. This means that the crop must obtain more of these nutrients from either the soil or from applied manures and fertilizers. Plant requirements for nitrogen are especially increased, accompanied by greater demands for potassium and phosphorus. The supply of the so-called microelements may also become limiting.

Figure 7–2 shows the interaction between fertilizers and water supply for both alfalfa and cotton. Increased water stress had relatively little effect on yields when nitrogen was limiting but caused a marked reduction under high nitrogen levels. This figure also calls attention to the marked effect of water stress on alfalfa yield at both low and high levels of phosphorus.

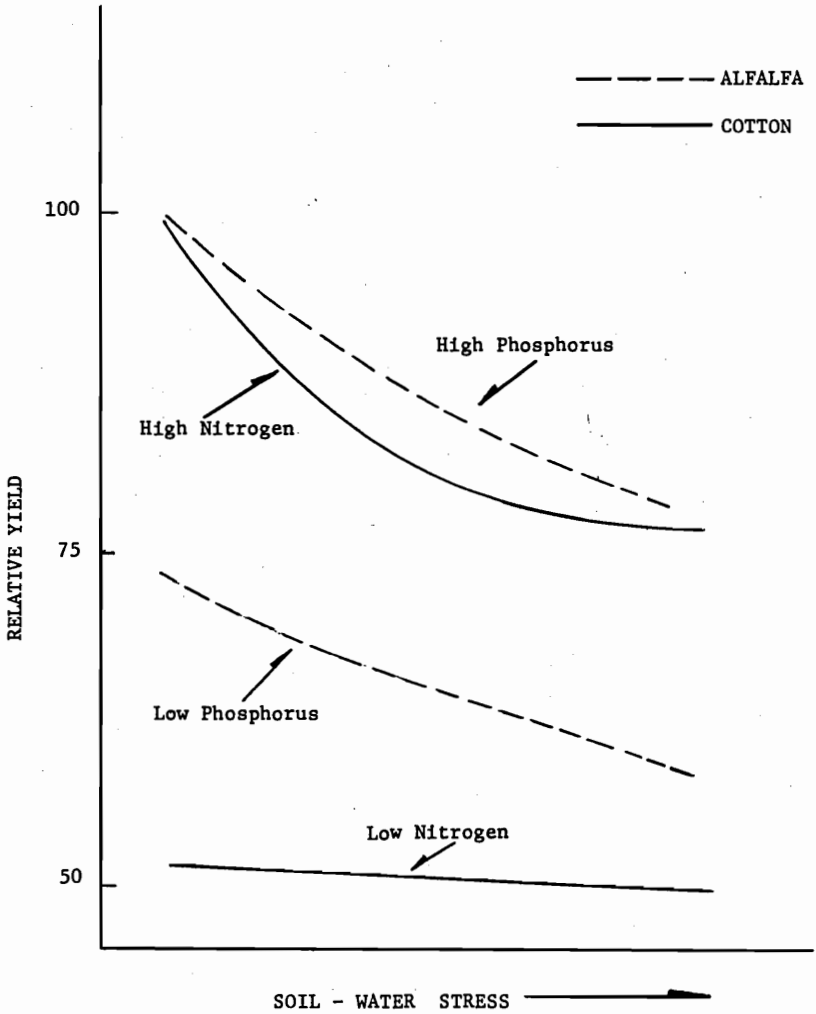
In many instances in the developing countries, very limited response and unfavorable economic returns from fertilizers and irrigation are obtained because of the poor quality of the local crop varieties. The use of low yielding varieties in field trials is most unfortunate because it discourages the farmers' adoption of practices which, with suitable plant varieties, would bring them great economic benefits.

If high yielding varieties are used and high nitrogen and moisture levels are achieved, then several new problems are likely to arise associated with rank vegetative growth, including lodging, increased boll rot, and difficulty in controlling insects. The over-riding importance of the interaction of all management factors is well illustrated by the results of field trials in Alabama with seed cotton on the same plots during three successive years, shown in Table 7–13.

In all cases, irrigation increased the yield of seed cotton, but clearly nitrogen fertilization was required to obtain any economic benefit from irrigation. The interaction of the two management factors is evident. Equally important is the fact that, with the higher moisture and nitrogen levels, the loss of cotton due to boll rot increased significantly. For the highest nitrogen and irrigation treatment in 1959, the loss was estimated at 1,300 pounds per acre. Thus, when other inputs are available for high yields, pest control is an essential factor for yield optimization.

Selection and breeding can be used effectively to provide crop varieties that will give high performance when grown with sufficient water and high nitrogen fertilization. This is illustrated with small grains where traditional wheat varieties if placed under high nitrogen fertilization and given sufficient water may have rank, vegetative growth, lodge badly, and be more susceptible to diseases and insects with only limited increased yield. New varieties developed specifically to utilize the high rates of nitrogen and water have short, stiff straw with yield potentials of 150 bushels per acre.

Figure 7-2 (1)




(1) Fertility-irrigation relationships for cotton and alfalfa on a sandy Arizona soil.

[1] (Henderson, D. W., Hagan, R. M., and Mikkelsen, D. S., Water use efficiency in irrigation agriculture. In: American Potash Institute. Moisture and fertility. Washington, 1963, 50pp. Reference on p. 46.)

### *7.5.2 Efficiency of Water Use*

Where water is scarce or expensive as it is in many areas of the world, irrigation project planners and farmers must strive to obtain maximum crop production per unit of water. Crop yield per unit of water actually used by the crop plus unavoidable evaporation losses from the

soil is usually called the water use efficiency. Fertilization and other cultural practices which lead to high yields usually increase water use efficiency.

TABLE 7–13.—*Interaction of nitrogen level, and irrigation on seed cotton yield, and boll rot incidence in Alabama*

| Year | Nitrogen, pounds per acre | Irrigation treatments [1] | | |
|---|---|---|---|---|
| | | $M_1$ | $M_2$ | $M_3$ |
| | | *0 inches* | *11 inches* | *13 inches* |
| 1957 | 0 | 2,101 | 2,191 | 2,212 |
| | 60 | 2,687 | 3,299 | 3,321 |
| | 120 | 2,614 | 4,052 | 3,967 |
| | 240 | 2,602 | 4,009 | 5,071 |
| | | | *4.6 inches* | *5.6 inches* |
| 1958 | 0 | 2,607 | 2,744 | 2,789 |
| | 120 | 3,940 | 3,967 | 4,394 |
| | 240 | 3,903 | 4,461 | [2] 4,824 |
| | 360 | [2] 3,840 | 4,304 | [2] 5,336 |
| | | | *7.1 inches* | *12.8 inches* |
| 1959 | 0 | 2,171 | 3,480 | 3,222 |
| | 120 | 2,246 | [2] 4,335 | [3] 4,181 |
| | 240 | 2,151 | [2] 4,405 | [3] 4,313 |
| | 360 | 2,168 | [3] 4,331 | [4] 4,400 |
| | 480 | ---------- | ---------- | [4] 4,221 |
| | 720 | ---------- | ---------- | [4] 4,302 |

[1] $M_1$: No irrigation. $M_2$: Irrigated at prescribed soil moisture tension. $M_3$: Irrigated at lower tension. Total irrigation for season in parentheses.
[2] Boll rot loss greater than 90 lb. per acre.
[3] Boll rot loss greater than 600 lb. per acre.
[4] Boll rot loss greater than 1,100 lb. per acre.
Source: Bennett, O. L., and others, Interrelation of nitrogen fertilization and irrigation of cotton. Int. Congr. Soil Sci. Trans. 7 (vol. 1): 657–662. 1960.

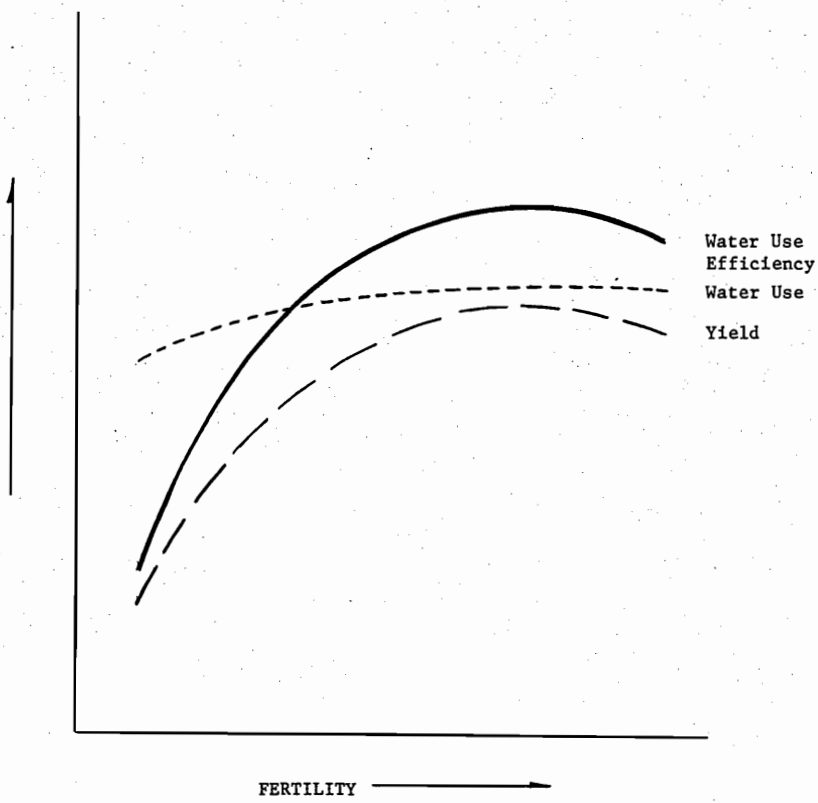
It is often thought that the use of fertilizers requires a parallel increase in water application. Unless the application of fertilizer results in denser foliage which provides a much more complete coverage of the soil surface and hence allows a higher rate of evapotranspiration per unit area, no significant increase in water use is to be expected with increased fertilization. In many cases, vegetative cover is already sufficient, and the higher yields obtained with fertilizer do not increase water use (Figure 7–3). Thus, fertilizers provide an important means of increasing crop production per unit of water applied.

The sensitivity of crops to moisture stress varies widely over the growing season. For seed crops, the critical periods for water application generally are at the time of fertilization or fruit set, and at the

time of seed ripening or "filling". Thus in areas of limited water supply, response to irrigation depends greatly on the timing of the irrigation, and the best management system may not be that which maintains high moisture levels all season. Optimum production may frequently be obtained at a level of water application well below that required to meet the evapotranspiration potential.

In the Texas High Plains, for example, irrigation is accomplished by mining a limited ground water supply; the preferable irrigation scheme seems to involve a limited water gift far below that required to attain the potential evapotranspiration. Experiments at Bushland,

Figure 7-3 (1)




(1) Fertilization and other cultural practices for top crop yield usually increase water use efficiency, because crop yields generally increase relatively more than crop water use. Any increases in water use accompanying fertilization are often negligible, as shown by this diagram.

[1] Henderson, D. W., Hagan, R. M., and Mikkelsen, D. S., Water use efficiency in irrigation agriculture. In American Potash Institute. Moisture and fertility. Washington, 1963. 50 pp.

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Texas,[29] summarized in the table below, were conducted with sorghum with different amounts of irrigation water. When projected to an area of 30 acres with a total supplemental water supply of only 10 acre-feet (120 acre-inches), the total production was much greater when the available water was spread with judicious timing over the entire area rather than concentrated in a part of it, even though the highest yields were obtained from the fully irrigated acreage.

*Results of field experiments on sorghum to test limited supply of irrigation water*

| Seasonal irrigations (inches) | Water use (inches) | Yield increase (pounds per acre) | Yield (pounds per acre) | Response (pounds per acre-inch) | Acreage irrigated | Dry | Yield (pounds) | Yield increase (pounds) |
|---|---|---|---|---|---|---|---|---|
| 0 | [1] 13.2 | 3,367 | ---------- | ---------- | 0 | 30 | 101,010 | ---------- |
| 4 | 18.1 | 5,750 | 2,383 | 595 | 30 | 0 | 172,500 | 71,490 |
| 8 | 21.6 | 6,537 | 3,170 | 396 | 15 | 15 | 148,560 | 47,550 |
| 12 | 24.7 | 6,983 | 3,617 | 301 | 10 | 20 | 137,170 | 36,160 |

[1] From rain.

Underirrigation should be used with great caution in arid regions, because of the danger of salt accumulation in the soil. At least during part of the year, the water supply must exceed the potential evapotranspiration to insure that the salt is leached out of the soil.

### *Additional Information on Capital Costs of Land and Water Development Given in Table 7–14*

Costs are extremely variable depending on the size and complexity of the project and what is included. Some information was collected on costs of projects currently under contruction or in various stages of planning. This is shown in Table 7–14. An attempt was made to classify projects into categories as follows:

*New Land in Areas Not Previously Settled.* Includes both irrigated and unirrigated land. Costs under the very large Rajasthan project are relatively low, $134/A. These were estimated several years ago and are probably on the low side. Most of othe other examples involving irrigation are from Colombia and range from $86/A to $1,230/A averaging $460/A. For very large irrigation projects (over 1,000,000 A) without extensive clearing and infrastructure, costs may be under $200/A; and for smaller projects (10,000 A–100,000 A) they may exceed $1,000/A. Costs for an irrigated sugar cane development in Iraq came to $1,310/A without the refinery.

Costs for developing a small rainfed sugar cane plantation in Hawaii came to $58/A; development of large dry-farm grazing and cereal land in Australia, $25/A. Two large developments in Peru, including clear-

[29] Musick, J. T., Personal communication.

ing roads and community development, cost $125/A and $200/A, respectively.

*New Land in Settled Areas.* Some projects reported both new lands in settled and in unsettled areas; many included both lands not previously cultivated and supplemental irrigation for lands now irrigated. Costs for the different types were not separable. Those whose sole or principal effort was oriented toward new lands to be placed under irrigation were assigned to this class. The weighted average of those where areas were known was $400/A excluding a small commercial cane sugar venture in Iran. The average is close to those incurred on the South Saskatchewan in Canada; with land leveling totals about $400/A and sprinkler irrigation systems another $100/A. While the range is from $230/A to $720/A, $400/A appears to be a good average figure for medium to fairly large projects (10,000 to 500,000 acres).

Development of lands for community pasture (rainfed) in Saskatchewan (clearing small trees, plowing and disking) cost about $36/A.

*Irrigation of Lands Presently Cultivated but Not Irrigated.* Again, most projects included both supplemental irrigation for lands now irrigated plus irrigation of lands now cultivated but not irrigated. Those which did *not* report supplemental irrigation of existing lands were classified in Group III. The weighted average cost was $325/A for projects ranging from less than 10,000 acres to 2,000,000 acres. The latter is the large Nagajunasagar project in India where costs are reported at $151/A. Omitting this project the average rises to $581.

*Supplemental Irrigation for Lands Presently Irrigated.* Almost all projects included areas of land not previously irrigated as well as supplemental irrigation, and costs were not separable. The weighted average cost for those using surface supplies was $320/A. Except for a few high-cost projects in the United States, most fell between $200/A and $600/A.

For the first large 1,000,000-acre West Pakistan groundwater development, investment costs for wells, electrification and surface drainage are reported at $41/A. Investment in fertilizer, plants, education and extension would raise this to $81/A. Well costs only, without electrification, for the remaining 20,000,000 acres have been estimated at $23/A. These are for an extremely large project under favorable conditions.

*Coastal Embankment for Flood Control.* This cost could be highly variable. For East Pakistan conditions where monsoon flooding submerges some 10,000,000 acres of agricultural land each year, capital cost of protection for approximately 3,000,000 acres is estimated at $84/A.

TABLE 7-14.—*Costs for selected water and land development projects or proposals*

| Name of project, country, location | Climatic zone | Source of water [a] | River basin | Clearing trees | Clearing brush | Leveling | Surface drainage | Subsurface drainage | Roads | Communities | Erosion control | Flood control | Power supply | Farm irrigation systems | Level of agricultural technology [b] | Arable/gross area | Construction technology [c] | Total project cost [d] (thousands) | Project area acres (net) | Cost in dollars per acre | Basis for cost [e] | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I | | | | | | | | | | | | | | | | | | | | | | |
| *New Land in Area Not Previously Settled* | | | | | | | | | | | | | | | | | | | | | | |
| IRRIGATION | | | | | | | | | | | | | | | | | | | | | | |
| A. Huila No. 2, Colombia, 3° N., 75°30′ W. | V | RR | Magdalena | (f) | (x) | (x) | (x) | (o) | (x) | (o) | (o) | (x) | (o) | (x) | MN | 0.66 | C | $555 | 6,430 | $86 | A | |
| B. Santander No. 2, Colombia, 7°30′ N., 74° W. | V | RR | Rio Lebrija | (x) | (x) | (x) | (x) | (o) | (x) | (o) | (o) | (x) | (o) | (x) | FM | .90 | FM | 5,240 | 42,500 | 124 | ------ | |
| C. Bolivar No. 1, Colombia, 10° N., 75°20′ W. | V | -------- | Magdalena | (x) | (x) | (x) | (x) | (o) | --- | --- | (o) | (x) | (o) | (x) | AO | .80 | C | 12,300 | 40,000 | 308 | EP | |
| D. Atlantico No. 3, Colombia, 1030′ N., 0°50′ W. | V | -------- | ---------- | (o) | (x) | (x) | (x) | (o) | (x) | (o) | (o) | (x) | (x) | (x) | MN | .85 | C | 55,400 | 45,000 | 1,230 | EC | |
| E. Norte de Santander, Colombia, No. 1. | V | -------- | Zulia | (x) | (x) | (x) | (x) | (o) | (x) | (o) | (o) | (x) | (o) | (x) | FM | .62 | FM | 12,100 | 52,500 | 230 | EF | |

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F. Rajasthan Canal Project, India, 28° N., 73° E. | IV | -------- | Beas-------- | (o) | (o) | (z) | (z) | (z) | (z) | (z) | (o) | (z) | (o) | (z) | FM, AO, MN, P | .44 | C | 386,400 | 2,875,000 | 134 | ------ | Costs from "India Irrigation and Power Projects". Central Water and Power Commission. |
| G. Haft Tappeh Cane Sugar Project, Iran, 32° N., 49° E. | IV | RS | Dez-------- | (o) | (o) | (z) | (z) | (z) | (z) | (z) | (o) | (o) | (z) | (z) | FM | .51 | FM | 27,500 | 12,600 | 1,310 | A | For sugar cane. Unit cost does not include $870 per acre for refinery. |
| NO IRRIGATION | | | | | | | | | | | | | | | | | | | | | | |
| H. Waialua Agr. Co., Hawaii, U.S.A. | V | NA | ---------- | (o) | (z) | (z) | (o) | (o) | (o) | (o) | (z) | (o) | (o) | (o) | FM | 1.00 | C | 9 | 157 | 58 | A | For growing sugar cane. Cost does not include depreciation on overhead. |
| I. Esperance, Australia. | IV | NA | Esperance Plains. | (o) | (z) | (o) | (o) | (o) | (o) | (o) | (o) | (o) | (o) | (o) | FM | .90 | C | -------- | 1,200,000 | 25 | A | For grazing and cereals. |
| J. Pirene-Satipo ENE Peru, 11° S., 75° W. | V | NA | ---------- | (o) | (o) | (o) | (o) | (o) | (z) | (z) | (o) | (o) | (o) | (o) | AO, MN | .50 | FM | 100,000 | 500,000 | 200 | ------ | Source: C.I.D.I.A.T. |
| K. Pomacocha-Tarapoto Road, Peru. | V | NA | ---------- | (o) | (o) | (o) | (o) | (o) | (h) | (i) | (o) | (o) | (o) | (o) | AO, MN | .12 | FM | 50,000 | 400,000 | 125 | ------ | Do. |
| II | | | | | | | | | | | | | | | | | | | | | | |
| *New Land in Settled Area* | | | | | | | | | | | | | | | | | | | | | | |
| IRRIGATION | | | | | | | | | | | | | | | | | | | | | | |
| A. South Saskatchewan, Canada. | III | Varies | South Saskatchewan. | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | FM | ----- | ------- | --------- | ---------- | 300 | ------ | Capital costs. Land leveling, $100 per acre more. Sprinkling, $100 per acre additional. |

See footnotes at end of table.

TABLE 7-14.—*Costs for selected water and land development projects or proposals*—Continued

| Name of project, country, location | Climatic zone | Source of water [a] | River basin | Clearing trees | Clearing brush | Leveling | Surface drainage | Subsurface drainage | Roads | Communities | Erosion control | Flood control | Power supply | Farm irrigation systems | Level of agricultural technology [b] | Arable/gross area | Construction technology [c] | Total project cost [d] (thousands) | Project area acres (net) | Cost in dollars per acre | Basis for cost [e] | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B. Lower Moulouya River, Morocco, 33° N., 8° W. | IV | RS | Moulouya | (c) | (c) | (i) | (c) | (c) | (c) | (c) | (c) | (c) | (c) | (c) | AO, MN | ----- | FM | $120,000 | 175,000 | $685 | EC | |
| C. East Ghor Project, Jordan, 32° N., 36° E. | IV | RR | Jordan | (c) | (c) | (z) | (z) | (c) | (c) | (c) | (c) | (c) | (c) | (z) | FM, AD | 0.65 | FM | 20,100 | 30,000 | 670 | A | Limited reservoir storage on local wadi. |
| D. Moquequa Project, Peru, 17° S., 72° W. | IV | RS, RR | Moquequa | (c) | (c) | (c) | (z) | (z) | (c) | (c) | (c) | (c) | (c) | (c) | OA | .70 | C | 23,907 | 16,800 | 1,420 | EC | |
| E. Amarah Cane Sugar, Iraq, 32° N., 37° E. | IV | RS | Tigris | (c) | (c) | (z) | (z) | (z) | (z) | (z) | (c) | (z) | (z) | (z) | FM | .53 | FM | 31,000 | 15,400 | 974 | EC | For sugar cane. Unit cost does not include $1,040 per acre for refining. |
| F. Helmand Valley, Afghanistan, 31° N., 65° E. | IV | RS | Helmand | (c) | (c) | (z) | (z) | (z) | (z) | (c) | (c) | (c) | (z) | (c) | AO | .77 | FM, C | 100,000 | 430,000 | 230 | EP | Includes lands not previously settled, or cultivated and supplemental supply for lands previously irrigated. |
| NO IRRIGATION | | | | | | | | | | | | | | | | | | | | | | |
| G. Saskatchewan, Canada | II | NA | Saskatchewan. | (k) | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | ------- | ----- | ------- | --------- | ---------- | 36 [l] | ------ | Community pasture. |

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| III<br>*Irrigation of Lands Presently Cultivated, But Not Now Irrigated* | | | | | | | | | | | | | | | | | | | | | | |
| A. Zapucay, Uruguay, 32° S., 55° W. | IV | RS, RR | Zapucay | (°) | (°) | (°) | (z) | (z) | (°) | (°) | (°) | (°) | (°) | (°) | AO | .88 | C | 4,150 | 8,750 | 475 | EC | Pilot project. Eventual irrigation of 205,000 acres. |
| B. Kano Plain, Kenya, 0°10′ S., 34° E. | V | RR, | Kibos, Luanda, Nyanda. | (°) | (z) | (z) | (z) | (°) | (z) | (°) | (°) | (z) | (°) | (z) | FM | .40 | FM | 31,164 | 30,000 | 1,038 | EP | Includes some land not previously cultivated. |
| C. Garrison, U.S.A., 48° N., 99° W. | III | RS | ---------- | (°) | (z) | (°) | (z) | (z) | (z) | (°) | (°) | (°) | (°) | (°) | FM | .29 | FM | 616,557 | 1,007,000 | 612 | EC | |
| G. EWA Plantation, Hawaii, U.S.A., 21°20′ N., 158° W. | V | GW | ---------- | (t) | (t) | (u) | (°) | (°) | (°) | (°) | (w) | (w) | (°) | (z) | FM | .80 | FM | 4,850 | 16,000 | v 243 | ------ | Investment in irrigation machine (sprinkler) $78 per acre additional. |
| D. Whitestone-Coulee, U.S.A. 49° N., 120° W. | III | (*) | Columbia | (°) | (°) | (°) | (°) | (°) | (°) | (°) | (°) | (°) | (°) | (°) | FM | .21 | FM | 5,153 | 2,660 | 1,937 | EC | |
| E. Zulu Plain, Ethiopia, 15° N., 38° W. | V | RS | Haddas | (°) | (°) | (°) | (z) | (z) | (°) | (°) | (z) | (°) | (°) | (z) | AO | .50 | FM | 7,660 | 10,000 | 1,766 | EP | |
| F. Bugolagrande, Certago, Colombia, 4°30′ N., 76° W. | V | RP | Rio Caveg | (°) | (°) | (°) | (z) | (z) | (°) | (°) | (°) | (°) | (°) | (°) | AO, MN, P | .64 | C | 15,900 | 75,000 | 213 | EP | |
| G. Tsengwen Reservoir, Taiwan, 24° N., 122° E. | V | RS | Tsengwen | (°) | (°) | (°) | (°) | (°) | (°) | (°) | (°) | (°) | (z) | (°) | FM | 1.00 | FM | 93,741 | 211,000 | 444 | EC | About 8 percent is land not previously cultivated. |
| H. Nagajunasagar India, 16° N., 79° E. | V | RS | Krishna | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | ------- | ----- | ------- | 302,000 | 2,000,000 | 151 | EF | From "India Irrigation and Power Projects." Central Water and Power Commission. |

See footnotes at end of table.

TABLE 7-14.—*Costs for selected water and land development projects or proposals*—Continued

| Name of project, country, location | Climatic zone | Source of water [a] | River basin | Clearing trees | Clearing brush | Leveling | Surface drainage | Subsurface drainage | Roads | Communities | Erosion control | Flood control | Power supply | Farm irrigation systems | Level of agricultural technology [b] | Arable/gross area | Construction technology [c] | Total project cost [d] (thousands) | Project area acres (net) | Cost in dollars per acre | Basis for cost [e] | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IV | | | | | | | | | | | | | | | | | | | | | | |
| *Supplemental Irrigation to Lands Now Partly Irrigated* | | | | | | | | | | | | | | | | | | | | | | |
| A. Rio Dulce, Argentina, 28° S., 64° N. | IV | RS | Rio Dulce | (e) | (e) | (e) | (e) | (z) | (e) | (e) | (e) | (e) | (z) | (e) | AO, MN, P | 0.93 | C | --------- | 295,000 | $265 | EC | Project has intensive salinity problem. Includes lands not previously cultivated. |
| B. Animas-LaPlata, U.S.A., 37° N., 108° W. | IV | RS | Colorado | (e) | (z) | (z) | (z) | (z) | (z) | (e) | (e) | (e) | (e) | (e) | FM | .44 | FM | $78,971 | 72,120 | 1,095 | EC | Adds some lands not previously cultivated. Non-Federal cost $35 per acre except sprinkling which is $85 per acre. |
| C. Auburn-Folsom, U.S.A., 39° N., 121° W. | III | RS GW | Sacramento: San Joaquin. | (e) | (z) | (e) | (z) | (z) | (z) | (e) | (e) | (e) | (z) | (e) | FM | .80 | FM | 146,175 | 413,400 | 354 | EC | Adds some lands not previously cultivated. 1962 price level. |

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D. Dixie, U.S.A., 37° N., 114° W. | III | RS | Colorado | (°) | (°) | (°) | (²) | (²) | (²) | (°) | (°) | (°) | (°) | (°) | FM | .73 | FM | 31,411 | 21,060 | 1,492 | EC | Includes lands not previously cultivated. Non-Federal cost. Clearing, $10 per acre, leveling, $100 per acre, ditch lining $100 per acre, on new lands. $30 to $38 per acre on presently irrigated lands. |
| E. Savery-Pot Hook, U.S.A., 41° N., 107° W. | III | RS | Colorado | (°) | (°) | (°) | (°) | (²) | (°) | (°) | (°) | (°) | (°) | (°) | FM | .26 | FM | 14,888 | 35,265 | 442 | EC | Includes additional land not previously cultivated. Non-Federal farm development cost $35 to $75 per acre. |
| F. Rio Colorado, Argentina, 39° S., 64° W. | III | RR | Rio Colorado. | (°) | (²) | (°) | (°) | (°) | (°) | (°) | (°) | (°) | (°) | (°) | AO | ----- | C | 5,900 | 40,775 | 145 | EP | Includes additional land not previously cultivated. |
| G. Sao Goncalo, Brazil, 5° S., 38° W. | V | RS | Piranhas | (°) | (°) | (°) | (²) | (°) | (°) | (°) | (°) | (°) | (°) | (°) | AO | .16 | C | 14,459 | 125,750 | 114 | EP | |
| H. Upper Pampanga River, Philippines, 15° N., 121° E. | V | RS | Pampanga | (°) | (²) | (²) | (²) | (²) | (²) | (²) | (²) | (²) | (²) | (°) | AO | ----- | FM | 40,505 | 200,000 | 202 | EC | Includes some lands not previously cultivated. |
| I. Lam Pao, Thailand, 16° 50′ N., 103°30′ E. | V | RS | Lam Pao | (°) | (²) | (°) | (²) | (²) | (²) | (²) | (°) | (°) | (°) | (°) | AO | ----- | FM | 11,052 | 39,526 | 254 | EF | Do. |
| J. Me Tang, Thailand, 19° N., 99° E. | V | RR | Me Tang | (°) | (°) | (²) | (²) | (°) | (²) | (²) | (°) | (°) | (°) | (°) | AO | ----- | FM | 7,750 | 58,102 | 134 | EF | Do. |
| K. Lam Pra Plerng, Thailand, 14° 30′ N., 102° E. | V | RS | Lam Pra Plerng. | (²) | (²) | (²) | (²) | (²) | (²) | (²) | (°) | (°) | (°) | (°) | AO | ----- | FM | 8,300 | 27,669 | 299 | EF | Do. |
| L. Lam Nam Oon, Thailand, 17° N., 104° E. | V | RS | Lam Nam Oon. | (°) | (°) | (²) | (²) | (°) | (²) | (²) | (°) | (°) | (°) | (°) | AO | ----- | FM | 13,885 | 56,284 | 246 | EC | Do. |
| M. Artibonite, Haiti, 19° N., 72°30′ W. | V | RR | Artibonite | (°) | (°) | (°) | (²) | (²) | (°) | (°) | (°) | (°) | (²) | (°) | AO | 86 | C | 19,200 | 80,000 | 240 | EP | Includes some lands not previously cultivated. Estimates are 1950 costs. |

See footnotes at end of table.

TABLE 7–14.—*Costs for selected water and land development projects or proposals*—Continued

| Name of project, country, location | Climatic zone | Source of water [a] | River basin | Clearing trees | Clearing brush | Leveling | Surface drainage | Subsurface drainage | Roads | Communities | Erosion control | Flood control | Power supply | Farm irrigation systems | Level of agricultural technology [b] | Arable/gross area | Construction technology [c] | Total project cost [d] (thousands) | Project area acres (net) | Cost per dollar per acre | Basis for cost [e] | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N. Tumbes, Peru, 30° 40′ S., 80°20′ W. | V | GW, RS. | Rio Tumbes | (o) | (z) | (o) | (z) | (z) | (o) | (o) | (o) | (o) | (z) | (o) | AO | 80 | C | $11,322 | 48,600 | $230 | EC | Includes some lands not previously cultivated. |
| O. Rio La Villa, Panama, 8° N., 80°30′ W. | V | RS | LaVilla | (o) | (o) | (m) | (z) | (z) | (o) | (o) | (o) | (o) | (o) | (z) | MN, P | 59 | FM | 12,925 | 27,500 | 470 | EP | Do. |
| P. Rio Sucio, El Salvador, 14° N., 89° W. | V | GW, RR | Rio Sucio | (o) | (o) | (o) | (z) | (z) | (z) | (o) | (o) | (z) | (o) | (z) | AO | 90 | C | 3,920 | 10,800 | 365 | EC | Do. |
| Q. San Lorenzo, Peru, 5° S., 81° W. | V | RS | Piura Buiroz Chipilliro. | (o) | (n) | (p) | (o) | (o) | (q) | (r) | (o) | (o) | (o) | (o) | FM | 70 | FM | 63,000 | 100,000 | 630 | EF | Includes 25,000 acres not previously cultivated. Cost: $403/A for construction, $200/A for colonization. |
| R. Tinajones, Peru, 7° S., 80° W. | V | RS | Chancay Lluacano. | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | FM | 60 | FM | 40,000<br>40,000 | 150,000<br>200,000 | 266<br>200 | EF<br>EP | Supplemental irrigation. 180,000 acre supplemental. 20,000 acres new lands. |

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S. Scarp I, West Pakistan, 31° N., 73° E. | IV | GW | Indus | (e) | (e) | (e) | (e) | (z) | (e) | (e) | (e) | (e) | (e) | (e) | FM, AO | ----- | FM | 30,800 | 1,026,017 | 30<br>41<br>81 | EF<br>EF<br>EC | Tube wells and electrification.<br>Total capital costs.<br>Total development costs including fertilizer, education, etc. |
| T. Upper Indus, West Pakistan, 31° N., 72°30′ E. | IV | GW | Indus | (e) | (e) | (e) | (e) | (z) | (e) | (e) | (e) | (e) | (e) | (e) | P, AO | .80 | FM | 483,094 | 20,896,000 | 23 | EF, EC, EP | Cost of tubewells (no electrification) only. |
| U. Wadi Arab Dam, Jordan. | IV | RS | Wadi Arab, Jordan Basin. | (e) | (e) | (e) | (e) | (e) | (e) | (e) | (e) | (z) | (e) | (z) | AO | .33 | C | 6,240 | 33,500 | 186 | EC | Supplemental water only. |
| V | | | | | | | | | | | | | | | | | | | | | | |
| *Coastal Embankment for Flood Control* | | | | | | | | | | | | | | | | | | | | | | |
| A. East Pakistan 22° N., 90° E. | V | NA | Ganges | (e) | (e) | (e) | (z) | (e) | (e) | (e) | (e) | (z) | (e) | (e) | AO, P | .80 | P | 238,000 | 2,840,000 | 84 | EF | No water supply furnished. |

*Storage already exists. Includes some land not previously cultivated.

†Apparently includes other costs than irrigation, but could be cost per gross area.

[a] RS=Reservoir storage; TS=tank storage; GW=ground water; RR=run of river diversion; PS=pumped from streams; NA=Not applicable.

[b] FM=fully modern; AO=animal power but fertilizer and pest control; MN=mechanical power, little or no fertilizer, or pest control; P=primitive.

[c] FM=fully mechanized; C=combination of modern and primitive methods; P=primitive.

[d] Assigned to irrigation or agriculture if multiple purpose.

[e] A=actual costs; EF=estimated final costs; EC=estimated costs at proposal or loan application stage; EP=estimated costs, preliminary study.

[f] $37 per acre.

[g] $40 per acre.

[h] $50 per acre.

[i] $50 per acre.

[j] $50 per acre.

[k] $20 per acre.

[l] Plowing and discing, 3 passes, $16 per acre.

[m] $60 per acre.

[n] $20 per acre.

[o] Not included.

[p] $100 per acre.

[q] $70 per acre.

[r] $30 per acre.

[s] $40 per acre.

[t] $17 per acre for both.

[u] $17 per acre.

[v] $35.62 per acre for ripping subsoil.

[w] $25 per acre for both.

[x] included but cost not specified.

[y] $62 per acre for rock raking.

# CHAPTER 8

# TROPICAL SOILS AND CLIMATES

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## Contents

| | | Page |
|---|---|---|
| 8.1.0 | Summary | 472 |
| 8.2.0 | Introduction | 473 |
| 8.3.0 | Characteristics of Tropical Soils and Climates | 474 |
| 8.3.1 | Climatic Regions | 475 |
| 8.3.1.1 | Regions of Rainy Climates | 475 |
| 8.3.1.2 | Regions of Humid Seasonal Climates | 476 |
| 8.3.1.3 | Regions of Wet-Dry Climates | 478 |
| 8.3.1.4 | Regions of Dry Climates | 479 |
| 8.3.1.5 | Regions of Semi-Desert and Desert Climates | 479 |
| 8.3.2 | Tropical Soils | 480 |
| 8.4.0 | Agricultural Systems in the Tropics | 484 |
| 8.4.1 | Shifting Cultivation | 485 |
| 8.4.2 | Mixed Tree Crops | 487 |
| 8.4.3 | Flood Farming | 488 |
| 8.4.4 | Livestock Enterprises | 488 |
| 8.4.5 | Consolidation of Fragmented Holdings | 488 |
| 8.4.6 | Plantation Cropping | 489 |
| 8.4.7 | Nomadic Gathering | 490 |
| 8.5.0 | Potentials for Tropical Areas | 490 |
| 8.5.1 | Theoretical Potentials in Tropical Food Production | 492 |
| 8.5.2 | Irrigated Soils | 493 |
| 8.5.3 | The Principle of the Inter-Continent Transplant | 494 |
| 8.5.4 | The Semi-Domestication of a System of Tropical Ruminants | 494 |
| 8.5.5 | Some Tropical Experiences | 495 |
| 8.5.6 | Tropical Forest Potentials | 497 |



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# 8.0 TROPICAL SOILS AND CLIMATES

## *8.1.0 Summary*

The developing nations, in which food production is rising at a slower rate than human reproduction, lie largely in the tropics. In much of this region crops must be grown on soils often severely leached of nutrients and in association with pests whose depredations never are interrupted by winter. The region is characterized by a tradition-bound peasantry that often is controlled by a political system with its power base in cities which are not familiar or concerned with problems of farming and with measures needed for its improvement.

In the tropics where general climatic and soil characteristics suggest a vast unused potential for food production, there are large areas of uncultivated or undercultivated land. To realize this potential two major deficiencies must be overcome: (1) deficiency of knowledge of tropical soils and of practical soil and crop management systems needed for sustained high yields; and (2) deficiency of technological and economic inputs of the kind and size now available to producers in temperate regions.

Tropical soils range from highly-leached ones of the rain forest to alkali-saturated soils of the desert; from rich volcanic soils of Java through alluvial soils of the Nile delta to impoverished soils of the Ancient uplands.

On some of these soils, cultural methods similar to those of temperate zones have resulted in annual yields greater than those of temperate regions. In other areas, these same cultural methods have spelled disaster, sometimes resulting in essential destruction of the tropical soils. Unfortunately, temperate zone farming methods have usually been inferior to those used by indigenous cultivators in managing soils of the tropics.

A common agricultural system of the humid tropics is the slash and burn method. The forest is cut and burned, the soil is cultivated until the natural fertility is gone, then abandoned to forest.

The local cultivators may be uninformed, but they do not lack intelligence. They have made adaptations to the needs of the tropics. For example, some send their cattle to forage in the daytime, pen them at night, collect the manure, and put it on their kitchen gardens. Primitive farmers in some countries have for centuries used human manure.

As a result, the soil in some places, especially in China, is reasonably fertile within walking distance or bullock-cart distance of the villages.

In the United States the man in the street thinks science and technology can save the hungry nations. In the past two decades, his congressman has reflected this feeling in the national foreign-assistance policy of "know-how, show-how." There are various difficulties associated with this policy, one of which Kipling stated as follows:

"The end of the fight is a tombstone white
with the name of the late deceased.
And the epitaph drear: A fool lies here
who tried to hustle the East."

Technology must be devised in each developing nation and vast efforts must be made to learn what technology will work in the tropics. The United States should cooperate with interested governments to develop agricultural research and education institutes in several tropical areas to focus on production, storage, processing, and marketing of food crops.

### *8.2.0 Introduction*

Most of the nations having food supply problems lie in the tropics where food production and income have lagged far behind the increasing population. It is in the tropics where trained manpower by modern standards is woefully inadequate, where inputs such as fertilizer, improved seeds, insecticides and credit are often nonexistent, and where processing, storage, and transportation facilities are also lacking.

In contrast many of the inputs known to improve food production are associated with environments and nations of the temperate zone. Sad experiences have demonstrated that these inputs often cannot be tranferred directly to meet the needs of tropical agriculture. This subpanel was formed to examine some of the problems and opportunities of tropical areas and to suggest means of using principles developed in temperate zones for the improvement of tropical agriculture.

There are some fertile soils in the tropics such as those derived from vulcanism in Java or those derived from silting in the Nile Valley. In vast areas, the soils are so infertile that native vegetation is able to exist because of its compost and a rapid recycling of minerals. In some areas, subsistence farming depends largely on the method of slash-burn-cultivate-fallow. With this method, the land is cultivated only a small portion of the time.

If a hungry nation is to have more food, it must either extract more food from its present cropland or expand food production on new land. In some countries a farmer can move only to ancient soils of low fertility which are intractable to limited resources of the peasant. Some soils are potentially productive with appropriate inputs of industry

and assistance from the government, provided other resources are developed which can share the costs of transport and other services.

Experience in developing countries shows that even the more infertile lands can be made productive provided appropriate technological inputs are developed and applied. Highly sophisticated basic research is needed to realize the potential productivity of the tropical areas. Also required is an immense amount of adaptive research and development of cultural systems acceptable to native farmers. Local problems of producing food in the tropics demand local inventions.

### *8.3.0 Characteristics of Tropical Soils and Climates*

The subpanel has confined itself to areas most commonly considered "tropical" by the general public. Deliberately excluded are regions subject to frost or regions which have a mean monthly temperature of less than 55° F.

Except for effects of air currents from oceans and deserts, most variations among tropical climates are associated with amount and seasonal distribution of rainfall. This fact is the basis of classifying tropical climates in Table 8–1.

Except for the rainy regions, pronounced seasonality of rainfall distribution is characteristic of tropical climates. In most places, length and intensity of the dry season are more critical criteria for appraising agricultural potential than absolute amounts of rainfall.

Compared with temperate zones, the tropics receive a much larger amount of the radiant energy potentially available for photosynthesis per unit area, other factors being equal. Equatorial regions free of clouds would receive between 56 percent and 59 percent of the potential 525,000 calories per square centimeter annually after correcting for losses within the atmosphere. This compares with 47 percent at 40° north or south latitude. The difference is attributed to the angle of incidence of sunlight and consequent passage of light through a greater thickness of atmosphere and its distribution over a larger land area.

Cloudiness reduces the amount of sunshine actually received in certain regions. Hours of sunshine annually in different tropical regions range from as little as 20 percent to nearly 100 percent of what is possible. Sunshine increases from wet to dry regions. A much larger part of sunshine received is available for photosynthesis in the tropics than in temperate zones because temperatures of the tropics are above the minimum for plant growth.

Generally the degree of weathering and leaching of soils increases from the driest to the wettest regions. With increased weathering, amounts of plant nutrients in the mineral fraction decrease as does the capacity of that fraction to hold added nutrients in forms plants can use. Thus the organic-fraction-nutrient-supplying capacity of

TABLE 8–1.—*Land areas of major climatic regions of the tropics* [1]

(Millions of acres)

| Tropical climatic regions | Asia and Pacific Islands | Africa | Australia and New Zealand | South America | North America | Total |
|---|---|---|---|---|---|---|
| Rainy climates. (9½ to 12 months humid) | 860 | 486 | ---------- | 1,484 | 111 | 2,941 |
| Humid seasonal climates. (7 to 9½ months humid) | 678 | 1,233 | 23 | 1,423 | 127 | 3,484 |
| Wet-dry climates. (4½ to 7 months humid) | 366 | 1,592 | 131 | 242 | 187 | 2,519 |
| Dry climates. (2 to 4½ months humid) | 216 | 1,202 | 281 | 170 | 38 | 1,907 |
| Semidesert and desert climates. (Less than 2 months humid) | 324 | 752 | 242 | 46 | 17 | 1,382 |
| Total | 2,444 | 5,265 | 677 | 3,365 | 480 | 12,233 |

[1] Climatic regions adapted from H.E. Landsberg, H. Lippman, K. H. Patten, and C. Troll. 1963. Die Jahreszeitenklimate der Erde. Heidelberg Akademie der Wissenschaften, E. Rodenwaldt and H. J. Jusatz, editors, Springer Verlag.

dominant soils increases from wet to dry regions as do limitations due to drought. These relationships can be seen from results in Table 8–2.

These generalizations do not infer that soils of tropical regions are uniform over large areas. Indeed, the local soil pattern is extremely complex in many areas and variety of tropical soil conditions probably exceeds that of the rest of the world.

### *8.3.1 Climatic Regions*

Climatic regions are described here in terms of selected critical climatic factors and in terms of the general character of soil resources. The various kinds of soils are described in more detail in subsection 8.3.2, which follows.

*8.3.1.1 Regions of Rainy Climates.* Tropical rainy climates (Table 8–1) are regions in which the vegetation is dense, high rain forest. Short interruptions of rains are too little and too mild to favor deciduous plant species. Some grow in native forests, however, in areas with 2 to 2½ months dry season.

Throughout the region, native vegetation is dense, high forest with understories of species tolerant of low light intensity. Anthropic savanna has encroached on margins of the zone where the dry season is conducive to burning. Humidity is high most of the year and daytime temperatures range from 80° to 90° F. Both diurnal and seasonal fluctuations of temperature are small. The incidence of cloudiness is high and sunlight energy available for photosynthesis is correspondingly reduced. Cropping is possible 12 months a year. A high proportion of the region is undeveloped.

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TABLE 8–2.—*Acreages of principal kinds of soils by major tropical climatic regions*
[Millions of acres]

| Soil groups | Tropical climatic regions | | | | | |
|---|---|---|---|---|---|---|
| | Rainy | Humid-seasonal | Wet-dry | Dry | Semi-desert and desert | Total |
| Light colored soils; base rich | 11 | 17 | 241 | 934 | 520 | 1,723 |
| Dark colored soils; base rich (Chernozemic, Grumusols, Rendzina, Brown Forest) | 57 | 139 | 294 | 229 | 2.4 | 722 |
| Moderately weathered and leached soils (noncalcic Brown, Ando) | 11 | 84 | 221 | 186 | 14 | 516 |
| Highly weathered and leached soils (Latosols, Lateritic, Red-Yellow Podzolic) | 2,299 | 2,678 | 1,170 | 122 | 2.2 | 6,271 |
| Shallow soils and dry sands | 201 | 259 | 419 | 378 | 830 | 2,087 |
| Alluvial soils | 361 | 306 | 175 | 58 | 13 | 913 |
| Total | 2,940 | 3,483 | 2,520 | 1,907 | 1,782 | 12,232 |

Highly weathered and leached soils (Table 8–2) cover almost four-fifths of the land in the rainy tropics. Dominant soils have the physical potential for excellent plant growth if problems of soil fertility, pests, diseases, and similar factors can be solved.

Soil fertility is an outstanding limitation in primitive agriculture. The much smaller area of moderately weathered and base rich soils (Table 8–2) is significant in primitive agriculture that lacks inputs of industry. Native fertility of these soils is a major factor in supporting production at low rates, but by modern standards the rate of release of nutrients is inadequate for even moderate rates of production.

The 350 million acres of alluvial soils are much more important. These relatively fertile soils of the lowlands along rivers include rice-producing areas of humid tropical Asia and vast areas of unexploited land along rivers of tropical rain forests of South America and Africa.

The acreage of truly recent alluvium is probably greatly exaggerated since soil estimates include older alluvial terraces with weathered, leached soils. Nevertheless, the resources of alluvial soils is large.

The cycle of plant nutrients through vegetation and back to the soil is extremely important in primitive agriculture of the tropics. Forest fallow, whether in unorganized shifting cultivation or in planned rotations, is more effective in the rainy tropics than in other climatic regions where drought reduces its effectiveness. The large amounts of nutrients cycled through forest trees are shown in Table 8–3.

*8.3.1.2 Regions of Humid Seasonal Climates.* With 2½ to 5 dry months, these are regions where vegetation is green during the major part of the year but where most species lose their foliage during the dry season. Most areas were probably once covered by deciduous or

TABLE 8–3.—*Amounts of dry matter and plant nutrients returned to the soil upon cutting vegetation of different ages in different climatic regions* [1]

| Climatic region | Kind and age of fallow | Pounds per acre | | | | |
|---|---|---|---|---|---|---|
| | | Dry matter | Nitrogen | Phosphorus | Kaolin | Calcium and Magnesium |
| Rainy | Forest, 40 years | 300,000 | 1,634 | 112 | 731 | 2,563 |
| | Forest, 18 years | 130,000 | 499 | 65 | 361 | 501 |
| | Forest, 5 years | 78,000 | 349 | 21 | 307 | 2,501 |
| Humid, seasonal | Woodland, virgin | 296,000 | 1,103 | 110 | 851 | 2,180 |
| | Woodland, 6 years | 42,000 | 277 | 24 | 155 | 336 |
| Wet-dry | Woodland, unknown age | 90,000 | ---------- | 45 | 153 | 441 |
| | Savanna, 20 years | 56,000 | 113 | 20 | 171 | 320 |
| | Tall grass | 3,500 | 15 | 5 | 31 | 17 |

[1] Nye, P. H. and Greenland, D. J., 1960. *The soil under shifting cultivation.* Commonwealth Bur. Soils Tech. Commun. 51. Harpenden, England.

dominantly deciduous forests, the dominant species ranging to more than 75 feet high and understories containing mainly woody vines and shrubs with little grass. Most of the area has been subjected to dry-season burning over long periods of time, and a high proportion is now anthropic savanna where tall grasses that are not soil-improvers are prominent.

Temperature, humidity, and cloud cover during the rainy season are similar to those of tropical rainy climates. Moisture is adequate for cropping during the long rainy season. In most areas, dry season crops can be grown with appropriate reduction in crop stand, control of weeds, and other moisture-conserving practices for part, if not all, of the dry season. Annual fluctuations of rainfall are large in absolute magnitude, and length and intensity of the dry season vary somewhat from year to year. However, rarely is the rainy season proper so short that crops fail.

This is the largest climatic region of the tropics, a region of reasonably dependable moisture in which a high proportion of non-irrigated agriculture is concentrated. Probably this is a consequence of at least moderate effectiveness of forest fallow in maintaining soil fertility, coupled with the effectiveness of fire as a tool to control plants that compete with crops.

Table 8–2 shows that about three-fourths of the region has highly weathered and leached soils. They are like the soils of the same group in the rainy climate though large areas of anthropic savanna have lost organic matter. Loss of organic matter also resulted in the physical deterioration of soils and loss of nitrogen.

Moderately weathered and leached soils and base-rich soils occupy greater areas than in regions with rainy climates. As in the rainy

climatic region, higher fertility is highly significant to primitive agriculture. It is less important under modern cultural methods.

The dark-colored base-rich soils are mainly clays which have major physical limitations but high mineral fertility. Some of these soils have high potential for rice production. The large area of alluvial soils in Table 8–2 is probably inflated because older, more highly leached, soils on terraces are included. Nevertheless, the acreage is very large indeed; the area of relatively fertile recent alluvium may rival the combined areas of the principal corn-belt states. Many of the principal rice-producing areas of this climatic zone in tropical Asia are on alluvial soils.

In primitive agriculture shifting cultivation maintains fertility on dominant soils. Table 8–3 illustrates that cycling of nutrients through forest fallow is more effective, though smaller, than in the rainy climate. A very large area has been burned repeatedly, however, and reverts to savanna vegetation when returned to fallow.

Table 8–3 shows the relative cycling ineffectiveness of grasses and shrubs in the wet-dry tropics. The data give a crude though exaggerated impression of ineffectiveness of fallow under anthropic savanna in this region.

*8.3.1.3 Regions of Wet-Dry Climates.* In these regions, generally half of the year is dry. The region supports dry open deciduous woodlands with grass ground cover, open savanna with woody plants in scattered groves within grasslands, or grasslands with scattered woody trees and shrubs.

Trees range to 50 feet in height. Fire, overgrazing, and other effects of man's activities have greatly reduced the number of trees.

The rainy season is long enough and intensive enough for at least one rainy-season crop. While cropping may extend into the dry season, the length of drought is too great for growth of any but drought-tolerant crops throughout the period.

These are regions of drought hazard; both absolute amounts of rain and the times at which the rains begin and end vary from year to year. In some years, only 15 to 25 inches of rain may fall, all in a four-month period.

During the rainy season, cloudiness is somewhat less than in rainy climates, and sunlight energy for photosynthesis is correspondingly greater. Cropping occurs during the rainy season, and grazing is of much greater importance than in more humid climates.

This is the largest region of the India-Pakistan subcontinent and of Africa. It contains much of the "game" areas of the latter. In tropical South America, it comprises 242 million acres—just one-sixth the size of that continent's rainy-climate regions.

Table 8–2 shows that soils of higher base status are major compo-

nents though highly weathered and leached soils cover a greater area than any other kind in this region. Nitrogen is low and in many areas phosphorus is very low, although bases and phosphorus on some soils are more abundant than in wetter climates.

The climate is one of short and uncertain rainy season and is hazardous for cropping without special inputs for conservation of moisture or for irrigation. Alluvial soils are important in these areas and represent a resource especially well-suited to irrigation.

*8.3.1.4 Regions of Dry Climates.* Here, where tropical thorn bush and thorn-bush savanna thrive, drought is the rule rather than the exception. "Short" and "uncertain" describe the rainy season.

It was on the margins of this zone on soils of poor structure that the major British "ground-nut" project failed in Africa in 1949–50. During the first cropping season only 10 inches of rain fell, mainly within a very short period. Normal rainfall is 22 inches.

Cropping during the rainy season is possible but hazardous. Grazing is more common than in more moist regions. In fact, overgrazing often is a serious problem.

The region is very extensive in Africa. It is also important on the India-Pakistan subcontinent where population pressure has forced agriculture into the zone. It is less extensive in South America.

Base-rich soils dominate. The areas of highly weathered and leached soils are mainly on very old land forms; many are relics of former more humid climates. Mineral nutrients are more abundant than in wetter regions, but nitrogen reserves are small. Salt is a problem in some low-lying areas.

Physical soil conditions range widely, but generally soil tilth is a greater problem than in wetter regions. Some soils have physical characteristics that prevent tillage with hand-tools until the rains come, which may then fail before a crop can be planted and matured.

Moisture is the first limiting factor, and without irrigation crop production is extremely hazardous. With irrigation and inputs of industrial products, large areas could be highly productive.

*8.3.1.5 Regions of Semi-Desert and Desert Climates.* Rainfall is not only low but highly uncertain. Vegetative cover ranges from sparse grass cover with thorn bush to barren land. Nomadic grazing is practiced. Cropping without irrigation is highly hazardous. Cloudiness and humidity are low. Diurnal fluctuations of temperature are very great, commonly ranging from 50° to 70° F. from day to night. Daytime temperatures are very high.

The soils are light-colored, rich in bases, low in organic matter and nitrogen reserves. Many in low-lying areas are salty. Important areas could be very productive with water for irrigation and with fertilizers and other products of industry. Many are productive at present as in

the Nile Valley. Without irrigation, the region has very low agricultural potential.

### *8.3.2 Tropical Soils*

In Table 8–2, acreages of broad groups of soils are tabulated by climatic regions. One notes that half of the aggregate area has highly weathered and leached soils inherently low in capacity to supply plant nutrients. These soils are abundant in regions where rainfall is most plentiful for production of crops. High rainfall and stable land surfaces that have not been rejuvenated by geologic erosion contribute to their condition. This is why primitive agriculture is often concentrated on steep land where erosion has removed weathered material or on alluvial soils of the lowlands which are rejuvenated by fresh sediments. The areas of these soils in drier regions mainly are relics of a time when rainfall was more abundant.

In primitive agriculture, alluvial soils and dark-colored base-rich soils have special significance. In climates with adequate rainfall, these two groups have the greatest inherent fertility for exploitation by primitive agriculture with its lack of fertilizers and other modern products. These soils also have high potential for modern agriculture.

Data relating to potential arable land of the different soil groups are summarized in Table 8–4. A total of some 3 billion acres of land is estimated as arable under a technology level equal to that now practiced in the United States.

These rather crude estimates are considered conservative in relation to the physical and biological potentials of the soils. However, they do not take into account the economic inputs necessary for de-

TABLE 8–4.—*Acreage of different soil groups and crude estimates of potentially arable areas*

| Soil Groups | Total area (millions of acres) | Estimates of percentage of land that is potentially arable [1] (percent) | Potentially arable area assuming median estimates (millions of acres) |
|---|---|---|---|
| 1. Light-colored soils base rich | 1,723 | [2] 10–30 | 330 |
| 2. Dark-colored soils base rich (Chernozemic Grumusols, Tendzina, Brown Forest) | 722 | 40–60 | 345 |
| 3. Moderately weathered and leached soils (Non-Calcic Brown, Ando) | 516 | 25–50 | 190 |
| 4. Highly weathered and leached soils (Latosols, Lateritic Row-Yellow Podzolic) | 6,271 | 30–55 | 2,645 |
| 5. Shallow soils & sands | 2,087 | 5–15 | 190 |
| 6. Alluvial soils | 913 | 30–60 | 430 |
| Total | 12,232 | | 4,130 |

[1] Under technology equivalent to that of the United States.
[2] Assumes the application of irrigation water.

velopments such as land clearing, drainage or irrigation, roads, etc.

A brief description of the characteristics of the soil groups listed in Table 8–2 follows:

*Highly-Weathered and Leached Soils.* Dominant soils are deep, friable and permeable to air and water, with some notable exceptions like Ground-Water Laterites. If topography permits, they are easy to till and many are resistant to erosion. Erosion is serious, however, when the soils on bare slopes are subjected to torrential rain.

The organic cycle is a major source of plant nutrients. Primitive cultivators have capitalized on this fact by cropping for only a few years before allowing the soil to return to forest for regeneration.

Accurate data on amounts of nutrients returned to the soil are scarce. One of the most comprehensive studies was done in Ghana and indicates that 10 tons of dry matter, 220 pounds of nitrogen, 12 pounds of phosphorous, 260 pounds of potassium, 200 pounds of calcium, and 60 pounds of magnesium are returned to each acre of soil annually under high forest. This is the primary mechanism by which soil fertility is maintained in a native enviroment.

Table 8–3 lists amounts of dry matter and nutrients returned to the soil after forest fallows of different duration on soils of this group. Typically, much of the dry matter and nitrogen is lost by burning, but mineral nutrients remain in the ash.

Mineral soils are strongly acid and low in macronutrients such as nitrogen, phosphorus and potassium. They also may be deficient in the secondary nutrients, such as calcium, magnesium, and sulfur, as well as micronutrients such as zinc, boron, and molybdenum.

In addition, the phosphorus in these soils is fixed in forms plants cannot exploit rapidly enough for good production. Among the soils of the groups, those derived from basalt have the best physical conditions and greatest nutrient reserves in the mineral fraction. It is common to find the best primitive agriculture on some of the highly-leached and weathered soils that have little potential for modern agriculture.

Ground-Water Laterite occurs where iron from water originating in adjacent higher-lying areas has impregnated a layer at varying depths in the subsoil. When this layer is allowed to dry it becomes cemented irreversibly and effectively prevents penetration of plant roots.

In many places hardened laterite is exposed on land forms that have been elevated by geomorphic processes in the distant past. All degrees of such iron impregnation exist and lower slopes commonly exhibit it to some degree. Other areas are too steep for cultivation with modern machines and if cleared and left bare are subject to serious erosion under torrential rains.

Crude estimates indicate that between one-third and three-fifths of the area of these soils is potentially arable and would be acceptably productive of food crops under agricultural technology equal to that of the United States. Equally crude estimates indicate that about one-fourth to one-half is neither arable with modern technology nor suited to grazing.

Data on present use are not available, but areas not in productive use in South America and Africa are very large (Table 8–5). All but the small area in dry regions is adapted to forests, and much of it is forested at the present time.

*Moderately-Weathered and Leached Soils.* Included in this group are (1) soils of the forest-grassland transition, analogous to non-calcic brown soils, and (2) soils from volcanic ash which have not been depleted of nutrients.

Soils of the first category are by far the most extensive and are present in most of the area shown in Table 8–1 in regions having only two to seven humid months. The volcanic soils, which are sometimes called "Ando" soils, are associated with volcanic mountains, as in parts of the Andean slopes of South America and areas adjacent to the rift valleys in Africa.

Though these soils contain weatherable minerals from which plant nutrients are released slowly, they lack a supply of readily available nutrients adequate to support intensive production without fertilization.

Only Ando soils of the high-rainfall areas have the massive cycle of nutrients through vegetation which is so significant on most of the highly-weathered and leached soils. They are not, however, so likely to be deficient in micronutrients, nor do they fix phosphorous so strongly.

These soils can maintain production at low levels for greater periods of time than can highly weathered and leached soils. For efficient production beyond subsistence levels they require large inputs of fertilizers and other management practices. Most of these soils occur in regions of short and uncertain rainy seasons. Consequently they are hazardous for cropping without special inputs for conservation of moisture or for irrigation. Crude estimates indicate 50 to 70 percent of the aggregate acreage is arable, most of it in Asia and Africa.

*Dark-Colored Base-Rich Soils.* This group includes the chernozemic soils of semi-arid and sub-humid grasslands, the dark tropical clays variously known as Regur, Black Cotton Soil, and Grumusol, and the young Brown Forests soils and Rendzinas on calcareous material in humid regions.

All have the advantage of high base status and relatively high content of other mineral nutrients. Except for the Brown Forest soils,

TABLE 8–5.—*Total acreage by continents of different soil groups in the tropical zone and estimates of the areas potentially arable and potentially available for grazing*

[Millions of acres]

| Soil Groups | Africa | | | Asia | | | Latin America | | | Australia and New Zealand | | | Total | Total arable [1] | Total grazing |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | Arable [1] | Grazing | Total | Arable [1] | Grazing | Total | Arable [1] | Grazing | Total | Arable [1] | Grazing | | | |
| 1. Light-colored soils; base rich | 1,128 | [2] 160 | 300 | 200 | [2] 80 | 40 | 204 | [2] 50 | 80 | 191 | [2] 40 | 50 | 1,723 | [2] 330 | 470 |
| 2. Dark-colored soils; base rich | 267 | 140 | 30 | 134 | 60 | 10 | 260 | 125 | 40 | 61 | 20 | 10 | 722 | 345 | 90 |
| 3. Moderately weathered and leached soils | 40 | 20 | 10 | 211 | 135 | 45 | 197 | 15 | 80 | 68 | 20 | 10 | 516 | 190 | 145 |
| 4. Highly weathered and leached soils | 2,437 | 1,200 | 500 | 1,220 | 270 | 660 | 2,514 | 1,135 | 180 | 100 | 40 | 30 | 6,271 | 2,645 | 1,370 |
| 5. Shallow soils and sands | 1,165 | 90 | 300 | 283 | 30 | 100 | 380 | 40 | 150 | 259 | 30 | 50 | 2,087 | 190 | 600 |
| 6. Alluvial soils | 198 | 105 | 15 | 420 | 285 | 50 | 295 | 40 | 190 | ------- | ------- | ------- | 913 | 430 | 255 |
| Total | 5,235 | 1,715 | 1,155 | 2,468 | 860 | 905 | 3,850 | 1,405 | 720 | 679 | 150 | 150 | 12,232 | 4,130 | 2,930 |

[1] Under technology equivalent to that of the United States.
[2] Assumes application of irrigation water.

they have low nitrogen reserves. The dark tropical clays and chernozemic soils predominantly are in regions where rainfall is concentrated in a two to seven months period and, therefore, they have problems of moisture deficiency. The dark tropical clays, a major part of the acreage tabulated in Table 8–2, are important soils in Africa and India (Table 8–5). They have poor physical conditions but are high in mineral nutrients. In India, the chernozemic soils are of primary importance. For the group as a whole, possibly two-thirds to three-fourths is arable using modern agricultural methods.

*Alluvial Soils.* These are fertile soils on the young sediments of large rivers. Where physical limitations of the environment permit, they are potentially very productive. In tropical Asia, they occur in rice-growing areas of relatively short to long rainy seasons. In South America, they occupy the flood plains of the Amazon, as well as terraces of other rivers predominantly in humid regions. In Africa, they are distributed along rivers in regions of both long and short rainy seasons.

Estimates in Table 8–2 may include acreage in older terraces along rivers. On such terraces soils are weathered and leached. It is impossible to separate these from areas of recent alluvium on the small-scale maps from which estimates were made. Even if soils on recent alluvium were only one-third of the tabulated acreage, they would represent an area greater than the agricultural heartland of the midwestern United States.

*Light-Colored Soils.* These soils have moisture deficiency as a common overriding problem and are relatively rich in mineral nutrients. All are low in nitrogen. Of the 1.7 billion acres tabulated, less than one-fourth would be arable if water were supplied. Approximately one-third of the acreage has grazing potential though it is non-arable.

*Shallow Soils and Dry Sands.* The shallow soils and dry sands are mainly non-arable. They are either too shallow to bedrock or too sandy for cropping. The sands are mainly in the regions having low rainfall; the shallow soils occur under all climatic conditions and most are steep as well as shallow. Some of these areas have limited grazing potential.

### *8.4.0. Agricultural Systems in the Tropics*

Most systems of cropping tropical soils have evolved through centuries of trial and error by native cultivators. In general, they involve minimum inputs from outside the immediate area in which the cultivator lives.

A brief consideration of several agricultural management systems follows. Because of the size of tropical areas and their variability, the systems have many variations.

### *8.4.1 Shifting Cultivation*

The term "shifting cultivation," which has scores of synonyms, refers to the practice of cutting trees and other plants, burning them, growing crops for one to about five years, and allowing a natural cover to return for five to 12 years to regenerate the soil. Centuries ago, most farmers in northern Europe followed this system which is still used in tropical areas.

Under heavy rainfall, soils are leached of plant nutrients not tied up in vegetation and animals. Large forest trees immobilize greater amounts of nutrients per acre than do grasses, and trees capture dust from the air. Thus tropical soils under forest normally are more fertile than those under savanna.[1, 2]

Nutrients captured by the plants are kept within the biological cycle: soil, plants, animals, and back to the soil. When they are released from decomposing plant remains, the live roots take them up.

A system of shifting cultivation has the following advantages:

(1) Ashes and products of decomposed organic matter release nutrients and enrich the soil. Among wild plants, some are much higher in nitrogen, calcium, phosphorus, and similar plant nutrients than others.

(2) Wild vegetation reduces common weed invaders and interrupts the generation cycles of insects and diseases that harm crops.

(3) The roots of growing trees stir the soil, and the canopy protects it from direct sun and beating rain. Microorganisms and small animals that decompose organic matter are stimulated. These effects make the soil porous.

(4) Fire kills harmful organisms in the soil and destroys diseases and weeds. It also temporarily loosens the soil. The potential of tropical soils for crop production cannot be discerned from looking only at wild vegetation. More and different nutrients are required by crop plants than by wild ones.

Fallow trees and shrubs differ widely in chemical composition and so do the soils. Thus, combinations of these effects vary greatly among soils.

A scheme for seeding the fallow area with trees and shrubs that are best for the soil gives better results than simply allowing the whole mixture of trees to regrow when the land is abandoned.

In Assam, cultivators of tropical soils under high rainfall use a special system of shifting cultivation with a short fallow cycle, which makes good maize and potato crops possible. Logs, branches, and other

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[1] Nye, P. H. and Greenland, D. J. *The soil under shifting cultivation.* 156 pp. illus. Tech. Communication No. 51. Commonwealth Bureau of Soils. Harpenden, England. 1960.

[2] Jurion, F. and Henry, J. *De l'Agriculture itinerante a l'Agriculture intensifiée.* Institut National pour l'Etude Agronomique du Congo (INEAC) (Hors série). Bruxelles 5, 1, rue Defacza. (In press.)

plant material are brought in from steep slopes or other uncultivatable places and placed on the soil surface in beds about 3 feet wide and 12 to 50 feet long.

The woody mass is then covered with thin sods from between the beds just before firing. After the fire the beds are smoothed. Compost may be mixed with the surface soil. Commonly, the beds are laid up and down slopes as steep as 65 percent. There is some washing but little highly destructive erosion.

In some of the areas where this procedure is used increased population has necessitated shortening of the fallow period of the cycle. This process is making soils so unproductive that cultivators are forced into even more remote places.

Prospects for gradual improvement are excellent provided local markets can be developed and appropriate fertilizers and plant varieties made available.

In regions with plentiful land, such as central Africa, fields are laid out in corridors about 500 to 700 feet wide which may be one or more miles long. They are arranged to get maximum solar exposure. On hilly areas they are laid out roughly on the contour.

With very good soil, five corridors could be in some stage of cropping while one is being cut and 10 to 12 are under regenerating forest. It is disastrous to this system to overlengthen the crop cycle where there is any dry season because coarse savanna grasses come in. Cultivators cannot eradicate them with their tools and the savanna burns each year.

*Possible Improvements of Shifting Cultivation.* Certainly the system could be greatly improved through the use of fertilizers provided research and testing reveals which ones should be used for various kinds of soil. The best mixtures will probably not be those most common in temperate regions.

Some tropical soils are high fixers of added phosphatic fertilizers. In these kinds especially, practical ways of using applications in the immediate proximity of the roots must be found to keep the amount required to a minimum. Large pellets of mixed fertilizer placed a bit below and to one side of the seed may be best.

The question has been asked of why fertilizers cannot be used to eliminate the need for natural fallow. Many millions of shifting cultivators have no money to buy fertilizers which are expensive and far from the main centers, and there is no transportation system to carry them to the villages. For many villagers, all transport is by head or back over miles of hilly footpaths. More important is the fact that little is known about many of the soils used by shifting cultivators. To advise such people to use a specific kind of fertilizer is to gamble with their limited means.

A great deal can be done to supplement the natural fallow and mixed plantings with compost, manures, and wood ashes. Here again, much depends on the kinds of soil and plants. Coconuts, for example, respond greatly to wood ashes whereas some other crops do not.

### *8.4.2. Mixed Tree Crops*

As emphasized earlier, many soils in the tropics and subtropics should not be clean-cleared and plowed. Some steeply sloping ones will erode, and others are underlain with doughy laterite that becomes irreversibly hardened on direct exposure to rain and sun.

Stability in moist tropical forests usually is achieved by natural dispersal of one plant species among numerous individuals of other species so that all are reasonably well-protected from disease and insect epidemics. Soil structure is maintained in a productive state by the ameliorating influences of shade, microclimate, root systems, and leaf fall on the soil complex. In mixed tree culture, clearings are made in the forest and a mixture of crops grown in them such as bananas, oil palm, cassava, and maize. Some of the forest trees can be gradually replaced with nut and fruit trees. The natural shrub layer is often replaced with cacao or coffee. As with shifting cultivation, mixed tree cultures can be improved with fertilizers, plant selection, and pest control.

Some Ground-Water Laterite soils are so thin over the doughy laterite that they harden after the trees are removed even without erosion to make the soil effectively thinner. There are beautiful mixed tree cultures along the Malabar Coast of India on Ground-Water Laterite soils that have been used for many hundreds of years. Somehow the people learned that these soils should not be exposed by clean-clearing.

Forests can be thinned gradually and the trees replaced with food and industrial crops. Large areas in the tropics and subtropics can be gradually changed from forests to mixed cultures without clean-clearing to avoid exposing soil to sun and rain for even a year. In Ghana, two-thirds of the canopy of the original forest has been replaced by a shrub layer of cacao.

With fertilizers, water control, and other modern management practices, there are soils that should be clean-cleared prior to developing cacao plantations. But there are others where this is not practicable. Both rubber and oil-palm plantings have been started under about one-half canopy. Then gradually the whole forest is replaced. Also, bananas and abaca can be grown successfully under one-fourth to one-half canopy. The determination of mixed cultures best suited to different soils and climates is a promising aspect of research and testing for improvements in tropical farming practice.

### *8.4.3 Flood Farming*

According to Popenoe[3] flood farming is successful in the wet tropics where rivers carry great volumes of sediments. "Many rice fields in Asia have been continuously farmed for centuries with little or no input of nutrients in the form of fertilizer." The blue-green algae in the water seem to fix the requisite amount of nitrogen. Rotation of flooded rice with dry land farming is popular in areas of tropical Asia where there is a long dry season.

### *8.4.4 Livestock Enterprises*

Popenoe also cites a method of livestock farming commonly used in Africa called "foraging for fertility". During the day, cattle are allowed to forage on range lands. At night they are penned in a small corral and each morning manure is collected for intensive food-crop gardens.

Minor element deficiencies in pastures on leached soils are important A high proportion of the animal health problems of the tropics have been attributed to minor element deficiencies. Often these are corrected by adding supplements to the animals' diet. An important limitation of livestock production in tropical areas is the lack of refrigeration or other storage and processing facilities.

### *8.4.5 Consolidation of Fragmented Holdings*

In many crowded countries individual farm families with five to six acres have their holdings in several scattered tiny parcels because of inheritance and marriage dowries. Modern productive systems of farming, especially those requiring water control, are practically impossible under these conditions. This problem is being solved in western Europe by consolidating areas of these parcels in to single individual farms in accordance with the number of acres held by each family and their productivity.[4]

The European experience serves only as a general guide in tropical villages with contrasting kinds of soil. There individual parcels are being consolidated into two or three separate holdings rather than one. This is done according to contrasting groups of similar soils. Only one may be suitable for cultivated plants.

A technical service, including a basic soil survey, is necessary in large parts of India and other Asian countries. It is needed to bring about orderly consolidation of the tiny parcels in order to lay out water control systems, terraces, irrigation lines, and drainageways.

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[3] Popenoe, Hugh (Director, Center for Tropical Agriculture, University of Florida, Gainesville). The humid tropics—potentials and problems. Reunion Internacional Sobre Problemas de la Agricultura en los Tropicos Humedos de America Latina 22 dy mayo, 1966 (Lima)—7 junio, 1966.

[4] Binns, Sir Bernard O. The consolidation of fragmented agricultural holdings. FAO Agricultural Studies No. 11. 99 pp. illus. 1950.

Cultivators on many millions of acres of unirrigated soil can increase yields tremendously with a proper system of terraces at slight angles to the contour which provides optimum penetration and storage of water in soil during monsoons for cropping during the following months. Terraces around the individual parcels are ineffective and even damaging because concentrated water can cause ponding or erosion.

An excellent example of the benefits of terracing can be seen in the village of Mawdika near Hazaribagh in India. Part of the village lands consist of gently sloping, good-quality soils. Other areas are hilly and dissected, suitable only for growing coarse grasses to be cut by hand. A system of terraces was constructed on the good soils at slight angles to the contour. Excess water escapes through a grassed waterway into a stream. When the project was finished, individual cultivators had a consolidated tract bounded by terraces on the upper and lower side and another tract of rough land. These improvements alone doubled yields. With better varieties, proper fertilization, and improved pest control, production could be expected to be at least five times the original.

Unless terraces are laid out properly, no benefit can be expected. Effective land consolidation involves social as well as engineering problems. It must be done on the basis of soil surveys in which both technicians and farmers have confidence. The villagers must be assured they will not lose equity in the process. Some of their previous experiences with ideas brought in from outside have made many of them highly suspicious. The job can be done, and in many thousands of villages it must be done before significant benefits can be expected from fertilizers, improved varieties, and pest control. Otherwise water will remain a limiting factor in the essential combination for success.

### *8.4.6 Plantation Cropping* [5]

Crops like bananas, sugarcane, fibers, cacao, rubber, coffee, and other crops are grown in large holdings in many places under a single administrative unit. Such organizations have potential for full application of modern technology with economies of scale. They require a high level of managerial skills and business acumen. The most successful units have research arms which seek combinations of practices to increase economic yield.

Commercial plantations under a single or corporate ownership normally require a large labor force. Although many follow enlightened labor policies, usually there is a sensitive social and political situation to contend with. Often local or government-owned plantations follow exploitive policies. Some countries have developed plantations under

[5] Grobman, Alexander. "Cropping Patterns in the Humid Tropics". Cornell Latin American Year Conference on the Hot Humid Tropics. 1965.

government administration and management with small holders who own individual parcels of land in the plantation. Only limited success has been attained under this system in very few countries. Probably the most successful of these are the small-holder rubber plantations in Malaysia and sugar plantations in Queensland.

The development of producer and marketing cooperatives is another approach to plantation agriculture. These have had only limited success for a variety of reasons. Lack of trained managers and administrators is a big handicap. The reluctance of many governments to permit a grassroots cooperative movement to develop is a serious limiting factor. Also, farmers themselves are suspicious of cooperatives because too often they have been imposed on them from the top with negative results.

### *8.4.7 Nomadic Gathering*

This is a simple exploitation of natural plant resources rather than a cropping system. However, it is practiced on extensive areas. In Latin America, it has not reached the degree of exploitation that it has in some African countries, but it is important on both continents. Rubber collected by nomadic gathering produced 25,000 metric tons in the Amazon basin in 1962. Brazil nuts are gathered in Brazil, Bolivia, and Peru in amounts exceeding 55,000 metric tons. Chicle, palm oil and waxes are also collected nomadically.

## *8.5.0 Potentials for Tropical Areas*

Judgments of the agricultural potential of tropical areas are as varied as backgrounds of those who appraise it. They range from dismal pessimism to strong optimism. Typically, pessimistic viewpoints are documented by records of actual performance including failures of educated people with capital resources. Also cited are ineffectual struggles of peasant farmers against physical, biological, economic, and political forces beyond their control.

Most commonly, optimistic projections cite tremendous basic resources of sunlight energy, water, and soil and what has been done on tropical soils used by people having full access to science and industry. They argue that human intelligence can find a way to harness the natural resources in the face of admittedly monumental obstacles as man has done elsewhere.

It cannot be denied that basic physical resources for crop and animal production exist. Available sunlight energy for plant growth in the humid tropics varies from perhaps 1.6 to 1.9 times that of humid temperature regions. These values fully discount offsetting effects of high incidence of cloudiness in the humid tropics as well as seasonal limitations modified by day-length in temperate regions. The high production of sugarcane in Hawaii and Queensland, rice in Taiwan and

Australia, African oil palm in places in the Belgian Congo and Indonesia are just a few examples of yields that can be obtained.

As illustrated in Table 8–1, there are 2.9 billion acres on which rainfall is generally a limiting factor in only one or two months of the year. Rainfall is adequate for good crop production for five to 10 months of the year on an additional 6 billion acres.

Most of the arable land in the rainy, humid summer and wet-dry regions has fair to excellent physical properties but is low in plant nutrient reserves, including micronutrients.[6] Most of it also has the capacity to fix some nutrients, such as phosphorus, in forms unavailable to plants. Experiments have shown that fertilization in combination with other needed practices gives good response of crops on these soils.

It is known that no single practice, such as fertilization, is effective even on farms of Europeans in the Rhodesias.[7] The average yields of corn for this region failed to reach 1,500 pounds (27 bushels) per acre prior to 1950 although fertilizers were used. Since 1955 the average yield of all farms in the area has increased sharply. In 1961, they reached 3,000 pounds (53 bushels) per acre without irrigation. (Experimental plots have yielded 10,000 pounds per acre.) This is not an isolated example on special soil resources but a massive improvement by many farmers on soils that are weathered and leached. It parallels the steady upward trend of rice yields in Japan since the 1880's and of crops in the United States since 1935.

Such improvements are accomplished by putting together many practices in combinations that complement each other. In Rhodesia, the improvement involved development of corn varieties not only for high yield but also for disease resistance, resistance to lodging, and capacity to respond to fertilization. It encompassed improved fertilization practices, including not only the macronutrients but also the micronutrients and placement, timing, and nutrient balance. It involved liming, which had previously been neglected and the careful return of crop residues to the soil for maintenance of physical conditions. It included weed control, insect control, and disease control as well as tillage, timeliness of operations and other practices.

This development of sets of practices appears to be the biological key to exploitation of physical resources which are undeniably present. It is the knowledge of how to put such sets together for tropical conditions that is lacking in the strictly biological aspects of increasing production, not the basic principles of biology. Beyond this are the

[6] An estimate by Kellogg in 1964 placed the total arable land of Latosols and red-yellow Podzolic soils at 2.8 billion acres and new arable land in the tropics at more than 1.0 billion acres.

[7] Von Burkesroda, K. W. 1964. Fertilizing maize in Rhodesia. Potash Review, December 1964. Subject 9. Cereals. 12 Suite.

263–888 O—67——33

enormous problems of economics, sociology, and education that must be solved before people will be able to apply that which is known.

Access to products of industry is an overwhelming problem. Without these products, production cannot increase significantly. Nevertheless, the potential for enormously increased production is present in the tropics. Ultimately it is the will of the government and its people to develop policies and mobilize its resources and energies for agricultural production which will determine how much of this potential can be realized. If other economic activities are developed along with farming, all can share in the cost of services.

### *8.5.1 Theoretical Potentials in Tropical Food Production*

Prior to the current century, many successful systems of obtaining food were developed in the tropics in which man utilized the natural processes as much as possible. In such systems there was an equilibrium of populations brought about by a stable cycle of the nutrients essential for life. The natural environmental components or systems of domesticated animals did much of the work of planting seeds, maintaining soil structure, preventing epidemic insects and disease, eliminating limiting factors, gathering food products, and injecting protein supply, often converting as much solar energy into biological production as has been recorded for natural systems. The energy going into the work processes for each of these services is to maintain stability, i.e., reduce the fluctuations caused by natural changes in the environment.

Net yields to man, however, were relatively small since much of the solar energy converted went into the necessary support of the natural system and animals.

In contrast, large energy supplements of fossil fuel (or other outside energy such as hydroelectric or nuclear power) are needed in modern industralized agriculture to replace the natural support system. The energy from fossil fuels is used to till the soil, plant seeds, and move produce and inputs to and from the farm.

Such intensified agriculture requires an intimate input-output relation to an intensified industrial culture. This permits the purchase of insecticides, herbicides, work and machinery, means for storage of produce without spoilage or decay, and means for market export and import of parts and materials from the industrial sector. New varieties of plants and animals must be bred and adapted to take advantage of the new services.

With the work done by the subsidy from outside fuel, more captured solar energy may be routed directly into food rather than into work processes that maintain stability in natural systems. Where industrial means are available, intensified agriculture can displace natural systems because there is adequate extra energy to produce higher net

yields. Without the inputs from industrialized culture, such systems cannot succeed, and if it is attempted, the workable older systems may be disrupted or destroyed.

The danger of such system disorganization is particularly great in tropical areas where some of the older systems are highly complex because some of the soils quickly deteriorate when the support system is altered and because the full availability of industrialized input-output resources is often remote. The cultivator in the tropics is dealing with a system of many parts each of which affects the others.[8]

The complex energy networks in natural systems (see Volume III, Energetics of World Food Production) show the need for planning whole workable systems if one is to use a technologically advanced form of agriculture in the tropics. One should not tamper with system parts or inputs without providing compensating return flows that produce positive and complete loops. There may be opportunities to upgrade existing tropical systems by using fossil fuels to overcome limiting factors that are not achieved in natural systems. These need to be added gradually so as to evolve continually workable systems.

### *8.5.2 Irrigated Soils*

The potential is enormous in the tropics for expansion of cultivated soils through water control and irrigation on both presently used and unused soils. At present, about 4 million acres are under irrigation in Africa south of the Sahara and 8 million acres in northern and northwestern Africa. The whole continent has a potential of about 36 million acres, about the same as irrigated acreage in the United States in 1964.[9]

In South America about 12 million acres are irrigated out of a total of about 189 million acres of arable land. Many of the countries have good potential for expansion of irrigated soils. Peru, Chile, Brazil, and Bolivia have a number of irrigation projects either being developed or planned. For the continent as a whole an additional 10 to 20 million acres might be economically feasible to irrigate during the next decade.

In Asia there also are excellent possibilities for increasing the amount of land under irrigation. In India there are about 60 million acres under irrigation, about 20 percent of the total cultivated area. The long-term objective of India's planners is to bring about 175 million acres under irrigation. Similar possibilities exist in Pakistan. The Brahmaputra-Ganges-Meghna River complex has the potential

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[8] Kellogg, Charles E. Interactions in Agricultural Development. In "Science, Technology, and Development"—U.S. papers prepared for the UN Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas. Geneva. 1963. Vol. III, "Agriculture: pp. 12–24, U.S. Government Printing Office, Washington, D.C.

[9] Greenshields, Elco L. Waste has a key role. In Farmer's World USDA Yearbook of Agriculture. pp. 75–96. 1964.

for irrigation of many millions of acres. Admittedly there are many major engineering problems in addition to the social and political difficulties involved, but the potential exists.

The Mekong River Multination project in southeast Asia is a promising development. Flood control and irrigation and drainage works now are under construction and in the planning stages. Ultimately, the acreage of rice under controlled irrigation will be doubled. To this are added possibilities of double-cropping hundreds of thousands of acres now only single-cropped with an uncertain water supply.

### *8.5.3 The Principle of the Inter-Continent Transplant*

In the tropical forest system, stability is apparently provided through competition and other interactions among herbivores, carnivores, fungi, and insects that keep the population level of each species regulated so that not too many of any one species survive. Consumers and diseases thus play a role in maintaining stability under natural conditions.

Any attempt to form plantations with a native species is likely to disrupt the mechanisms operating in nature to keep all species regulated at safe low levels; in other words, stability is destroyed. Efforts to develop Brazilian plantations with Brazilian rubber trees have resulted in epidemic diseases, destruction and financial disaster.

Species, separated from their natural enemies, often grow phenomenally well when completely removed from the continent where they were part of a stable system. Brazilian rubber has done better in Africa and Asia than in Brazil. Monterrey pine grows vastly better in Australia than in its native California but eucalyptus do just the reverse. They grow better in California than in their native Australia.

A search for better yielding varieties might be guided by the principal of inter-continent transplantation. The possibility of areas for transplant could be identified from a world soil map of about 1:2,500,000 scale with a uniform legend.

### *8.5.4 The Semi-Domestication of a System of Tropical Ruminants*

Harnessing natural animal herds of Africa has been suggested as a system that would be preferable to importing traditional domestic herds. A system of several game animals based on a moderate amount of diversity in feeding habits might provide a system that would be ideally suited where full energies for protection and intensified care are lacking. It may ultimately lead to an intensified agriculture based on genetic modification of these species.

The stocks of the African range certainly are high, resembling the systems of the sea more than the usually low populations of animals of most terrestrial systems. These species carry their microbial symbionts, necessary to convert plant yields into multi-nutritious mixtures

of food that enable these animals to produce meat. (See Chapter 4 for additional discussion on wild animals.)

*8.5.5 Some Tropical Experiences*

Dramatic examples of failures and successes of agricultural programs in the tropics can well serve as object lessons. A few are cited below.[10] The British "Groundnut Schemes" were a dramatic failure in the savanna of Tanganyika. The project, begun shortly after World War II, was designed to provide the United Kingdom with edible fats and oils which were in short supply. The plan involved complete mechanization of the operation from clearing the land to harvesting the peanuts from hundreds of thousands of acres at several different centers. After several years and $100 million expended, the project was liquidated as a failure. What went wrong? Many factors contributed to the disaster but a few stand out. In the first place the overall planning proved woefully inadequate. Neither the soils nor the climate were suitable for the crop. The unprotected soil washed badly during the rainy season exposing subsoil layers having poor structure. Clearing trees and shrubs was much more costly than anticipated, especially removing the roots for mechanized cultivation. Basically, it was a lack of understanding of the important factors that needed to be considered in a crop production and marketing program.

A year or two after the British had their troubles in Tanganyika, the French proceeded to make similar mistakes in a peanut project in the Casamance Valley in Senegal. Here again, the idea was a mechanized operation in which American equipment and methods developed for Virginia were used on some 75,000 acres of wooded savanna. The clearing operation and deep plowing exposed subsoil which had poor structure and was relatively infertile. The tree roots which remained after clearing caused problems in mechanical cultivation.

In contrast to the failure of the peanut projects, the intensive Gezira irrigation project in the Sudan is a success story.[11] This project, planned early in this century, was launched as a three-way partnership of the government of the Sudan (then British controlled), a private company that provided management and some financing, and the farmers. It was preceded by research and pilot projects. At the present time, Gezira has some 70,000 settlers on 1.8 million acres. The entire cost of the scheme has been paid from the cotton that was produced; the food and fodder crops belong to the settlers.

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[10] Numerous examples of successes and failures of agricultural projects in Africa are found in "False Start in Africa". Rene Dumont, Translated to English by Phyllis Nauts Ott. Frederick A. Praeger, N.Y., 1966.

[11] Policies for Promoting Agricultural Development. A report of a Conference on Productivity and Innovation in Agriculture in the Underdeveloped Countries. David Hapgood, Editor, and Max F. Millikan, Conference Chairman. Published by the Center for International Studies, Massachusetts Institute of Technology. 1965.

In the development of this project, some of the important factors taken into account were:

1. An area with the greatest potential for development was selected.
2. The economic objective was evaluated and given priority.
3. The inclusion of private enterprise, capital and management filled a crucial gap in capital needs and provided incentives.
4. Experimentation with pilot schemes preceded actual dam construction. This provided the technical knowledge on methods of production and served to convert the farmers to the project.
5. The scheme was made as simple as possible. Of the three crops grown by the settlers, two (the food and fodder crops) were already grown in the area. The fact that only the cash crop, long staple cotton, was new to the farmers reduced the burden of innovation. It was known that there was a ready market for this cash crop.
6. The social controls imposed on the settlers were designed to protect them against antisocial actions but not to suppress individual initiative. The controls consisted of the planned family holding, tenancy rather than ownership, prescribed rotation, and a prohibition on mortgage and fragmentation. Organized services such as research station, seed farm, fertilizers, pesticides, machinery for cultivation and pest control, and supervised credit and marketing made it easier for the individual to obtain maximum returns. Nonetheless each settler's returns depended on his own initiative and effort.
7. The elimination of landlord control and land speculation prevented the scheme from benefiting only a few.

The early experiences of the Belgian agricultural scientists in the Congo are of interest. When they first arrived in the 1920's, they were shocked to find the primitive "Bantu system" (shifting cultivation) based on polyculture, a short period under crops and a long-term fallow. It seemed logical to them that to improve yields, the "Bantu system" had to be completely modified. At several experiment stations, they performed experiments based on European techniques. They cleared all stumps, deep plowed, introduced short-term grass or legumes in crop rotations, and used commercial fertilizers. But these European practices failed because they were not adapted to the local conditions.

After the failure of these "modern" techniques, the research center at Yangambi reconsidered the "Bantu system" which alone seemed to protect and regenerate the soils. The subsequent research over a period of 20 years concentrated on making improvements in the native system of shifting cultivation: systematizing the long time rotation

through a corridor system, and introducing in the crop rotation perennial cash crops such as oil palm, cocoa, coffee, and rubber. Field studies were initiated to introduce intensive cultural practices such as the use of mechanical equipment for some of the operations, green manures and chemical fertilizers. Unfortunately, this work stopped prematurely when the Belgian Congo became independent and the Belgians left.

In the Lake Aloatra area of north-central Madagascar there is an excellent example of what can be done with suitable agricultural practices. For years, a French company on 1,500 acres of lowlands has produced an average of over 2 tons of rice per acre which is more than double the yield on adjacent soils. Success is attributed to good water management, use of improved seed, control of insects and diseases and, probably most important, weed control. Though some fertilizer is used, experience has shown that this is of secondary importance in this particular area.

What can be done by small land holders is well illustrated in Taiwan. Production of rice has increased nearly 50 percent during the past 10 years. Most of the increase is from higher yields which have moved from about 2 tons per acre to 3 tons per acre. Supplementary crops are also produced on a substantial portion of the same land. Use of improved seeds, fertilizers, pest controls, better agricultural tools and equipment, improved land tenure, and price incentives have contributed to the Taiwan success story. An example of an important industrial contribution in technical assistance is provided by the Shell Italiana experiment in rural extension and development which was begun in 1953 in a rural commune of 16 villages and 8,000 people in a mountainous part of Tuscany. The problems were those characteristic of subsistence farmers everywhere: smallness of farms; acute land fragmentation; limited technical knowledge; lack of roads; and shortage of capital. In the first 10 years the total net farming income increased 154 percent. These methods and principles demonstrated at Borgo a Mozzano have been adopted on about 20 percent of Italy's agricultural land, and Shell has welcomed recent cooperation with the University of Florence and FAO. By 1966, 204 agronomists from 59 countries and 300 Italian rural extension specialists had attended courses at the training center at Borgo.

### *8.5.6 Tropical Forest Potentials*

Information on the potential productivity of tropical forests is fragmentary despite the fact that the tropics include half of the world's forested area (Table 8–6).

Only one-sixth of the forests are now being exploited although nearly half of the total area of tropical forest is rated as accessible. The currently unmanaged and unexploited tropical forests provide a

TABLE 8–6.—*World forest area by regions, 1958* [1]

[Million acres]

| Region | Total | Accessible forests | Forest area in use |
|---|---|---|---|
| Tropical | 5,059 | 2,084 | 843 |
| Subtropical [2] | 620 | 467 | 180 |
| Temperate [3] | 4,956 | 4,127 | 2,457 |
| Total | 10,635 | 6,678 | 3,480 |

[1] Exclusive of Mainland China and Mongolia which have a total forest area of 190 and 62 million acres, respectively.

[2] North Africa, South Africa, Turkey, Near East, Japan, Korea, Mexico, Argentina, Chile, Uruguay, Australia, New Zealand.

[3] North America, Europe, and U.S.S.R.

tremendous reservoir for wood in the future despite the present lack of adequate technology, transportation, markets and information on productivity. Estimates of current and potential productivity of tropical forests are complicated by the lack of data on productivity and the uncertain status of land-use on the readily accessible and highly productive tropical forest land.

Rural populations are invading forested land for cultivation of crops. Lands which will be more productive for either food or forage production will eventually be eliminated as permanent sources of forest products. Need for food and forage-producing lands is expected to account for at least 1 billion acres of the 2 billion acres of accessible tropical forest. As transportation networks develop in the tropics, this shift in land use may be partially offset by improved accessibility to the 3 billion acres of currently inaccessible forest land.

The productivity rates of tropical forests are given in Table 8–7. These could be documented by an impressive list of literature citations but this is not considered necessary nor appropriate here.

Estimates of mean annual increment in cubic feet per acre for the eight land categories used in Table 8–7 are those that might be reached over large areas. Estimates of current productivity are based on an admittedly subjective blend of research results, reported mass experience, and crude estimates found in the literature from Africa, South America, India, Malaya, Australia, New Zealand, Borneo, Indonesia, and the Philippines. Technology, levels of forest management and markets available in the tropics were considered in these values.

The estimated ranges are conservative. The lower end of the scale represents a reasonable level of exploitation and a rudimentary level of forest management. It does not include unexploited tropical forests in which growth is being offset by mortality. The upper end of the range is based on yields achieved under a high level of exploitation and

TABLE 8–7.—*Tropical forest productivity*

[Mean annual increment—cubic feet per acre]

| Land category | Current productivity | | Potential productivity—realizable maxima under management |
|---|---|---|---|
| | Mean | Range | |
| A. Wet tropics: | | | |
| 1. With 2- to 4-month dry season | 40 | 20–80 | 100–200 |
| 2. With no dry season | 50 | 30–100 | 150–300 |
| B. High tropics: | | | |
| 1. Cloud forest | 5 | 0–10 | 15–25 |
| 2. Intermediate elevation | 35 | 15–60 | 70–150 |
| 3. Alto plano | 0 | ---------- | 0 |
| C. Dry tropics: | | | |
| 1. Desert | 0 | ---------- | 0 |
| 2. Short and intermediate grasses | 0 | ---------- | 0 |
| 3. Dry woodlands and savanna | 10 | 0–20 | 20–40 |

good forest management. Intensively managed tropical forests are in Malaya, Nigeria, Trinidad, India, North Queensland, and Puerto Rico. The upper end of the scale on the range of productivity values does not include the well-documented but isolated successes reported on rain forest sites with certain *Pinus*, *Araucaria*, and *Eucalyptus* spp. in intensively managed plantations.

George Bauer's 1964 Unasylva article reports increments of 200 to 600 cubic feet per acre for these plantations but says, "It seems that the absolute maximum production from most rain forest species is about 150 cubic feet per acre per year, and on a routine scale in managed forest about a third of this is all that can be hoped for." Twenty-two pages later in the same issue, a note from Indonesia reports annual increments for *Albizzia falcata* of 1,400 to 2,000 cubic feet per acre.

Ranges of realizable maxima shown for potential productivity (Table 8–7) assumes a level of technology, level of forest management, and level of exploitation and markets comparable to those in the most intensively managed forests of Australia, New Zealand, South Africa, and the southern United States. The realizable maxima probably are not more than one-fourth to one-half of the theoretical biological maxima. They are, however, near the borderline of remote probability and bare possibility.

The timetable for reaching the levels of productivity shown as realizable maxima will be determined by the broader timetable for a general upgrading of technology, transportation systems and the entire rural economics of tropical countries.

The probable shift of forest production to sites now classed as inferior in either inherent productivity or in accessibility has important implications for kinds of forests needed and for appropriate forest

management practices. Greatly increased yields as opposed to simple increases in exploitation, cannot be realized from the naturally developed forests of the tropics. The species composition must be simplified to include only those species of potential utility and amenability to management.

Despite dangers of insects, diseases, and site maintenance problems, natural forests must be partially replaced by forest plantations, if they are to be utilized commercially. Too many of the "natural" forests cannot produce yields that are profitable economically in spite of their great ecological success.

Widespread use of planted stands may depend on the successful use of taungya, the system of shifting agriculture now used and misused in Africa and Asia. The agricultural aspect of taungya probably will govern its applicability.

West Africa can support 2.5 adults and 4 children per acre of taungya. Some conditions for successful taungya are land hungers; stable soil suited for agriculture; nearby population that can adapt its farming methods; a fast-growing and useful tree species capable of early site dominance; and finally, a well-trained administrative staff. Without taungya the costs of clearing and planting may be prohibitive.

# CHAPTER 9

# PRODUCTION INCENTIVES FOR FARMERS

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## Contents

| | | Page |
|---|---|---|
| 9.1.0 | Summary | 504 |
| 9.2.0 | Introduction | 506 |
| 9.2.1 | Production Incentives in Perspective | 506 |
| 9.2.2 | The Semi-Commercial Production of Food Grains | 507 |
| 9.2.3 | Factors Influencing Farmers' Incentives | 508 |
| 9.2.3.1 | Influences Are Many, but Decisions Are Single | 508 |
| 9.2.3.2 | Three Sources of Influences on Production Incentives | 509 |
| 9.2.4 | Side-Effects of Efforts To Influence Farmers' Incentives | 510 |
| 9.3.0 | The Nature and Impact of General Cultural and Political Influences | 512 |
| 9.3.1 | Some Aspects of Low-Technology Cultures | 512 |
| 9.3.1.1 | Traditions and Values | 512 |
| 9.3.1.2 | Social Organizations | 513 |
| 9.3.1.3 | Legitimation is Local and Personal | 513 |
| 9.3.1.4 | Pervasive General Influences | 513 |
| 9.3.1.5 | Influences Having Specific Impact | 514 |
| 9.3.2 | Land Ownership and Tenure | 514 |
| 9.3.2.1 | Major Types of Land Ownership and Tenure | 515 |
| 9.3.2.1.1 | Tribal or Communal Tenure | 515 |
| 9.3.2.1.2 | Feudal and Semi-Feudal Tenures | 516 |
| 9.3.2.1.3 | Share Rental of Land | 516 |
| 9.3.2.1.4 | Cash Rental of Land | 517 |
| 9.3.2.1.5 | Owner-Operatorship | 517 |
| 9.3.2.1.6 | Socialist Forms of Land Tenure | 518 |

Page

9.3.2.2 Tenure Systems' Influence on Agricultural Productivity ..... 518
9.3.2.2.1 Distribution of Political Power ..... 518
9.3.2.2.2 Effect on Current Production Decisions ..... 519
9.3.2.2.3 Incentives to Invest ..... 519
9.3.2.2.4 Concentration or Dispersion of Decision Making ..... 519
9.3.3 Conclusions ..... 519
9.4.0 The Influence of Production Opportunities on Incentives ..... 521
9.4.1 Markets for Farm Products ..... 521
9.4.2 Farm Supplies and Equipment Embodying New Technology ..... 522
9.4.3 Transportation Facilities ..... 522
9.4.4 Production Credit ..... 522
9.4.5 Irrigation Water ..... 522
9.4.6 Attractive Consumer Goods ..... 523
9.5.0 Programs Undertaken Specifically to Influence Production Incentives of Farmers ..... 523
9.5.1 Price Incentives ..... 523
9.5.1.1 Introduction ..... 523
9.5.1.1.1 Traditional Thinking about Peasants' Price Responsiveness ..... 524
9.5.1.1.2 Peasants' Price Responsiveness in Perspective ..... 524
9.5.1.1.3 Unsound Price Policies ..... 525
9.5.1.1.4 Need for Research ..... 526
9.5.1.2 Farmers' Response to Price Incentives ..... 526
9.5.1.2.1 Changes in Prices of Individual Crops ..... 526
9.5.1.2.2 Response of Aggregate Output to Price ..... 528
9.5.1.2.3 Price Effects on Marketed Surplus ..... 529
9.5.1.3 Farm and Retail Price Behavior ..... 531
9.5.1.4 Conclusions ..... 532
9.5.2 Extension Education ..... 532
9.5.2.1 Concepts of the Task of an Extension Service ..... 532

Page

9.5.2.2 Important Roles of Extension Workers 533
9.5.2.2.1 Encouraging Farmers to Innovate 533
9.5.2.2.2 Imparting Knowledge and Skills 534
9.5.2.2.3 Analyzing Farm Businesses 534
9.5.2.2.4 Reducing Risk and Uncertainty 534
9.5.2.2.5 Stimulating Auxiliary Services 535
9.5.2.2.6 Participating in Planning for Development 535

# 9.0 PRODUCTION INCENTIVES FOR FARMERS

## *9.1.0 Summary*

Agricultural development, in the last analysis, depends on the production decisions and actions of farm operators.

The factors that influence production incentives of farmers are of three types. Some flow from the general cultural, political and economic characteristics of each country or region. Some are effects of policies and programs designed to serve agricultural development but not primarily to affect incentives. Some are programs undertaken primarily to influence farmers' incentives and decision-making.

General cultural influences include traditions and values, social organization, and, particularly, arrangements with respect to land ownership and tenure. These affect primarily each farmer's *degree of freedom of action.* They determine whether he is under pressure to adhere to traditional ways or is free to innovate. In general, traditions and values are not subject to direct manipulation; instead they change under the impact of new opportunities and new pressures. The laws governing land ownership and tenancy determine the distribution of political power, and thereby influence policies and programs that can aid or inhibit agricultural development; they affect current production decisions of farmers by establishing the basis for division of the harvest and the sharing of production costs; they affect farmers' incentives to invest in farm improvement; they concentrate or divide decision-making on farm operations. The legal structure determining farm ownership and land tenure can and must be changed in many countries before the potential for agricultural developmet can be realized fully.

The second set of influences arises from private or public programs undertaken to speed the progress of agriculture but not aimed primarily at incentives. These programs include the development of markets for farm products, local outlets for farm supplies and equipment, the transportation system, production credit agencies, and irrigation facilities. All of these taken together determine *the opportunities for farmers to adopt more productive methods.* The availability of these facilities is a powerful stimulus to farmers to use them and they are the essential pre-conditions for the success of efforts aimed more directly at influencing the decisions of farmers.

The third set of influences includes programs undertaken primarily to increase production incentives. The most important of these are price policies and programs of extension education. Recent studies have verified the positive response of peasant farmers to price changes, at least with respect to the acreages devoted to commercial crops (grown primarily for the market) and of subsistence crops (grown for consumption by the farm family) in regions that are already market-oriented. There is little or no evidence that pricing can induce *yield*-increasing changes by peasant farmers, but this observation is inconclusive because other pre-conditions for yield-increasing changes (the facilities listed in the preceding paragraph) were still lacking in the localities where the effect of price changes were studied. Where these pre-conditions are met and farmers are market-oriented, it is highly likely that price relationships will be a very influential factor in encouraging farmers to increase yields. The unfortunate tendency in most developing countries is to base pricing more on the need for low food costs in cities than on the production incentive needs of farmers.

Programs of extension education can have a substantial positive effect on the production incentives of farmers, once essentials such as markets for farm products, local outlets for farm supplies and equipment, and favorable price relationships exist. A broader comprehension of the potential role of extension in developing countries is required if these programs are to have a maximum effect on incentives. Extension programs not only can "take research results to farmers" and "impart knowledge and skills," but also can substitute new procedures for old traditions and values, overcome reservations about the risks and uncertainties involved in innovation, speed the transition of farmers from a subsistence to a market orientation, stimulate the development of local auxiliary services, and generally make agricultural planning more realistic and practical.

Early in a country's agricultural development, attention needs to be concentrated upon the whole range of factors which influence farmers' incentives. Price policy is of great importance at this stage. At the very least, a farmer must remain solvent. He cannot be expected to produce for the market at a loss. But price relationships are production incentives only where farmers (1) have a considerable degree of freedom of action without general or specific cultural restraints, (2) have production alternative opportunities *available* provided through research and appropriate off-farm services to distribute farm inputs and to market, process, and distribute farm products, and (3) are, in consequence, able to operate primarily in a market rather than a subsistence economy. Each of these pre-conditions requires much

additional attention in most of the countries of Asia, Africa, and Latin America.

### *9.2.0 Introduction*

Crucial decisions which affect both the amount and efficiency of agricultural production can be made only by individual farm operators. These decisions are relatively few in a largely traditional agriculture but become more numerous as agriculture advances. Farmers must decide what crops to grow, based on current and anticipated market prices; whether or not to use fertilizer and, if so, what kind and when; whether or not to purchase seeds and, if so, what kind to buy; whether or not to purchase pesticides, based on a judgment as to the severity of the loss if no counter steps are taken; whether to buy a tractor, and, if so, what kind, whether to do their own plowing or hire it done; whether or not to employ extra labor; and whether to confine cash expenditures to what they can finance without borrowing, or to obtain credit. It is possible to make some decisions for farmers by administrative decree, but there are very narrow limits to what can be accomplished by this means. The enormous variations among farm units in soil, micro-climate, and local price relationships, and the multitude of unpredictable problems arising from pests, disease, and weather require, even in socialist and other planned economies, that many decisions be left to individual farm operators. The question of what influences farmers' decisions becomes a topic of major importance in our concern about the world's supply of food.

While others have been seeking to breed more productive plant varieties, to find effective measures for combatting against plant and animal diseases, to devise more efficient farm implements, to manufacture and distribute fertilizers, and to create production credit institutions, social scientists have been exploring the factors that influence farmers in their decision-making. This paper is a report of some of their findings and hypotheses.

#### *9.2.1 Production Incentives in Perspective*

The discussion of production incentives for farmers that follows should be read with the importance of other requirements for agricultural development constantly in mind. We find Mosher's classification of these requirements useful. He points out first, that there are four elements of farming and that any measure intended to contribute to agricultural development must change one or more of these: (1) the biological production process of agriculture; (2) the behavior of farmers; (3) the physical farm; and (4) the nature, and the costs and returns, of the farm as a business. He also lists five essentials for agricultural development, among which the complementarity is so

high that all must be present in any locality before agricultural production can increase. These essentials are:

1. Markets for farm products.
2. Constantly changing production technology.
3. Local availability of farm supplies and equipment embodying the new technology.
4. Production incentives for farmers.
5. Transportation connecting farms with markets for farm products and outlets for farm equipment and supplies.

Mosher goes on to point out that in any locality in which all five essentials are adequate the addition of any one or more of five accelerators of agricultural development can increase the rate of agricultural growth. These five accelerators are: (1) education for development (including extension education for farmers); (2) production credit; (3) group action by farmers; (4) land improvement and expansion of the cultivated area; and (5) planning for agricultural development.

Production incentives are one of the five essentials of agricultural development in each locality before agricultural development can occur. Without adequate production incentives the other four essentials will have no effect. Conversely, without all of the other four, even very favorable production incentives will have no effect. The relevance of production incentives to Mosher's "elements" of farming is that they are aimed primarily at changing the behavior of farmers with respect to production.

While we find this classification of the requirements for agricultural development useful, our analysis of factors affecting production incentives in the pages that follow will demonstrate that these various "essentials" and "accelerators" are not unrelated. In fact, it appears that the presence of markets for farm products, outlets for farm supplies and equipment, and transportation facilities have, in themselves, a substantial effect on production incentives. Furthermore, two of the accelerators—extension education and production credit—can provide a similar stimulus.

### *9.2.2 The Semi-Commercial Production of Food Grains*

This report has been prepared using the problem of semi-commercial production of food grains as a prototype. By "semi-commercial production" we mean production of commodities of which the farm family itself consumes a significant share. It is for farmers such as these, many of whom produce primarily for subsistence and only marginally for the market and use "innovations" to only a small extent, that the decision-making is most complicated.

We have concentrated largely on production incentives for the food grains because these crops are of major importance to the world's supply of food.

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Semi-commercial production of food grains prevails in most of the "developing" world. The exceptional "islands" of highly productive plantation crops such as sugar, pineapples, cocoa, coffee, tea and rubber, and the similar "islands" of largely commercial general farming, pose fewer and less serious problems of incentive and are not treated specifically.

### *9.2.3 Factors Influencing Farmers' Incentives*

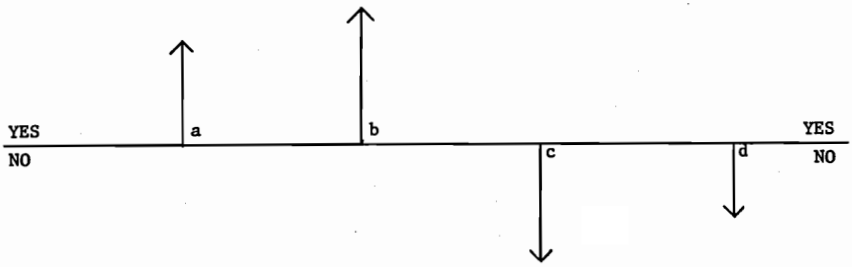
The influences that are most widely recognized are: (1) prices of farm products, (2) land tenure arrangements, and (3) traditions. Other less universally recognized influences include: (1) the physical availability and quality of marketing channels for farm products, farm supplies and equipment, production credit, information about improved practices, purchasable consumer goods, and irrigation water; (2) the local prices of farm supplies and equipment relative to their quality; (3) tax structure and policy; (4) forms of local organization; (5) personal support by extension agents, and (6) exposure to outside ideas and innovations.

*9.2.3.1 Influences are Many, but Decisions are Single.* While the factors influencing the production decisions of farmers are many, it is the *total effect of all factors* that leads a farmer to adopt or to shun a new practice. In any single instance, factors that encourage the farmer to adopt a practice are weighed against others that discourage him.

Each factor entering into a decision can be depicted by an arrow pointing up (if the influence encourages adoption of a practice) or down (if the influence discourages or inhibits adoption of the practice). The length of each arrow can indicate the measured or estimated strength of each factor and the division between "yes" and "no" can be depicted by a horizontal line. For example, if a farmer is influenced in whether or not to use fertilizer on a particular crop by (a) a favorable set of price relationships for farm products and for farm inputs, (b) a favorable land tenure situation, (c) a cultural setting that discourages change, and (d) a high cost of credit to finance the new practice, these influences and the strength of each might be depicted as follows in Figures 9–1 and 9–2.

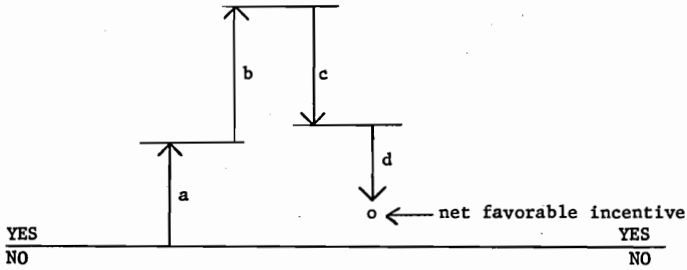
This example is based on only four influences. In actuality, of course, there are many others. Furthermore, this diagrammatic treatment is misleading if one infers from it that the length of each arrow (the strength of each influence) can be measured with exactness. It is not meant to imply that the overall effect of all influences on farmer incentives can be calculated and neatly predicted. Instead, it is used to indicate that the direction and relative strength of each influence are important, and that for each decision concerning a new technique of production, the effect of all influences is summed up in the farmer's mind to a single "yes" or "no" decision.

Figure 9-1




Since these influences combine into a single "yes" or "no" decision, the summation of their influence might be depiced as below, indicating that their net effect, in this case, is the adoption by the farmer of the new practices.

Figure 9-2




*9.2.3.2 Three Sources of Influence on Production Incentives.* The factors which influence farm production incentives are of three types.

*Type I.* The first group arises from the general political, social, economic, and cultural setting within which farmers must operate. These are inherited from the past and modified in the present not *primarily* to affect agriculture but in pursuit of the general welfare of people living within the culture. General cultural values, provisions for the maintenance of law and order, monetary policy, family structure including the traditional roles of its different members, and general village culture are examples of Type I influences. Land tenure arrangements are of this type since they are usually established more to affect the distribution of power and to serve purposes of social justice than because of their effect on farmers' incentives.

*Type II.* A second group of influences includes side-effects of policies and programs adopted primarily to provide other requisites for

agricultural development. Examples are the availability of new inputs provided by research, the adequacy of access to markets for farm products and to purchasable production inputs, and the availability of production credit.

*Type III.* Finally, there are policies or programs aimed specifically at influencing farmers' decision-making. Prices and price policies, and extension programs are important examples of these. Tax policies may have the same effect. Land tenure policies can be redesigned specifically for this purpose although, historically, they are Type I influences.

These three types of factors overlap and limit conditions of farmers' incentives to a relatively small area. The following figures represent an attempt to graphically present the impact of these influences.

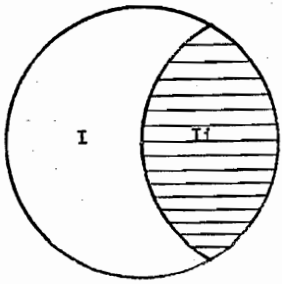
Combining these three figures gives us a representation of the complex of influences that together determine production incentives for farmers.

### *9.2.4 Side-Effects of Efforts to Influence Farmers' Incentives*

Additional explanation is needed regarding the dotted lines in Figures 9–5 and 9–6 above. The dotted lines in Figure 9–5 reflect the fact that measures undertaken to affect farmers' incentives *directly* have side-effects that influence other parts of the society as well. The location of the two crescent-shaped areas $IIIs_1$ and $IIIs_2$ in Figure 9–6 indicates that some of these side effects influence other measures undertaken to accelerate agricultural development, while others influence the general political, social, economic, and cultural totality of the society.

So far as the side effects on other measures to improve agriculture are concerned, they are generally favorable. They increase the economic demand for and use of the larger production opportunities that the other measures for agricultural development provide.

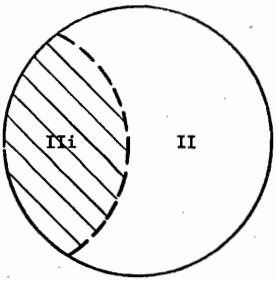
Figure 9-3




I. Every farmer is influenced by the general political, social, economic and cultural setting within which he lives. The total influence of these factors is much broader than their specific impact on farmer incentives, but influences on farmer incentives are among them. (Influence on farmer incentives, Ii, is a sub-set of set I).

Type I. Influences of the general political, social, economic and cultural setting.

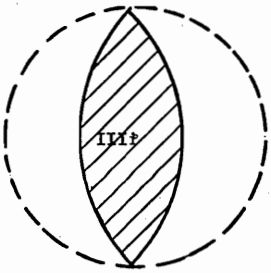
Figure 9-4




II. Wherever measures such as agronomic research, irrigation, provision of new farm inputs, or production credit are undertaken, these (along with each serving its major objective) also have an influence on farmer incentives (IIi) through the facilities that they make available.

Type II. Influences of other measures undertaken to spur agricultural development.

Figure 9-5

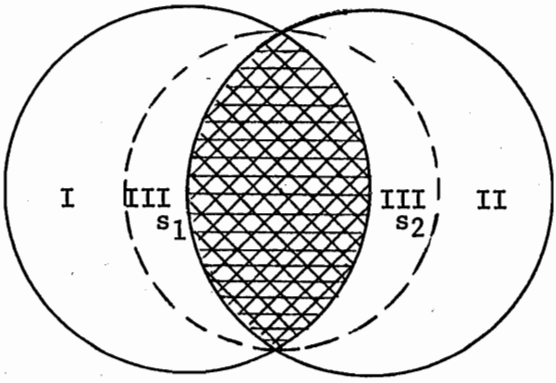



III. The joint effect of Type I and Type II influences on farmer incentives may be either inimical to rapid increases in agricultural production, or they may simply be inadequate. To achieve a net result favorable to rapid agricultural development, specific policies and programs can be adopted (and may be essential) to augment or intensify production incentives of farmers. The dotted lines indicate that in addition to their influence on farmer incentives such measures also affect other measures for agricultural development and the general political-social-economic-cultural setting.

Type III. Influences of measures undertaken specifically to influence farmers'incentives.

The side effects on the general political, economic and cultural structure of the society may or may not be "beneficial" and, in any case, are certainly more complex. The distribution of land ownership and the conditions of tenancy, for example, have a pronounced effect on the distribution of political power among a particular group of people. This effect may decisively affect public policy with respect to a wide variety of factors influencing the rate of agricultural development in addition to its influence on farmers' incentives by increasing each

Figure 9-6




Composite Impact of Influence from all Sources on Farmer Incentives

farmer's share of the harvest. Even beyond this, land tenure arrangements may have important effects on non-agricultural political goals in a nation if, for example, they broaden the base for citizen participation in government. Serving goals of this nature may need to take precedence over its effect on the supply of food.

In other words, the forms of organization of a society, its "institutions", can have a marked influence on the rate of agricultural development but they also have much broader social effects. These pervasive effects should be taken into account in development planning. The effect of institutions on food supply cannot be the only consideration; in some countries, the immediate impact on food supply may deserve a lower priority than other consequences.

## *9.3.0. The Nature and Impact of General Cultural and Political Influences*

### *9.3.1 Some Aspects of Low-Technology Cultures*

*9.3.1.1 Traditions and Values.* The function of tradition in any culture is not to promote change but to insure stability, continuity and predictability in human affairs. To ignore or violate traditions by the application of new inputs is a risky business.

Habits, customs, and traditions change only when they are challenged by the emergence of problems they cannot solve. They wither under the impact of new products imported by trade. They are modified by the availability of new production techniques. When a farmer becomes concerned about a new problem, he will first try to solve it within the sanction of old traditions. Consequently, if a new practice

can have an old sanction, it is more easily introduced. Eventually, if problems remain unsolved, the old way weakens, and traditions change or are replaced.

*9.3.1.2 Social Organizations.* Tradition and social structure go hand in hand; social structure is traditional in its own form and function and, in turn, promotes the continuance of traditions.

There is a large variety of human groupings, and each society has its distinctive combinations of them. In most traditional societies, the family and closely associated groupings of caste, clan, kin, and neighbors are powerful in their controls of members. In such groups, it may not be enough to win one individual to a new idea or a new practice. The attitude of several influential members may have to be changed.

*9.3.1.3 Legitimation is Local and Personal.* In premodern societies with subsistence agricultural systems which produce only enough food for the farmers, their families, and neighbors, norms are particular to the farmer, the family, and the *local* culture rather than general for the whole nation. The concept of the proper way to operate a farm is controlled by the personal approval of individuals, not impersonally by findings of experiment stations or tags on bags of fertilizer and seed. Consequently, change agents must become respected among the people with whom they work if they are to be effective. This is because it is not *what* is said as much as *who* says it that leads to acceptance or rejection of a new practice.

If a practice is frowned on by a venerable spokesman for tradition, or derided by a member of one's family or village, the practice is usually dropped. Few persons in any culture can risk innovation while being scorned by those to whom they look for approval and support.

*9.3.1.4 Pervasive General Influences.* Farmers are influenced in decision making by many factors from the general culture. One of these is maintenance of law and order. Farmers are deterred from improving their livestock if the animals are likely to be stolen. A second factor is the administrative efficiency of governmental services. A farmer is unlikely to make use of credit facilities if the procedure for getting a loan requires visits to several offices which may not be open or are staffed by officials who treat the farmer as an inferior. Third, it is characteristic of most low-technology economies that group welfare has a much higher value than individual freedom. People who live close to the margin of subsistence cannot afford to let one person endanger the group's precarious balance. A fourth general influence is what Foster has called "the doctrine of limited good"; the idea that the total amount of goods and services available to a community is

rigidly fixed, so that if one person gets more, someone else must inevitably have less.

*9.3.1.5 Influences Having Specific Impact.* Other cultural influences bear specifically on the making of particular decisions in farming. One of these is the tradition that the raising of each type of crop or animal is the exclusive responsibility of a specific group; one caste, or family-line, or clan grows vegetables or wheat; one and only one raises pigs, or chickens, or cattle. Another is the tradition in many regions that a tenant should share his harvest with the landlord but should bear the full cost of purchased inputs. A third is the tradition that livestock should be privately owned but grazed on public lands without regulation as to numbers; this makes for over-grazing, prevents improvement of pastures, and makes selective breeding or control of livestock diseases virtually impossible. A fourth such influence is food habits; some of these are strict taboos, preventing any consideration of raising pigs, chickens, or cattle; others are merely food habits of long standing, such as the strong reluctance of many to substitute other grains for rice in their daily diet.

*9.3.2 Land Ownership and Tenure*

No single aspect of a culture has a greater impact on production incentives of farmers than the set of arrangements (legal, customary or both) that each society has adopted for land ownership and tenure.

There is an enormous literature on this topic which ranges from reports written by persons with a passionate conviction that one or another form of land ownership is ideal, to studies conducted by persons trying to achieve scientific objectivity, but there is as little unanimity of opinion among the latter as among the former. One difficulty in drawing general conclusions on this subject is the almost endless variety of arrangements for land ownership and tenure found in different parts of the world or within a single country such as India. Our concern is with production incentives for farmers, and patterns of land tenure affect them in several ways. Land tenure arrangements are part of any society's way of meeting other goals. They help achieve goals of social justice or income distribution, objectives of social stability, of individual or group "social security" in the current American meaning of that term, and of distribution of political power. Additionally, they serve to strike a balance between *individual* needs for productive opportunity or employment, on the one hand, and *social* needs for full utilization, conservation, and improvement of land resources on the other.

Three general conclusions can be drawn from the literature on land tenure.

First, *no land tenure system can be optimal with respect to one social objective without being less than optimal with respect to others in the same society.*

Second, *no land tenure system can confidently be adjudged to be best in the abstract; land tenure systems can only be judged within the context of the other elements of particular cultures.* Put another way, the "best" land tenure system for a particular country or region can only be judged in the light of currently prevailing circumstances such as land availability, non-farm employment opportunities, available agricultural technology, existing distribution of political power, rate of population growth, and social structure.

Third, *the optimum pattern of land ownership and tenure for any given country or region changes over time* with technology, population, alternative employment opportunities, and other facets of the local culture. To make appropriate changes possible, the legal arrangements for land ownership and tenure must either provide for considerable flexibility or they must be revised periodically. While flexibility would appear to be preferable in an ideal sense, there are circumstances where periodic revision of legislation is not only more feasible but also more advantageous. Such revisions cannot be frequent, however, without disastrous affects on the rate of investment in agriculture.

*9.3.2.1 Major Types of Land Ownership and Tenure.* While specific land ownership and tenure arrangements vary enormously in different parts of the world, there are six general types, each associated with a different set of historical and contemporary influences.

*9.3.2.1.1 Tribal or Communal Tenure.* In this type, land is not "owned" by any individual or family. Each tribe or clan has a territory within which it may assign plots to individuals or families to cultivate, or families may be free to choose and cultivate plots not currently claimed by someone else. No rent is paid. No sales of land take place. Cultivating families may be free to keep all they grow or may be required to share their produce in any of a wide variety of ways with other members of the tribe. Plots may be reassigned periodically, or families may have hereditary rights to cultivate their plots.

Tribal tenure tends to persist only so long as more land is available than the population needs for subsistence agriculture. It is not appropriate for an agriculture in which farm inputs are purchased or in which appreciable amounts of produce are sold.

The tribal tenure arrangement still characterizes large areas in Africa and is found in other isolated parts of the world. It must give way to other types if an exchange economy is to develop, but there is no consensus about the best way to achieve the transition. The world needs the food and other products that the extensive lands of Africa

could yield. To realize this potential, a radical shift in social patterns, of which tribal land tenure is only a part, will be required.

*9.3.2.1.2 Feudal and Semi-Feudal Tenures.* The tenure system that exists in many forms is that in which one person collects rent or services from a large number of laborers or peasants who cultivate a given territory of land. This feudal or semi-feudal system, in many places, makes it a responsibility of the landlord to provide emergency rations for his tenants and their livestock in lean years. This responsibility is frequently combined with his granting of credit to the tenants, almost always on terms more favorable to him than to them. The rent and/or services he collects from his serfs, tenants, or share-croppers may be regulated by custom or by law, but frequently is not, so that the trend is for the owner to collect all but subsistence requirements. Political as well as economic power usually resides with the landowners. Where landholdings are very large, the resulting concentration of political power usually supports a self-perpetuating oligarchical form of government.

There is seldom much incentive for feudal landowners to increase productivity on their holdings. Ownership carries political power and social prestige and the measures necessary to increase productivity would (or so the landowners believe) undermine the system. As one writer has pointed out, "the marginal utility to the landlord of an increase in productivity is very small".

This type of tenure exists in an extreme form in many parts of Latin American and it is found in more attenuated forms in the Middle East and South and Southeast Asia.

*9.3.2.1.3 Share Rental of Land.* Scattered throughout much of the agricultural world one finds share rental of land in which a designated part of each harvest goes to the landlord and the remainder to the operating tenant. It involves two special problems in connection with agricultural development: the financing of production inputs and land improvement. In most cases, the tenant must turn over a fixed share of each harvest to the landlord but must bear the full cost of purchased production inputs. Under such circumstances, a tenant operator has, at best, a weak incentive to incur additional production costs in hope of a larger harvest. All of the additional *cost* is his, but he receives only a part of the additional *returns*. Where share tenancy persists in advanced agricultural economics, schemes for sharing production costs as well as the harvest have been worked out between the tenant and the landlord. While isolated examples of this situation exist in the developing countries, the practice is not widespread.

The other problem involved in share tenancy is insecurity of tenure. Within a feudal system each tenant has security of tenure but as soon

as rent is paid wholly in kind or in cash this security disappears. Many countries have given certain classes of tenants security of tenure by legislation but in most places share tenants can keep farming the same land only at the will of their landlords. Wherever this is true, share tenants have little incentive to invest in land improvement since they have no assurance that they can reap the benefits of such investments.

*9.3.2.1.4 Cash Rental of Land.* The obligation of an operating tenant to pay a contracted cash rental per acre, instead of a share of the crop, has the substantial advantage over share tenancy that the entire increment in production made possible by use of improved methods accrues to him. The tenant's incentive to use purchased inputs increases because of this. It is primarily for this reason that cash tenancy is generally preferable to share tenancy.

The problem of insecurity of tenure can arise under cash rental as well as under share tenancy. Again, the only feasible ways to solve this problem are legislation or long-term rental contracts. A few countries have legal requirements that the landlord reimburse a tenant for his investments in land improvement if the tenants' occupancy of the land is terminated.

Under both share and cash tenancy systems, rental payments tend to approach the "economic rent", leaving the tenant only enough for scant subsistence. Legal ceilings need to be set on rental payments, whether in the form of the percentage share of the harvest due the landlord or in the form of maximum cash rental per acre.

*9.3.2.1.5 Owner-Operatorship.* This is the type of land tenure that most farm operators prefer, since it grants them maximum independence of action and security. An owner-cultivator system probably provides the strongest production incentives of any land tenure system. Each owner-operator receives the combined earnings of his labor, his management, and the improvements in the land he cultivates. Thus, he has the maximum incentive to increase current production and to invest in land improvement. He is free to change cropping patterns and methods of cultivation to the extent that local traditions, new technology, markets and prevailing price relationships may allow. He is in a stronger position to go counter to prevailing local traditions by virtue of his ownership. He is freer than any other type of farm operator to join with others in organizations to further their own interests, whether locally or nationally. This type of land tenure is found in most non-socialist parts of the world and, in varying degrees, in some Communist economies. The proportion of owner-operators is increasing substantially, especially in Japan and Taiwan, but also in India, Egypt, and other countries as a result of recent land reforms.

*9.3.2.1.6 Socialist Forms of Land Tenure.* It is a basic tenet of a socialistic society that the nation owns the land. While this is similar to tribal land rights, socialistic economies stress industrialization and this implies an intricate exchange economy for both agriculture and industry. Most socialistic economies have tried with unimpressive results to organize agricultural production in a pattern similar to that of industry. This has involved large-scale collective or state farms, using various devices for allocating land and for collecting produce. The products are not looked upon as compensation to the state for use of the land.

In view of the indifferent success of socialistic efforts to increase agricultural production, it cannot be said that an economically defensible and stable socialistic pattern of land tenure has evolved yet. Pragmatically oriented regimes in countries like Yugoslavia and Poland continue to condone "anachronistic" and "capitalistic" land tenure systems to protect their productivity.

It would be premature to conclude that a dynamically productive agriculture cannot develop in a system where the state owns all land, but the institutional forms and procedures to make such a system effective have yet to emerge.

(A sixth form of land tenure—cooperative farming—has been tried in many places, often with satisfactory short-term results, but this system has not developed to a point where it can be considered as a major form of land tenure or of farm organization. Enthusiasm for it continues only in small regions where special conditions support it.)

*9.3.2.2 Tenure Systems' Influence on Agricultural Productivity.*

*9.3.2.2.1 Distribution of Political Power.* The most important influence of tenure systems on agricultural productivity goes far beyond influences on the production incentives of individual farmers. Governmental policies and programs affecting agriculture are most likely to offer opportunities only to farmers who have political power. If the tenure system concentrates this power in a few landowners, their interests will be served by governmental policies and programs. If the tenure system is such that owner-operators and cash and share tenants predominate, political power will lead to governmental policies and programs which serve the interests of the actual cultivators.

The whole complex of services which support agriculture, including sources of supplies and equipment, markets, credit, research, and extension education tend to take a form consistent with the existing type of land tenure. If services are designed to serve large landowners, they are inappropriate for or unavailable to owner-operators

and tenants. Only the wider distribution of political power can remedy this.

*9.3.2.2.2 Effects on Current Production Decisions.* Farm operators, whether owners or tenants, are guided in their current production decisions by cost and returns *to them.* They cannot be expected to increase production if another person is to receive the profits. An owner-operator collects all proceeds from sales of his farm products and bears all costs of purchased inputs. A tenant never receives the entire proceeds from sales, since he must pay rent, and only in enlightened share tenancy arrangements (seldom found in the developing countries) does the landlord bear a commensurate share of the cost of purchased inputs. Specific practices with respect to sharing costs and returns vary widely, but in most countries of Asia, Africa, and Latin America, tenancy limits drastically the income incentive to use purchased inputs. Where the landlords' share of the harvest is large and the tenant must bear most or all of the costs of purchased inputs, the tenant has little incentive to produce beyond the point at which his share of the harvest gives him and his family their customary level of living Figure 9–3 on page 510 shows dramatically the effect of land tenure on incentives to use fertilizer in the Philippines.

*9.3.2.2.3 Incentives to Invest.* Agricultural development requires more than the annual use of purchased inputs. It involves continuous investments to improve the land and to construct buildings, wells, fences, etc. An owner-operator has great incentive to make investments because he can anticipate receiving the additional income that they make possible. A tenant knows that he will only receive part of the income that each improvement justifies and that he may, in addition, have to pay a higher rental than at present. Furthermore, if he can be dispossessed at the will be of the landlord, he has no incentive at all to improve the farm.

Even an "owner" may have a limited incentive to invest in farm improvements if his title to his land is not clear. In many developing regions, cadastral surveys have not yet been undertaken, and the registration of land titles is still inadequate.

*9.3.2.2.4 Concentration or Dispersion of Decision Making.* The use of purchase inputs in increasing amounts and continuous investment in the land are crucial to the development of progressive agriculture. If decisions with respect to these have to be made jointly by two persons—a landlord and a tenant—this introduces an additional impediment to rapid agricultural development.

### *9.3.3 Conclusions*

We can summarize what is "known" about the influence of the general culture of any region on the production incentives of farmers in the following propositions:

(1) Influences on a general culture which are grounded in traditional beliefs and values can rarely, if ever, be changed by direct attack on these beliefs and values as such. Food taboos and the joint family system are examples of this type of influence.

(2) Most methods for changing the general climate of traditions and attitude work slowly. The most rapid effect is achieved by increasing the mobility of both people and goods through improving transportation and marketing channels for farm products, farm inputs, and consumer goods.

(3) The doctrine of limited good and resistance to change which stems from communal living at the margin of subsistence, can be modified by local demonstrations of new practices that will increase over-all production so significantly that gains by some members of the community are clearly no threat to the welfare of others.

(4) Food preferences, as well as the idea of limited good, can be changed by improving transportation and marketing channels so that a wider variety of consumer goods, including food, becomes available locally.

(5) Inefficiency of government services can be modified by appropriate administrative changes accompanied by a system of in-service training and by improved "upward communication" from field agents to high administrators who respond by revising policies and procedures.

(6) The total impact can be magnified by general education that widens the horizons of citizens, making them aware of ways of thinking and acting in other cultures and societies.

(7) Under circumstances too variable and complex to be discussed here, community development programs, farmer cooperatives, and the expansion of the powers of local government can create the initiative needed to break the tradition of "waiting for the central government to help us". As such programs overcome local fatalism, they can improve maintenance of law and order and many other community and governmental services.

(8) Selected traditions and local forms of social organization can be utilized to advantage in changing the general culture as it affects farmers' incentives. New interpretations of old sanctions can frequently be found and extension agents can cultivate the approval of established community leaders.

(9) Systems of land tenure influence the incentives of farm-operators to increase production through: a) the way in which political power is distributed; b) their effects on current production decisions; c) their influence on incentives to invest in the land and in other capital improvements; and d) their concentration or dispersion of decision-making.

(10) Security of tenure, or the legally-enforced right to fair compensation for improvements made by the tenant in the land and farm structures, is essential if a farm-operator is to be expected to make investments that will increase productivity.

(11) If *share* tenants are to be expected to utilize purchased inputs to increase production, the landlord must pay a fair share of the cost.

(12) No system of land tenure is ideal in the abstract; only one flexible enough to allow changes to meet new conditions can be "best" for a particular region over long periods of time if agriculture is growing in productivity and efficiency.

### *9.4.0 The Influence of Production Opportunities on Incentives*

So far we have been discussing production incentives that flow from the general political and social culture: from traditions, values, and social structures that are not primarily concerned with agriculture.

We turn now to a second group of influences that arise from activities specifically intended to spur agricultural *development.* These are the Type II influences previously defined in this chapter. They include the "essentials" of agricultural development: markets for farm products, locally available farm supplies and equipment, and transportation facilities. Additional stimulating factors are the availability of irrigation facilities, production credit, and additional arable land.

Whereas the Type I influences affect each farmer's degree of *freedom to choose*, Type II influences consist of *concrete and available opportunities* to undertake specific innovations that can lead to higher agricultural production. These offer the farmer choices among *specific lines of action.*

The relevance of these factors is so obvious that extended discussion is unnecessary. Two points should be emphasized: (1) it is the *local* availability of each factor that affects a farmer's decision-making with regard to it and (2) complementarity of factors is so great that the benefits when all are available in the same locality are greater than the sum of benefits produced by each one in isolation.

#### *9.4.1 Markets for Farm Products*

Farmers adopt production-increasing methods first for those crops and livestock that can be marketed locally. Most *yield-increasing* techniques require the purchase of inputs, and the cost of these inputs will be incurred only to grow crops for which money will be received. Increased production that can be achieved through extending the cultivated area, or by increasing the number of livestock tended, will be sought beyond immediate farm family consumption needs only if there is a market demand for the surplus.

There have been numerous instances in which new crops have been introduced into a region, and new techniques adopted to increase their yields, simply because a cash market for them suddenly became available.

*9.4.2 Farm Supplies and Equipment Embodying New Technology*

The local availability of seeds, pesticides, fertilizers, tools and implements, and sources of power provides farmers with the opportunity to use them and helps induce farmers to try them. New knowledge and skills are needed for their use but there is incentive to learn how to use new inputs only when they are available. Once these inputs are at hand, and a few farmers begin to use them, a substantial "demonstration effect" sets in. Higher production on his neighbor's fields is a strong inducement for a farm-operator to experiment with the new methods himself.

*9.4.3 Transportation Facilities*

Studies of village behavior in Turkey and Guatemala have demonstrated that the citizens who innovate most readily are those whose "world" is not limited by the community but has been broadened by frequent contact with the cities. This same phenomenon has been observed, although not so well documented, in many other places. Personal travel to other places, visits to the village by sons, relatives, and friends who have moved to the city, and visits to the village by officials of governmental development agencies can all stimulate farmers to adopt new methods. Studies in the Philippines have shown that visits to a village by extension agents, credit agents, health workers, and other government employers increased four to tenfold after construction of a feeder road connecting it with a main highway.

These effects of personal mobility are in addition to the role that transportation facilities play in moving farm products from local to central markets and production inputs from centers of manufacture or importation to local outlets.

*9.4.4 Production Credit*

Without new sources of credit, only a few farmers with access to markets for farm products and to supplies and equipment will adopt production increasing methods. Provision of credit through a system tailor-made to the production needs of farmers through convenient local outlets provides an additional incentive to adopt improved practices.

*9.4.5 Irrigation Water*

The effect of the availability of irrigation facilities is not so much to increase production of crops already grown as it is to open opportunities to grow new crops or to engage in multiple cropping. More-

over, irrigation is essential in many regions to utilize both fertilizers and optimum amounts of soil moisture more effectively.

*9.4.6 Attractive Consumer Goods*

Does the availability of attractive consumer goods in rural markets cause farmers to increase production? The answer seems to be "yes". Bringing farmers more and more into the market economy is an important part of agricultural development. Attractive consumer goods that farm families want act as a stimulus to produce a larger surplus above family needs to be sold for the money needed to purchase these non-agricultural goods and services. These goods are not placed in local markets primarily to provide incentives to farmers to increase production, of course, but their impact on farmers' incentives is very important. The desire to buy bicycles, radios, flashlights, household equipment, clothing, etc. brings more farm products to market.

## *9.5.0 Programs Undertaken Specifically to Influence Production Incentives of Farmers*

We come now to the Type III influences which are the programs and policies designed *primarily* to increase the incentives of farmers to increase production. The two that overshadow all others in importance are *price policies* and *extension education.*

*9.5.1 Price Incentives*

*9.5.1.1 Introduction.* In modern industrial societies the notion that changes in prices are important determinants of producer and consumer behavior is firmly grounded in economic logic and is confirmed by observation and analysis. In all such societies, whether they are relatively free or are rigorously socialistic, prices play a leading role in guiding decisions about agricultural production and in directing the flow of commodities through marketing channels. Indeed, the responses to price incentives have been so powerful that programs designed to support the incomes of agricultural producers by holding prices above normal market levels have typically induced the production of surpluses except where they have been accompanied by marketing quotas or restraints on resource use.

A very important question in designing programs to achieve rapid growth of agricultural production in developing countries is whether peasant producers will respond to price and income incentives as do commercial farmers in industrialized countries. If peasant producers are unresponsive to price incentives, (a) the efficient functioning of a free market economy becomes virtually impossible, and (b) the effec-

263-888 O—67——35

tiveness of price manipulation in achieving production or marketing goals in a planned economy is sharply reduced.

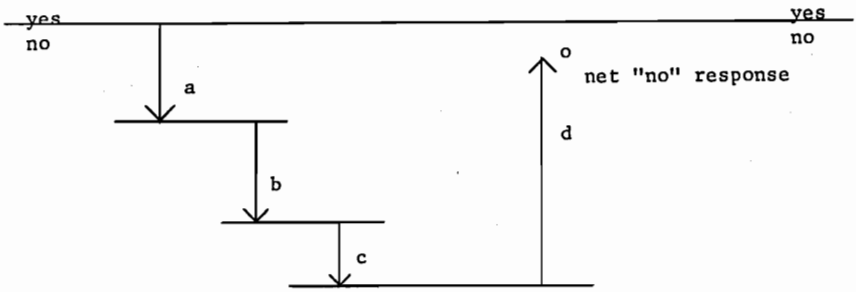
*9.5.1.1.1 Traditional Thinking about Peasants' Price Responsiveness.* Many have postulated that peasant producers would be unresponsive or would respond perversely to price incentives. The argument for a perverse response has rested typically on a hypothesis of limited economic aspirations, particularly for the purchase of goods coming from outside the self-sufficient family or village economy. The implication of this hypothesis is that an increase in the price of farm commodities would allow peasant producers to meet their limited needs for goods produced outside of the local economy with less effort and that a lower volume of farm products would be offered for sale.

Another line of reasoning leading to a similar conclusion is that under the conditions of extreme poverty which characterize large numbers of peasant producers, a rise in income is associated with a disproportionate rise in food consumption. Higher prices for food commodities would, therefore, result in farmers retaining more of their production for their own use with the result that the marketed surplus would decrease.

In situations where peasants are more fully integrated into the market economy or where the pressure of food supplies is less intense, it is frequently argued that the high value placed on traditional patterns of production and consumption effectively dampens the response to price incentives. This argument is frequently coupled with references to the importance of ceremonial consumption.

*9.5.1.1.2 Peasants' Price Responsiveness in Perspective.* The seeming conflict between experience with respect to price responsiveness of agriculture in the more advanced economies and peasant price responsiveness in other parts of the world grows out of failure to recognize the complex nature of the factors which influence farmers' decision-making. It is undoubtedly correct that many farmers in the developing countries are deterred from responding to price changes because their landlords receive a large share of the harvest but do not help pay for new inputs that might raise production (vector *a* in Figure 9–7). Many of them also live in extended families whose customs force them to share any increased production (vector *b*). Many of them live where there are few opportunities to spend increased income on consumer goods that they would like to buy *if* such goods were available in nearby markets (vector *c*). In these circumstances, it is clear that even a substantial price incentive (vector *d*) will elicit from the farmer a "no" response to suggestions that he adopt a new farming technique. This does *not* indicate that the price, considered by itself, is not a positive incentive even to a farmer in such a situation. It merely means that among the complex of influences on farmers'

Figure 9-7




**Lack of Positive Decision in Response to Even a Strong Price Incentive**

decision-making, the price incentive alone may be inadequate to overcome the combined effect of other influences.

*9.5.1.1.3* Unsound Price Policies. Unsound generalizations about agricultural price incentives frequently have led governments to adopt price policies intended solely to benefit industry and urban consumers on the assumption that prices "do not matter" to farmers.

Several countries that export agricultural commodities impose substantial export taxes on food and other farm commodities either to hold prices to domestic consumers below world market prices or primarily for revenue purposes. Some countries have required peasants to sell part of their production at substantial discounts. Others have used commercial imports or commodities obtained through concessional food aid programs in a way that has held the prices paid to their domestic producers below those paid to producers in the country from which food was imported.

It is not surprising that such self-defeating agricultural development policies are employed in many of the developing countries. In addition to fixed ideas about the response of peasant producers to price incentives, two other factors are involved. First, there is the hope that the availability of food and agricultural raw materials at low prices will encourage industrial growth. There is also the historical fact that the present developed countries followed agricultural policies emphasizing low prices for food and agricultural raw materials during the early stages of their industrial development. In the United Kingdom the 19th century free trade movement was aimed at lowering the price of food and raw materials in relation to the price of manufactured products. In Japan agriculture was taxed heavily to finance industrial development. In Russia the collectivization of agriculture had as an important objective the extraction of surplus production from agriculture. In citing these examples, developing countries overlook the coun-

tervailing forces that existed at the time these practices were formulated. England was primarily an importer of food and raw materials and an exporter of industrial goods. In Japan, while agriculture was being taxed, the government was simultaneously pouring substantial amounts into agricultural research and into general education, and Japan possessed such a high degree of social discipline and national purpose that farmers kept at their tasks under relatively unrewarding circumstances. Russia succeeded in industrializing but has not yet achieved comparable success in building a highly productive agriculture. Certainly, any developing country faces conflicting needs in trying simultaneously to industrialize and to increase agricultural productivity. But one of the things it cannot afford to do is to ignore the considerable responsiveness of market-oriented farmers to price incentives.

*9.5.1.1.4 Need for Research.* When agricultural production depends entirely on the land and the labor of peasants, the possibilities of achieving a rapid growth in output are sharply limited. Modern technical inputs such as new seed varieties, fertilizer, pesticides, and power equipment are now becoming available to farmers in some of the developing countries. These new inputs differ strikingly from those of traditional subsistence agriculture in that they *must be purchased from the non-farm sector.* A major effect of this new technology is to make farmers far more sensitive to price policies than in the past. Moreover, rapid population growth has accelerated the growth rate of demand for agricultural products in most developing nations to a level that is much greater than that which existed in the presently developed countries at a comparable stage in their history. This raises a serious question, therefore, about whether the rate of agricultural output required to meet this growth in demand can be achieved without direct encouragement to farmers through positive agricultural price policies.

In undertaking studies of farmer responsiveness to prices, two cautions are in order. The first is to avoid the error of generalizing from one developing country to another, particularly on the basis of studies carried out in one region. The second is to consider the correlative operational force of influences other than price on farmers' incentives, rather than to disregard them simply because they cannot be quantified for inclusion in econometric models.

*9.5.1.2 Farmers' Response to Price Incentives*

*9.5.1.2.1 Changes in Prices of Individual Crops.* Recently a substantial body of data has become available on the responsiveness of acreages of individual crops to relative price movements in a number of major geographic regions or countries. This information is summarized in Table 9–1. The "*elasticities*" given in the table indicate the

TABLE 9–1.—*Estimated short-run area price elasticities for selected subsistence and commercial crops in South and Southeast Asia*

| Commodity | Country | Period | Elasticity | Remarks |
|---|---|---|---|---|
| Subsistence crops: | | | | |
| Rice | India-Pakistan (Punjab) | 1914–45 | 0.31 | Irrigated. |
| | East Pakistan | 1948–63 | .05 | Summer and winter. |
| | do | 1948–63 | .12 | Summer only. |
| | Indonesia (Java and Madura). | 1951–62 | .30 | |
| | Philippines | 1954–64 | .10–.30 | Typical. |
| | do | 1954–64 | .40–.60 | High irrigated areas. |
| Corn | India-Pakistan (Punjab) | 1915–43 | .23 | Irrigated. |
| | Philippines | 1954–64 | .10–.30 | Typical. |
| | do | 1954–64 | .30–.70 | Major commercial areas. |
| Wheat | India-Pakistan (Punjab) | 1914–43 | .05 | Irrigated. |
| | West Pakistan | 1944–59 | .20 | |
| Barley | India-Pakistan (Punjab) | 1914–45 | .39 | |
| Millets | do | 1914–43 | .09 | |
| Sorghum | do | 1914–43 | –.58 | |
| Commercial crops: | | | | |
| Cotton | do | 1922–41 | .72 | American. |
| | do | 1922–43 | .59 | Domestic. |
| | India | 1948–61 | .64 | |
| | Pakistan | 1933–58 | .41 | |
| Sugarcane | India-Pakistan (Punjab) | 1915–43 | .34 | |
| Jute | India-Pakistan | 1911–38 | .46 | |
| | India-Pakistan (Bengal) | 1911–38 | .68 | |
| | India-Pakistan (Bengal, Bihar, Arissa). | 1898–1938 | .61 | |
| | East Pakistan | 1931–53 | .60 | |
| | do | 1948–63 | .40 | |

Source: Summarized from original sources identified in Mahar Magahas, Aida E. Recto, and V. W. Ruttan, "Price and Market Surplus Relationships for Rice and Corn in the Philippines," Journal of Farm Economics, Aug. 1966, pp. 696, 698.

percentage change in the crop acreage associated with a 1.0 percent change in the price of that crop relative to prices for competing crops.

There are difficulties in drawing general inferences from these studies since: (a) different statistical designs were used; (b) the relative price variable was defined in different ways; (c) the regions studied are not comparable; and (d) a majority of the information was collected in South and Southeast Asia.

*Acreage Response.* Despite these shortcomings it is possible to conclude that peasant producers responded to changes in the relative prices of individual commodities by reallocating crop acreages.

The individual studies also indicate that producers of crops normally grown for sale such as cotton, sugarcane and jute (commonly called "commercial" crops) are more responsive to price changes than producers of crops that may enter directly into the consumption pattern of the farm families producing them even though part of the crop is sold. Producers of these latter, or "subsistence", crops, are typically more responsive to price changes in the major commerical regions of

a country than elsewhere. These areas are characterized typically by good irrigation, transport, and marketing facilities. In these regions the response elasticities are of roughly the same magnitude as those found in studies of commercial farmers in developed countries. (See Table 9–2)

*Yield Response.* Attempts to relate changes in yield in developing countries to price changes have not been successful. While this may seem to imply a less optimistic view of the role of price as a development tool, studies may still demonstrate that price changes have induced positive *yield* responses in addition to *area* shifts. It may be that price incentives are effective only in localities where the farm supplies and equipment necessary to increase output are physically available, where marketing channels for farm products are adequate, and where other influences which might oppose farmers' decisions to adopt yield-increasing technologies have largely disappeared.

*9.5.1.2.2 Responses of Aggregate Output to Price.* Information on the response of aggregate agricultural output to general price changes for agricultural products relative to the price changes of nonagricultural products is quite inadequate. Furthermore, it is not possible to draw firm inferences on the response of agricultural output as a whole from data on the response of individual crops except in monoculture areas. It is entirely possible that individual crop studies merely indicate that land may be reallocated among different crops in response to relative price changes, but total output remains essentially unchanged. In densely settled areas, the responsiveness of aggregate output to price changes depends on the potential for increasing productivity per unit area.

TABLE 9–2.—*Estimated price elasticities of acreage (output) of individual crops, United Kingdom and the United States*

| Commodity | Country | Period | Elasticity | | Source | Year |
|---|---|---|---|---|---|---|
| | | | SR [1] | LR [2] | | |
| Barley | United Kingdom | 1924–39 | 0.63 | 1.76 | Jones | 1962 |
| Beans | do | 1907–40 | .39 | .53 | do | 1962 |
| Corn | United States | 1909–32 | .10 | .18 | Nerlove | 1958 |
| Cotton | do | 1909–32 | .27 | .67 | do | 1958 |
| Grains (all) | United Kingdom | 1924–39 | .12 | .52 | Jones | 1962 |
| Oats | do | 1924–39 | .11 | .16 | do | 1962 |
| | | 1946–58 | .18 | .24 | do | 1962 |
| Peas | do | 1938–58 | .65 | 3.10 | do | 1962 |
| Wheat | United States | 1909–32 | .48 | .93 | Nerlove | 1958 |
| Do | United Kingdom | 1924–39 | .33 | .46 | Jones | 1962 |

[1] Short run.
[2] Long run.

Two types of information can be brought to bear on this issue in the absence of more carefully designed aggregate supply analyses.

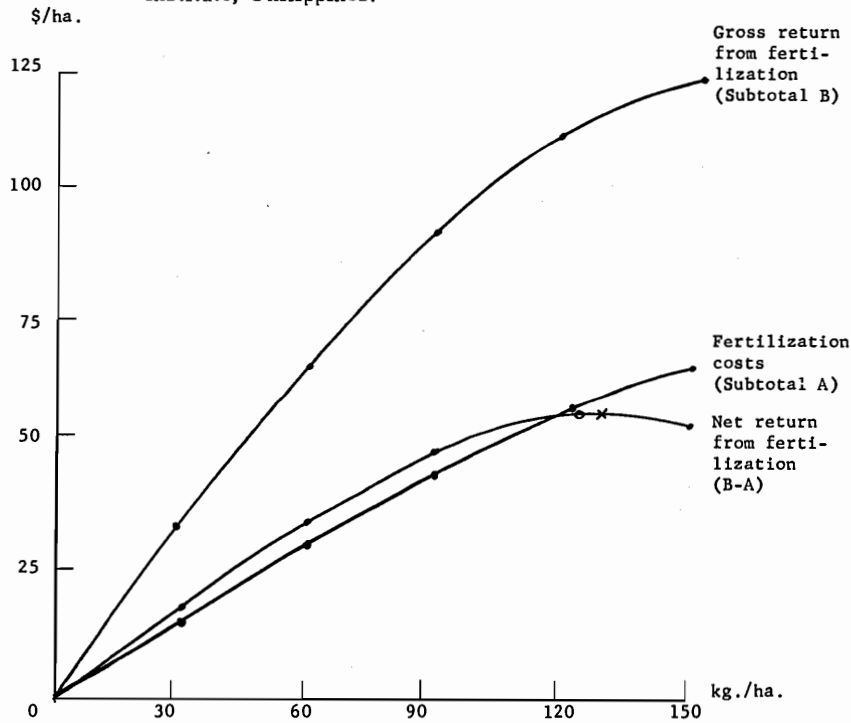
First, there are intercountry comparisons of the relationship between the prices of technical inputs such as fertilizer and the prices of farm commodities, the amount of the technical input used, and yield per unit area. Comparisons of this type usually illustrate that a reduction in the price of a technical input relative to the price of a product (or a rise in the price of a product relative to the price of an input) is an important incentive for increased production. The inferences that can be drawn from such data, however, are relatively weak guides to policy with respect to the prices of specific inputs. Inputs such as fertilizer must be available in local markets and the crop varieties available to farmers must be responsive to fertilizer inputs before price incentives can have any impact on aggregate output.

A second type of information that is used to make inferences regarding the impact of prices of inputs on prices of products are the yield response and product value relationships such as those illustrated in Figures 9–8, 9–9, and 9–10. Such data come from the records of experiment stations or from trials in farmers' fields. A number of studies support the view that when increased inputs of the type already used by peasant farmers (mostly land and labor) yield low returns, the returns on a single new technical input, such as fertilizer, are also low unless there is simultaneous use of fertilizer-responsive seed varieties, water control, and other complementary technical inputs.

All inferences concerning the contribution of price incentives to aggregate agricultural output rest on a very weak empirical foundation at the present time. It does appear that prices of farm products, *taken alone*, are relatively poor incentives for achieving growth in total output in densely populated areas characterized by a traditional agricultural technology. *These studies* relate *prices only* to aggregate output. They do not take account of the many other influences on farmers' decision-making: the availability, nearby, of yield-increasing farm inputs, the share of the landlord in the harvest, the impact of a joint-family system, the availability of efficient marketing facilities, and all the others. These results do *not* say that favorable price relationships will not encourage farmers to increase yields. They do indicate that favorable prices for farm products *alone* were not sufficient in the regions covered by the studies to bring about an increase in aggregate agricultural output.

*9.5.1.2.3 Price Effects on Marketed Surplus.* A complete evaluation of the potential contributions of price policy must consider not only the effect of prices on total agricultural production but also their effect on the quantity of food that is made available to the non-agricultural sector, the marketable surplus.

Figure 9-8
Cumulative Costs and Returns of Fertilization of Rice (Peta) 1963 Dry Season, International Rice Research Institute, Philippines.




| | | | | | | |
|---|---|---|---|---|---|---|
| Gross return | | | | | | |
| - total | $0.00 | $34.13 | $68.25 | $95.55 | $115.95 | $126.19 |
| - change | $34.13 | $34.12 | $27.30 | $20.40 | $10.24 | |
| Cost | | | | | | |
| - total | $0.00 | $15.95 | $31.25 | $45.36 | $58.40 | $69.74 |
| - change | $15.95 | $15.30 | $14.11 | $13.04 | $11.34 | |
| Net return | | | | | | |
| - total | $0.00 | $18.18 | $37.01 | $50.20 | $57.55 | $56.45 |
| - change | $18.18 | $18.83 | $13.19 | $ 7.35 | -$1.10 | |

Sufficient evidence on changes in marketable surpluses in response to price changes is not available and inferences have to be made from data on the area elasticity of individual crops and on the consumption behavior of peasant producers in response to price and income changes.

The evidence available at this time indicates that if the elasticity of output with respect to price is greater than zero the elasticity of marketable surplus will, under most conditions, also be positive and greater than the elasticity of output. A conclusion from this finding is that when output is rising sales can be expected to rise even more rapidly, but when output declines the supply marketed can be expected to decline even more rapidly than output.

Figure 9-9
Cumulative Net Return from Fertilization at Alternative Prices for Rough Rice (based on the fertilizer response reported in Figure 9.8).

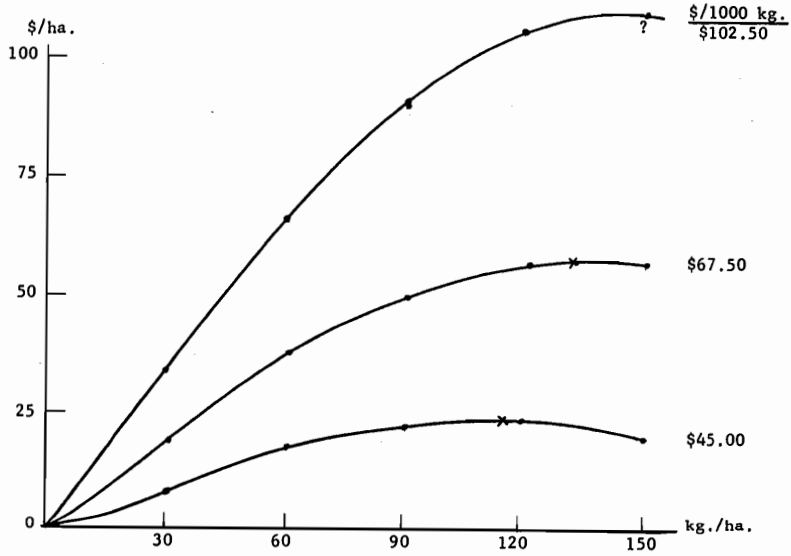
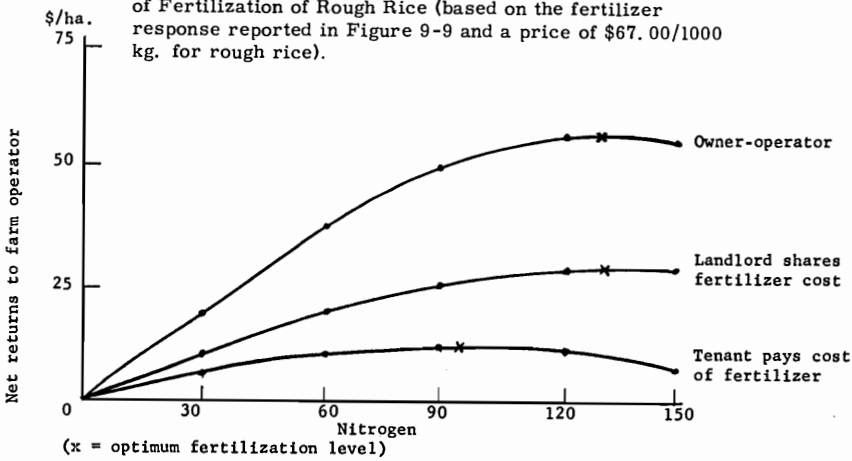



Figure 9-10
Implications of Tenure for Net Returns and Optimum Level of Fertilization of Rough Rice (based on the fertilizer response reported in Figure 9-9 and a price of $67.00/1000 kg. for rough rice).




*9.5.1.3 Farm and Retail Price Behavior.* The relationship between farm and retail price is an important consideration in the design of agricultural price policies. If price incentives are to be effective: (a) prices at the retail or wholesale market level must be reflected back through the system to the producer; or (b) the government must intervene in the marketing process to guarantee producers incentive prices that are consistent with production objectives. Major economies

can be achieved by increasing the technical efficiency of marketing services, thus reducing the costs that contribute to substantial differences in prices between local and central markets.

*9.5.1.4 Conclusions.* 1. Peasant producers are about as responsive to changes in the prices of farm products customarily marketed relative to each other, as are farmers in more highly developed economies.

2. Price-support, subsidy, or importation programs with *other* objectives (to reduce prices to consumers, for example) tend to be reflected rather rapidly in shifts in the acreage devoted to individual crops.

3. Price incentives can be used as an effective complement to other policies to redirect production to achieve certain commodity targets.

4. Favorable price movements can speed up the diffusion of new technology and the utilization of idle or less intensively developed resources.

5. The only prices that affect a particular farmer's decisions are prices *at his farm.* For this reason the impact of favorable central market price relationships can only affect those farmers who are connected with central markets through efficient transportation and marketing channels.

6. Prices affect the incentives of only those farmers who: (a) sell part of their produce in the market, (b) have access locally to production inputs at favorable prices and (c) know, or have access to means of learning, how to use these inputs.

*9.5.2 Extension Education*

Either a farmer operates by habit and tradition or he recognizes that he has alternatives, analyzes these alternatives, experiments with new methods, and tries to find the combinations of enterprises, cultural practices, and purchased inputs that maximize his net income. This statement is somewhat unrealistic as most farmers are somewhere along a continuum between the two extremes.

*9.5.2.1 Concepts of the Task of an Extension Service.* Agricultural extension services have the task of moving farmers in the direction of more frequent and wiser choicemaking. The specific mission of an extension service varies with the state of farmer knowledge and the adequacy of other services to agriculture that are operating n the region. It is this fact that has given rise to the "rural vacuum" definition of extension responsibility: that the task of an extension service is to do whatever needs to be done in a locality that no one else is doing. This definition has some validity but is a very hazy concept on which to build a program.

Three more definite concepts of the role of an extension service are widely held. One is that the task of extension is to "tell farmers what

to do." This concept is most widespread where it is assumed: (1) that farmers are incapable of making, or learning to make, the crucial decisions that would lead to greater production; (2) that farmers are not responsive to price incentives; and (3) that a progressive agriculture can be built on a system in which public planners and officials make the important production decisions and farmers follow instructions. All three of these assumptions are fallacious and no progressive agriculture has ever been built on the basis of this concept.

The second widely-held concept holds that the task of an extension service is "to take the results of research to farmers." This concept of extension has more to recommend it than the preceding one, since it assumes that actual decision-making will be left to farm operators. But it is a gross over-simplification of the task of inducing farmers to adopt more productive practices. It gives centrality to only one (research results) of a much broader set of requirements for changed production practices by farmers, and it fails to place sufficient emphasis on the procedures by which a local extension agent can achieve his part of the task of increasing production on farms.

The third concept of extension is that it is "education": the imparting of knowledge and the development of farmers' skills to put improved practices into use on their farms. This concept is the most appropriate of the three, partly because it leaves decision-making to farmers and partly because, while relying on research for knowledge, it does not limit extension to this aspect of the broader problem. The limitation of the "education" concept, however, is that it assumes the presence in each locality of all of the "essentials" for agricultural development: markets for farm products, local availability of supplies and equipment, adequate price incentives and appropriate patterns of tenure, and transportation facilities. It is a concept that is appropriate in an already dynamic agriculture but which ignores the realities on which the "rural vacuum" hypothesis is based and the small but important grains of truth in the assumptions underlying the concept that extension agents must "tell the farmers what to do."

*9.5.2.2. Important Roles of Extension Workers.* No abstract definition of the role of an effective extension service is applicable in all places and at all times, but the substantial role that extension can play in increasing production incentives of farmers is to be found in some combination of the various roles discussed in the paragraphs that follow.

*9.5.2.2.1 Encouraging Farmers to Innovate.* Recall that the stage of agricultural development with which we are primarily concerned is that at which farmers are still producing largely for subsistence and only partly for the market. Most of them live in regions where traditional patterns of social values and organization are still dominant.

Recall also that people living in such cultures tend to place confidence in *persons* whom they know well, rather than in impersonal ideas on statistical generalizations. In such cultures, innovation is rare, and habit and tradition tend to dominate behavior.

In such circumstances, one of the most important tasks of the extension worker is to encourage the more venturesome farmers to try new methods. To do this, the extension worker must, of course, know about, and know how to apply, methods that will raise production. His biggest problem is to persuade farmers to *try*. To do this he must establish such rapport with the more venturesome farmers that they will have faith in the new practices *because they have faith in the extension worker* and will then try the practices in their own fields despite risk, uncertainty, and disapproval or derision of their family and neighbors. To fill this role the extension worker: (1) makes farmers aware of alternative opportunities, (2) imparts the necessary knowledge and skills, and (3) *gives the farmer emotional support* in his first ventures in innovation.

*9.5.2.2.2 Imparting Knowledge and Skills.* The product which the extension worker distributes is knowledge and skill, and he does not charge farmers for it. He makes *locally available knowledge and skill with respect to specific changed practices* and "packages" of practices that have been developed and proved to be economic through research. The range of this knowledge and skill is small in the beginning, at the time when the extension worker's primary task is encouraging farmers to innovate. This range widens, and the agricultural knowledge and skills of the extension worker must increase accordingly as innovation becomes more common. When it widens to the point where the individual extension worker cannot encompass it, then he must depend increasingly on a corps of subject-matter specialists.

*9.5.2.2.3 Analyzing Farm Businesses.* One of the more difficult new skills for a farmer to learn as he moves from production for home consumption to farming for the market is farm business analysis and management. Even in a highly dynamic agriculture, many progressive farmers find it profitable to use management consultants to help them analyze and plan their operations. At the stage with which we are concerned, farmers need such help even more. In these circumstances, an extension worker can help farmers analyze their farm businesses and teach them to operate market-oriented enterprises.

*9.5.2.2.4 Reducing Risk and Uncertainty.* A competent extension worker can take an appreciable amount of the risk and uncertainty out of new innovations by farmers in his locality. He can do this by making sure that local field trials of proposed new practices are made before they are recommended to farmers for general use and by

noting the "local economics" of each practice in the light of local price relationships.

*9.5.2.2.5 Stimulating Auxiliary Services.* As extension personnel work with the farmers of a locality, they become aware of the gaps in the services locally available to farmers. There are many examples in the history of United States agriculture where extension workers took the initiative in getting farmers to organize seed associations, to join together in bulk purchases of fertilizers, and to organize cooperatives to purchase farm inputs or to market farm products. (These are examples of the kind of efforts that gave rise to the "rural vacuum" definition of the role of extension.)

These gaps also can be filled when an extension worker passes on to governmental research organizations information about special problems and unmet needs of his locality or tries to get governmental credit organizations, seed supply agencies, or other services of government to serve his locality more helpfully.

*9.5.2.2.6 Participating in Planning for Development.* In the last analysis, plans for agricultural development are only effective as they result in production increases *on farms*. We speak frequently of involving farmers in the planning process. There is a similar need to involve extension workers. Farmers know some of their own needs but extension workers know the needs of both the farmers and their localities. They may be more articulate than farmers about the strength and impact of existing traditions and values, about the efficiency of existing auxiliary services, and about the needs of their localities that are not being met. Because of this, they can make a substantial contribution to development planning.

The various roles that extension workers *can* play in strengthening the incentives of farmers to increase production are seldom all performed by any one individual. These roles are so varied that specialization and division of labor among different workers may increase efficiency. Properly oriented and trained extension workers, however, can be important *integrators* of various influences on production incentives discussed throughout this paper. An extension service alone cannot substitute for the presence in a locality of adequate supplies of production inputs, markets for farm products, favorable price relationships, or an appropriate land tenure system. Where these are present in a locality, however, a competent extension worker can *accelerate* the adoption of improved practices. Where essential factors are not present, extension workers can help identify local needs and take steps toward getting them met.

# CHAPTER 10

# MARKETING, PROCESSING, AND DISTRIBUTION OF FOOD PRODUCTS

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## Contents

| | | Page |
|---|---|---|
| 10.1.0 | Summary | 539 |
| 10.2.0 | Introduction | 540 |
| | 10.2.1 What is Marketing | 540 |
| | 10.2.2 Role of the Farmer | 541 |
| | 10.2.3 Role of the Consumer | 541 |
| | 10.2.4 Development of Marketing System To Meet Needs | 541 |
| 10.3.0 | Marketing Services Provided by Government | 542 |
| | 10.3.1 Development of Transportation System | 543 |
| | 10.3.2 Development of Systems for Quality Identification | 543 |
| | 10.3.3 Development of Systems To Regulate and Monitor Food Purity | 546 |
| | 10.3.4 Development of Market Information System | 546 |
| | 10.3.5 Public Storage | 547 |
| | 10.3.6 Marketing Research and Education | 547 |
| | 10.3.7 Encouragement of Private Investment | 548 |
| 10.4.0 | Marketing Services Provided by Private Investments | 548 |
| 10.5.0 | Post-Harvest and Post-Slaughter Losses in Developing Countries | 549 |
| | 10.5.1 Causes of Food Losses | 550 |
| | 10.5.1.1 Micro-organisms | 550 |
| | 10.5.1.2 Insects | 550 |
| | 10.5.1.3 Rodents | 551 |
| | 10.5.1.4 Mycotoxins | 552 |
| | 10.5.1.5 Improper Maturity | 554 |
| | 10.5.1.6 Mechanical Damage | 554 |
| | 10.5.2 Significance of Losses | 554 |



PREVIOUS PAGE BLANK

Page

10.6.0 Discretionary Channeling Use of Food Resources ---- 556
10.7.0 Food Protection Technology ---------- 556
10.7.1 Importance of Food Preservation ---------- 556
10.7.2 Methods of Food Protection ---------- 557
10.7.2.1 Dehydration ---------- 557
10.7.2.2 Refrigeration ---------- 558
10.7.2.3 Heat Sterilization ---------- 559
10.7.2.4 Radiation ---------- 559
10.7.2.5 Fermentation, Brining and Smoking ---- 559
10.8.0 Utilization of Food Protection Techniques ---------- 559
10.8.1 Home and Community Storage and Processing ---- 560
10.8.2 Industrialization of Storage, Processing, and Distribution of Foods ---------- 561
10.9.0 Development and Marketing of New Food Products ---- 563
10.9.1 Creation of High Protein Foods ---------- 564
10.9.2 Collection and Processing of High Protein Food Components ---------- 565
10.9.3 Development of Consumer Demand ---------- 565

# 10.0 MARKETING, PROCESSING AND DISTRIBUTION OF FOOD

## *10.1.0 Summary*

The improvement of food storage, processing and distribution systems in the developing nations is as important as increasing production. The encouragement of private investment to develop facilities for storing, processing and distributing foods deserves a high priority. Governments of developing countries must provide a climate hospitable to the kinds of private enterprises that can stimulate change from a subsistence oriented farming economy to a market-oriented one.

In the subsistence farming economies of developing countries a small fraction of the food produced by a farmer gets into market channels outside the community in which it is produced. In the developed countries, the farmer selects crops for production that are in greatest demand in the market place. One system emphasizes production of crops to provide food for the farmer and his dependents, while the other system emphasizes production of crops that provide the farmer with the greatest cash return. The latter system encourages increased production, but it can operate only in conjunction with a highly developed marketing system.

The factors that induce a change to a market-oriented agriculture are: (a) services that can be provided by government; (b) private investment in facilities and organizations to collect, store, process, and distribute farm products; and (c) consumers with money to buy the foods required to meet their nutritional requirements.

The services provided by government for a market-oriented agriculture will change as marketing systems develop. In the early stages, minimal requirements are a usable transportation system, a simple system of quality and quantity identification, a means for communicating market information, and an official attitude that will encourage private investment. Later, more sophisticated regulations, market information systems, and institutions for market research and education will be required.

One of the serious problems inherent in a subsistence farming economy is the loss of valuable food after it is harvested. Losses caused by microorganisms, insects, rodents, and other factors are not accurately known, but distribution of 10 to 30 percent of some crops has been re-

ported in certain areas. The reduction of such losses in grains by better storage facilities is an immediate necessity. As rapidly as possible improved food protection practices should be applied to highly perishable products such as fruits, vegetables, meats, and dairy products. The application of superior storage and preservation techniques will require a shift to large scale operation to be economical. Conservation of available foods by adaptation of existing procedures is a practical way to quickly increase world food supplies.

The urgent need for high protein foods for preschool children, necessitates a major effort to develop, process, and distribute foods of this kind. The development, production and distribution of high protein food products should be performed by private enterprise. Governmental and private organizations should collaborate on the development of model marketing systems that could gradually be expanded, developed, and adapted to less specialized foods for other segments of the population.

## *10.2.0 Introduction*

Food requirements of an existing or a projected population and food production capabilities of a nation can be estimated with fair accuracy, both in terms of existing technology and anticipated developments. A third factor that affects food supplies is the effectiveness with which the marketing system distributes available food to consumers.

### *10.2.1 What is marketing*

In the United States the agricultural marketing system collects $37 billion worth of products from 3.5 million farms, and transports, stores, processes, and distributes these agricultural products to both domestic and foreign consumers. The system provides every United States citizen with a great variety of food, in adequate amounts, at desired times, and at reasonable cost. It performs this function through an orderly arrangement of processes and techniques operated by private enterprise, augmented by government services, and supervised by government agencies. The United States agricultural marketing system operates in an environment in which only 6 percent of the population lives on farms. After our farm products enter the marketing system an additional 10 million people are involved in transporting, processing, financing, selling, and delivering these products to consumers. Their services raise the value of agricultural goods to about three times the initial farm price. The marketing of farm products is based on a rapid and reliable system of market information and quantity and quality standards provided by federal and state governments.

In the subsistence agricultural economy characteristic of the developing countries, the services provided by the marketing system to the farmer and to the consumer are very simple. Adequate storage, processing, and distribution facilities are not available. The absence of a marketing system is as great a barrier to improved nutrition as poor agronomic practices.

The alternatives available to correct the situation in the developing countries are (a) upgrading the subsistence farming system, or (b) increasing production and creating an adequate system of marketing. The second alternative is the only acceptable solution and promises the greatest rewards. It also promises to be costly and complex. Requirements will differ from country to country and the building process will require new skills, new investments, and new public and private institutions.

### *10.2.2 Role of the Farmer*

In the subsistence agriculture practiced in India, 80 percent of the population is rural and 65 to 70 percent of the grain produced is utilized locally. The farmer produces primarily to meet his immediate requirements and only secondarily to generate cash. In the developed countries farmers tend to specialize in crops that provide the greatest financial return. It is often only a coincidence if his crops provide food for his immediate consumption.

### *10.2.3 Role of the Consumer*

The complexity of a marketing system is conditioned by many factors. One of the most important is the consumer's ability to purchase the kinds and amounts of food needed to meet his basic nutritional requirements. In developing countries a large segment of the population simply cannot afford to buy the needed food. If consumer prices are maintained at levels based on ability to buy, the farmer has no incentive to produce much in excess of his actual needs. To encourage increased production, farmers must become market-oriented and a larger segment of the population must increase its purchasing power by increasing productivity in some non-farm activity.

### *10.2.4 Development of Marketing System To Meet Needs*

Marketing systems must be organized to reduce waste and spoilage, to provide fast and effective distribution, and to provide modern storages that can serve as reservoirs both on a seasonal basis and for longer periods of time to smooth out fluctuations in annual production. Food protection practices employed within the marketing system should conserve existing supplies and promote innovations that will provide the consumer with dependable supplies of wholesome and nutritious food.

It is unlikely that a more effective marketing system will reduce food costs to the consumer. The ability of the consumer to afford the quantity and quality of food needed will require an increased earning capacity. An alternative would be some sort of financial assistance to farmers or to consumers, but such assistance would tend to dull the incentives built into a market-oriented agricultural economy.

For the immediate future attention should be given to better protection of presently produced plant and animal products. In the initial stages emphasis should be placed on preservation of food grains. Later attention should be given to more perishable products such as fruits, vegetables and meats. The food processing industry should concentrate on the development, production and distribution of high protein foods that will meet the needs of pre-school children. Innovations are needed to develop products with greater appeal for children and to develop the kinds of marketing plans that will create a demand consistent with actual need. Highly acceptable high protein foods for pre-school children have not yet been developed. Development of acceptable products could serve as the catalyst for a growing food processing industry and accelerate the development of other key parts of the marketing system needed for a market-oriented agriculture.

### *10.3.0 Marketing Services Provided by Government*

"Marketing is as critical to better performance in agriculture as farming itself and should be regarded and developed as such. Government has the primary responsibility for providing the essential elements of the infrastructure required for an efficient marketing system." [1]

Among these "essential elements" for which government has a primary responsibility in the early stages of a developing economy are a good transportation system, a market information system, a system of quality identification and public storages to supplement private storage. Government also should develop research and education facilities related to marketing and adopt policies that will encourage private investments in an effective system for assembling, processing, and distributing food supplies.

These government responsibilities imply viewing food marketing as an essential and productive part of the economic system that "adds value" in the same sense as the production of food products on farms. Government should do everything possible through research, education, service, and regulation to promote the most efficient marketing

[1] Hapgood, D. (ed). Policies for promoting agricultural development, report of a conference on productivity and innovation in agriculture in the underveloped countries. Cambridge, Center for International Studies, Massachusetts Institute of Technology, 1965. 321 pp.

system at lowest possible cost. It should be recognized that greatly improved marketing services will be required to achieve the necessary enlargement of markets for farmers in most developing countries.

Some food processing industries operate most effectively if they are located in rural areas. Government policies to encourage and facilitate the development of essential marketing capabilities for assembly, processing, and distribution of food materials can correct some of the rural-urban migration problems by providing employment to surplus rural labor.

Governments of developing countries must give particular attention to the kinds of marketing services that are compatible with other segments of the economy. Likewise, marketing services must be geared to the production and quality of raw and processed products and to the incomes, needs, and desires of the nation's consumers. The role of government in developing countries may be very different than that of the United States government during the frontier expansion period. Governments of developing countries must work with private enterprise and build on the existing structure of agriculture and commerce rather than create entirely new marketing facilities.

### *10.3.1 Development of Transportation System*

Roads, waterways and railroads are needed to move raw and processed food products from field to factory, to consumers and for the movement of production inputs (fertilizers, pesticides, fuels, and other supplies) to farms. Transportation facilities are a prime necessity for the development of specialization in production and in marketing. Some productive areas, in terms of fertile soils and favorable climatic conditions, are not being used advantageously because suitable transportation facilities do not exist. "A program of road expansion in Mexico resulted in a substantial increase in grain and fruit production in the regions the roads serve and has contributed generally to development." [2]

In the development of a transportation system, particular attention should be given to arterial and feeder roads, rail lines and waterways that will minimize costs of moving foods and supplies between productive agricultural areas and industrial communities. Very simple improvements such as the use of pneumatic tires on carts or the development of relatively primitive feeder roads may yield the greatest economic return per dollar of investment.

### *10.3.2 Development of Systems for Quality Identification*

In a subsistence farming economy farmers have relatively little to sell and produce is marketed and consumed locally. Visual inspection

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[2] Finner, W. F., Problems in marketing. U.S. Dep. Agr. Yearbook of Agr., 1964: 581–584. Reference p. 582.

by the buyer is the only basis for determining the quality of produce. In a market-oriented economy the farmer and the consumer may be separated by great distances. The farmer must rely on others to market his produce. An essential requirement of such a marketing system is a basis for communications between buyer and seller who may be separated by both distance and time. The produce may be changed in form by processors and packaged in containers that render visual inspection impractical. When any part of agriculture emerges from the subsistence level, government must develop a system of quality identification.

There are different bases of quality identification including specifications, standards, grades and labels.

*Specifications* are used to describe and identify specific attributes of products. They provide detailed, technical descriptions of the product that is acceptable to the buyer. In developing economies specifications may consist of very general designations of a product, defining its attributes only broadly.

*Standards* provide for uniformity of specifications; they are established by governmental agencies as minimum acceptability levels for trading or for health and sanitation reasons.

*Grades* are used to group a supply of products according to defined ranges of attributes, specifications, or use characteristics. Products in each grade grouping generally are acceptable from a health and sanitation standpoint. In contrast to standards, grades usually are the result of voluntary agreements between buyers and sellers.

*Labels* provide quality information as an assurance to traders and consumers that minimum standards have been met. Labels also are an important aid to private firms in establishing product differentiation.

The U.S. Department of Agriculture administers a number of laws that have been developed to facilitate marketing processes. Some of these laws are permissive and other are mandatory. The Grain Standard Act establishes official standards for grades of grain. It does not prohibit sale of grain that has not been graded, but requires that graded grain be inspected by an authorized person for compliance with specifications. Similar standards are provided for grades of fruits, vegetables, meat, poultry, and dairy products. An official inspection of meat and poultry for wholesomeness and adulteration is mandatory for movement in interstate commerce. Another law provides inspection and authorizes standards of quality and specifications for containers. The Warehouse Act licenses warehousemen storing agricultural products and thus provides protection for producers whose property is being stored. A Seed Act requires labeling of agricultural seeds for kind and variety, weed seed content, and percent germination.

Changes in quality identification criteria and methods should be

gradual. There should not be abrupt and complete rejection of criteria and methods currently used for quality identification.

The first standards that must be established by a government is a uniform system of weights and measures. Other essential standards are sanitation and adulteration minimums designed to protect consumers from impure or unhealthy foods. Minimum moisture standards for grains can have a large and immediate impact by providing a basis for reducing grain spoilage in storage.

The government must establish rules regarding the kinds of information put on labels. It must also provide a means for arbitration and settlement of disputes among buyers and sellers relating to standards and specifications.

Grading services, such as those provided in the United States, may have a low priority in the early development of a marketing system. Grades that differentiate products in a very refined manner are useful if consumers are sufficiently affluent to pay the higher prices that superior grades of produce demand. In some countries efforts to establish a grading system for fresh meat have not been successful because consumers were either unwilling or unable to pay higher prices for the superior portion of the supply.

Special attention to quality identification is necessary to compete effectively for export markets. More sophisticated grading systems and more restrictive standards may be needed for produce moving to export markets than for produce intended for domestic consumption. Efforts such as the United Nations Codex Alimentarius Commission, designed to establish uniform international standards, should be encouraged to aid developing countries which depend on foreign exchange developed from agricultural exports.

It is important that a government provide the integrity necessary in a marketing system by arbitrating differences that arise in the marketplace. The government must consult with producers, processors, and consumers to determine the definitions and procedures that will fit needs in the marketplace. Quality identification should be viewed as an instrument to facilitate innovation on the part of industry (e.g., the development of brands of products) not as a restrictive instrument.

Quality identification systems can improve consumer food standards because buyers are provided with a method of communicating their choice to the producers. Quality identification functions as an effective incentive to farmers by providing a pricing system that rewards producers delivering the most desired grades, qualities and varieties of produce. Quality identification systems may reduce food loss by enforcing minimum moisture standards for stored grain. The quality identification system may also be useful for the conduct of government programs to accelerate agricultural development.

### *10.3.3 Development of Systems To Regulate and Monitor Food Purity*

Government agencies also conduct activities that directly affect marketing systems and, ultimately, the welfare of the consumer. The regulation of agricultural pesticide use and the monitoring of agricultural products for toxic residues after they enter the marketing system are examples of this type of activity.

In some developing countries the regulations affecting use of pesticides and the tolerances established for toxicants in raw products are patterned from the laws and practices of developed countries. While there is an obvious need for food free of toxic substances, great care must be exercised not to impose restrictions that are unrealistic. Educational programs must be conducted to inform farmers of the dangers of improper use of pesticides before regulations are adopted. It may be desirable to consider the dangers of food shortages in comparison with the dangers from toxic residues.

Other regulations affect the kinds of food additives that are used to facilitate processing or to affect keeping quality of finished products. In some developing countries the use of hexane for extraction of oil from seeds is prohibited. This regulation prevents use of some modern processing techniques with oil seeds.

While a certain amount of regulation is essential for maintenance of food purity and wholesomeness, these regulations should not be developed at a pace inconsistent with other phases of the economy. Thus, the need for food and education among producers, processors, and consumers should be satisfied before comprehensive regulatory systems are initiated.

### *10.3.4 Development of Market Information System*

An important adjunct to a quality identification system is the development of market reports for communicating news to growers, processors, and distributors. Market information may consist of news about prices and supplies, production estimates, disappearance estimates, and other information necessary to coordinate production and marketing decisions.

Market information capabilities should be developed gradually. Initially only basic kinds of information will be required. When agriculture moves from a subsistence orientation to a market orientation, information about markets and the dissemination of this information will become necessary. The cooperation of private and public agencies is essential for a satisfactory market information system.

Initial attention should be given to the development of reliable estimates of production and supplies of food products on a national basis. This information will be essential for effective planning by both

private and public agencies. Daily or weekly reporting of prices and supplies in single markets should be initiated only when conditions make such refinement necessary.

The availability and conditions of credit to producers may be significant market information. In many developing countries farmers must deliver their produce to creditors as a condition of obtaining credit. The government may need to give concurrent attention to policies and programs related to credit and market news programs. To effectively use market information, the farmer must have options to exercise in selecting the place, time, and buyer of his produce.

The importance of confidence in market news and information reports cannot be overemphasized. Statistical methods and procedures used must be independent of government programs. Basic data must be collected and distributed on a completely objective basis.

### *10.3.5 Public Storage*

As indicated elsewhere in this report, losses of grains after harvesting are extremely high in many developing countries. The quality and amount of available grain can be increased by providing proper storage. Construction and operation of storage facilities will also provide the basis for a more stable market by making it possible to avoid gluts and shortages.

A joint public-private effort may be necessary to obtain the desired storage facilities. Initially the government might build public storages and provide technical assistance and other incentives to encourage private firms and farmers to improve their facilities for storing, drying, and cleaning grain. For the long-term, storage facilities should be owned and operated by non-government agencies.

### *10.3.6 Marketing Research and Education*

Research and education are important for the development of modern marketing. In the early stages of development, total resources devoted to production may predominate, but this situation should change as demands on the marketing system increase. For balanced development of a developing nation's resources, a substantial investment must be made in research and education related to processing and distribution.

It is desirable that the concept of educational services be broad enough to include the small traders in developing countries. Initial educational efforts should be directed to understanding elemental market mechanisms followed by consideration of existing institutions and their members.

Reorientation, through educational efforts to an emphasis on a low-price and high-turnover system will be needed before a satisfactory marketing system can be constructed.

Research can perform a vital role in identifying the bottlenecks that will arise in the emerging marketing systems. Primary attention should be given to these problem areas.

Another approach by government should be encouragement of an inflow of managerial talent from developed countries. Such people working at local levels can contribute to both formal and informal education in schools and industry.

*10.3.7 Encouragement of Private Investment*

Because of urgencies that exist in the developing nations, their governments will need to become more involved in the development of markets and market facilities than might be desirable under more favorable circumstances. The most critical factor will be the business climate created by government. Factors conditioning this climate are confidence in stablity of government, integrity, official attitude toward development of private enterprise, and non-confiscation policies with respect to foreign investments and profits. Regulation of credit and sound fiscal and monetary policies are examples of key requisites for creating a good business climate.

Because a good business climate cannot be established easily in developing economies, the United States and other developed countries may need to help create this environment. This might take the form of guarantees or insurance plans to protect selected foreign investments against losses.

If a government continues to perform certain functions after private investors are capable of taking them over, private enterprise will be prevented from making improvements that are necessary for a dynamic market economy. Government must assume an aggressive role in "priming the pump", but it should not be the permanent supplier of the water.

### *10.4.0 Marketing Services Provided by Private Investments*

Allocation of responsibility for certain parts of the marketing system to private enterprise and other parts to the government cannot be done on a formula basis. The marketing system can be wholly dominated by government as in Russia or Red China. It is apparent that this domination has failed to motivate either individuals or organizations to increase productivity. Presumably, a marketing system entirely devoid of government involvement also would not be in the best interests of a nation. Experience has indicated that some portions of the marketing system can best be performed by public agencies and other parts by the private sector. In this section an attempt is made to examine the segments of the marketing system that private investment is able to handle best and some of the factors that condition this ability.

In a favorable economic and political climate, private enterprise can stimulate competition, reward innovation, and motivate a continuous search for better ways to utilize capital profitably. Where a hospitable climate exists for private investment and capital is available, investment opportunities tend to be developed rapidly and in a logical sequence with respect to the needs of the economy.

The facilities for collection, processing, and distribution of farm products in many developing countries are entirely inadequate to meet consumer needs in a marketing economy. So long as most farm products are consumed locally and production is low, the system can handle the small surplus that reaches the market.

If farm production were increased 50 percent as seems technically possible, and if food protection were exploited to conserve what is produced, the marketing systems would need to be expanded greatly. As demand for food increased, capital could be mobilized for investment in the physical facilities required to meet domestic needs and export opportunities. Capital cannot be attracted unless a receptive investment climate exists and there are good opportunities for suitable, financial return on investments.

The opportunity for an acceptable return on capital invested in facilities for collecting, storing, and processing food is dependent upon the existence of domestic or export markets. The appearance of active markets will quickly be followed by the development of required physical facilities and their presence will be further manifested in the form of an increased demand for farm products. The missing element in this chain in developing countries is the low productivity and hence the low purchasing power of most consumers. Their needs for food cannot be transformed to a demand because they lack money with which to purchase the needed food.

Some developing countries have controlled markets for some agricultural products to depress food prices to levels the population can afford. The same countries have utilized foods from developed countries to keep prices at low levels. These measures have discouraged private investment in the marketing system.

### *10.5.0 Post-Harvest and Post-Slaughter Losses in Developing Countries*

One of the functions of food marketing systems is the collection of produce from farmers, the processing and storage of these materials and, finally, the distribution of foods to consumers. It is important that the system operate efficiently and that food losses, both in terms of quantity and quality, be kept at a minimum. The nature and extent of these losses are important reasons for consideration of changes in the marketing systems and marketing techniques.

### *10.5.1 Causes of Food Losses*

Losses in food supplies following harvest of crops and slaughter of animals occur because initial quality is poor or because of improper or inadequate treatment during the marketing process. The initial quality of food resources is affected by climatic conditions, production practices, the prevalence of insects and diseases, and other factors. The extent to which the initial quality is retained is conditioned by handling, storage, processing, transportation, and distribution procedures. Some of these factors are discussed below and where possible, data have been presented to illustrate the significance of each kind of loss.

*10.5.1.1 Micro-organisms.* A large number of pathogenic bacteria, fungi, and viruses attack fruits and vegetables causing spoilage or blemishes after harvest. Following unfavorable growing conditions such post-harvest diseases may become unusually severe. Physiological disorders also cause storage problems. At harvest, most food grains are contaminated with a wide variety of micro-organisms. The organisms most likely to cause deterioration in grain are fungi that become active when the moisture content of the grain or the atmosphere is too high. Moldy grain is unsatisfactory for food or feed. It is costly to mill and it may contain toxic materials injurious to humans and animals. The viability of moldy grain is impaired, rendering it useless for seed purposes. The quality of oil and seed protein is affected when oil seeds become moldy. The high atmospheric temperatures and the high relative humidity of the wet tropics are particularly conducive to mold development. FAO has estimated that 1.0 percent of the world's grain production is lost from mold activity.[3]

The rapid spoilage associated with highly perishable foods, such as fruits, vegetables, meats, and other animal products, is also caused by micro-organisms. The extent of losses sustained by such highly perishable food is unknown for developing countries. It is probably very large because facilities for short-term storage under refrigeration or long-term storage by appropriate techniques are not available. Highly perishable foods tend to be consumed seasonally and locally. Animals may be moved long distances on foot and slaughtered under primitive conditions where there are no facilities for utilizing by-products. Lack of refrigeration commonly necessitates consumption of meat within 24 hours of slaughter.

*10.5.1.2 Insects.* In warm, humid climates insect infestations in grain may begin in the field, and additional species of insects appear after the grain is stored. Studies in Louisiana have shown that 10 percent

[3] International Symposium on Mycotoxins in Foodstuffs, Massachusetts Institute of Technology, 1964. Mycotoxins in foodstuffs, proceedings. Cambridge, Mass., M.I.T. Press, 1965. 291 pp.

of corn kernels may be infested at harvest time. After six months storage the infestation may increase to 17 percent, and after nine months more than 30 percent of the kernels may be attacked.[4] The record of farm storage efficacy in developing countries is meager and contradictory. It is reported that Bantu tribes in Southern Africa have stored sorghum safely for four years in mud-plastered baskets. In Cameroun, farmers' storages for sorghum, peanuts, corn and beans were not infested until purchased food grains were stored in the same facilities.[5] A study of grain storage in underground mud-brick ghattis of India showed that deterioration occurred in these structures.[6]

Available data on storage losses in developing countries from insects can be divided into two categories: (a) estimates based on controlled experiments, and (b) estimates based on surveys and expert judgment. Losses based on experimental evidence obtained in different parts of Africa are shown in Table 10–1. Losses of a similar magnitude have been reported for other tropical countries. Estimates of losses in India and Africa at different points in the storage and marketing system are shown in Table 10–2. Weight loss is the usual basis for reporting, but this can be misleading because in some cases insect fragments, frass, and other debris were not removed. The loss of rice in Sierra Leone, for example, rose from 25 to 41 percent when this correction was made. Some insect species preferentially attack the germ and thus destroy a disproportionate amount of nutrients. For these reasons figures in Tables 10–1 and 10–2 may considerably underestimate losses in nutritive value.

*10.5.1.3 Rodents.* Rats are a serious pest to the farmer and storage operator. Individual rats consume 20–30 grams of dry food daily and their caloric consumption is 6–8 times as great and food consumption 16 times as great as humans in terms of body weight. In addition to the amounts of food consumed, large quantities are contaminated. Rats feed on grains, dried fruit, peanuts, oil and many partially and fully processed foods.

In India, rodents are reported to cause losses of up to 20 to 30 percent of stored grains.[7] [8]

Losses in other tropical areas range from 5 to 60 percent. In some regions losses fluctuate, depending upon sudden and unexplained rat population explosions. World-wide, it is estimated that 33 million

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[4] Floyd, E. H., Oliver, A. D., and Powell, J. D., Damage to corn in Louisiana caused by stored-grain insects. J. Econ. Ent. 52(4) : 612–615. August 1959.

[5] Nonveiller, G., Storage problems in North Cameroun (abstr.). Food & Agr. Org. United Nations Plant Prod. and Protect. Div. Grain Storage Newsletter & Abstrs. VII(3) 49. 1965.

[6] Hapur. Grain Storage Research and Training Institute. Progress report (1958–62). India, Ministry of Food and Agriculture.

[7] Dykstra, W. W. Seminar on Rodents and Rodent Ectoparasites. WHO October 1966, Geneva, Switzerland.

[8] Ahiya, S. S. All about Rats. Farmer (Bombay), 12(10) : 3–5. October 1961.

TABLE 10-1.—*Storage losses caused by insects for 5 crops in Africa based on experiments*

| Commodity | Weight loss [a] Percent | Storage period months | Country |
|---|---|---|---|
| Corn | 23.1 | 6 | Kenya.[1] |
| | 9–22 | 7 | Uganda.[2] |
| | [b] 7(14) | 24 | Nyasaland.[3 4] |
| | 8.8 | 5 | Southern Rhodesia.[5] |
| Sorghum | 50 | 12 | Congo.[3 4] |
| | [b] 19.7(23) | 11 | Tanganyika.[6] |
| Beans | 20 | 12 | Congo.[3 4] |
| | 13.3 | 5 | Southern Rhodesia.[7] |
| | 6–7 | 6 | Uganda.[7] |
| Peanuts | 15 | 12 | Congo.[3 4] |
| | 4.5 | 12 | Nigeria.[8] |
| | 3.0 | ---------- | Gambia.[9] |
| Rice (parboiled) (rough) | [b] 25(41) | 12 | Sierra Leone.[10] |
| | [b] 4–5(14–15) | 12 | West Africa.[11] |

[a] Based on results of untreated controls.

[b] Insect fragments and trash removed.

[1] Kockum, S., Control of insects attacking maize on the cob in crib stores. East African Agr. J. 23(4): 275–279. April 1958.

[2] Davies, J. C., Experiments on the crib storage of maize in Uganda. East African Agr. J. 26(1): 71–75. July 1960.

[3] Meeting of specialists on stored food products, Salisbury, 1957. London, C.C.T.A., 1958. 200 pp. (Scientific Council for Africa South of the Sahara. Publication No. 31).

[4] Hall, D. W. 1963. FAO Informal Working Bulletin No. 24, 176 pp. NAL°.

[5] Cockbill, G. F., Investigations on the control of insect pests of stored grains and pulses. Rhodesian Agr. J. 50(4): 294–323. July/August 1953.

[6] Tanganyika Territory. Department of Agriculture. Entomologists' report, 1937. Dar es Salaam, 1938. 8 pp.

[7] Davies, J. C., A note on the control of bean pests in Uganda, East African Agr. J. 24(3): 174–178. January 1959.

[8] Howe, R. W., Entomological problems of food storage in northern Nigeria. Bull. Entomol. Res. 43 (Part 1): 111–144. March 1952.

[9] Hall, D. W., The quality of groundnuts from the Gambia with special reference to insect infestation. Colonial Plant & Animal Products 4(3): 227–235. 1954

[10] Prevett, P. F., An investigation into storage problems of rice in Sierra Leone. Great Brit. Colon. Office Colon. Res. Study No. 28, 1959. 52 pp.

[11] Hall, D. W., Problems of food storage in tropical territories. Ann. App. Brol. 42: 85–97. February 1955.

tons (3.55 percent of the 1961–62 production) of bread grains and rice are lost to rodents each year.[9]

*10.5.1.4 Mycotoxins.* Some species of fungi that normally occur on stored grain and oil seeds produce toxic substances that have been implicated in human and animal diseases. One such toxic material is aflatoxin, a heptatoxin and a carcinogen to certain mammals and fish. It has been found in peanuts grown throughout the world, but it occurs most commonly where warm, moist post-harvest conditions prevail. This problem has limited the use of this protein-rich seed for food and feed purposes. It has created economic problems in develop-

[9] Ling, L. Man Loses a Fifth of the Crops He Grows. Atlantic, Special Issue for FAO for Freedom from Hunger. 1961.

TABLE 10-2.—*Storage losses caused by insects for several crops in Africa and India based on survey data* [1]

| Place of storage and commodity | Apparent loss (in percent) | | Storage period (months) | Country |
|---|---|---|---|---|
| | Average number of damaged grains and kernels | Average weight loss | | |
| Producer storage: | | | | |
| Beans | 38-69 | 6 | 6 | Uganda. |
| Do | 3.6 | | 4 | Northern Rhodesia. |
| Do | 80.7 | | 12 | Do. |
| Cowpeas | 13.0 | | 4 | Do. |
| Do | 81.6 | | 12 | Do. |
| Corn | 0.3-30.6 | | 12 | Matabeleland. |
| Do | | 20+ | 8 | Ghana. |
| Do | 30-50 | | 5 | Dahomey. |
| Do | 30 | | 5 | Togoland. |
| Do | 45-75 | 20+ | 7 | Uganda. |
| Do | 90-100 (30 and 40) | | 12 | Northern Rhodesia. |
| Corn (cobs) | 5-10 | | 12 | Ivory Coast. |
| Millet (finger) | 0 | | 12 | Matabeleland. |
| Bulrush (or pearl) | 15 | | 12 | Do. |
| Sorghum | 0.3-29.0 | | 12 | Do. |
| Sorghum (unthreshed) | 3.78 | 1-26 | 9 | North Nigeria. |
| | 2.33 | 0-13 | 6 | Do. |
| | 2-62 | 3-13 | 14 | Do. |
| Sorghum | 11-88 | 6-37 | 26 | Do. |
| General produce | | 5 | | India. |
| Trader storage: | | | | |
| Beans | 35-44 | 6 | 12 | Uganda. |
| Corn | 20 | | | Togoland. |
| Do | | 5-10 | 6 | Uganda. |
| Do | 16.7 | 4 | 3 | Do. |
| General produce | | 10-15 | 12 | Zanzibar. |
| Central depot storage: | | | | |
| Corn | | 5-6 | 11 | Southern Rhodesia. |
| Do | | 12-19 | 24 | Do. |
| Do | 35-38 | 10 | 9 | Uganda. |
| Rice (rough) | | 11-12 | 9 | India. |
| Rice (milled) | | 13 | 9 | Do. |

[1] Source of data: Hall, D. W. 1963. FAO Informal Working Bulletin No. 24, 176 pp. NAL°. Rice in India, A Techno-Economic Review. Mysore, Central Food Technological Research Institute, 1965. 27 pp. Report of the Working Group for the Formulation of the 4th 5-year Plan Proposals on Plant Protection, Ministry of Food and Agriculture, Government of India.

ing nations which had good export markets for peanuts and peanut meal for animal feed. No completely adequate solution has been developed for the aflatoxin problem.

Toxins produced by fungi are important only when environmental conditions are favorable for growth of the fungi. Favorable conditions are generally high relative humidity and unsanitary storage situations. Species of *Fusarium*, *Aspergillus* and *Penicillium* have been associated with production of mycotoxins in cultures or on feeds. Strains of *Aspergillus flavus* produce aflatoxin at maximum levels at 23 to 25 degrees C. A shift of 6 degrees will reduce toxin production

markedly. In addition to peanuts, mycotoxins have been found in cottonseed and rice among the food crops.

*10.5.1.5 Improper Maturity.* Mandatory maturity standards are used for fruits and several other crops in the developed countries because immature produce has poor flavor and lower nutritional value. Immature grain and pulses have a high moisture level and are more susceptible to spoilage from micro-organisms. Immature grain may shrivel and be of low nutritional value.

Over maturity also tends to increase susceptibility of plant products to spoilage. The importance of maturity is particularly apparent in the case of peanuts. Peanuts that remain in the soil too long are more likely to be invaded by the fungi that produce aflatoxin.

*10.5.1.6 Mechanical Damage.* Bruising and other kinds of mechanical damage tend to accelerate deterioration in storage. For example, hand picking citrus fruit, rather than mechanical clipping, facilitates the entry of fungi that induce storage diseases. Injury and cracking of seed coats of grain and oil seeds increase their susceptibility to invasion of insects and micro-organisms. Injury of this type may reduce viability of seeds to be used for planting purposes substantially.

*10.5.2 Significance of Losses*

In the developing countries, grains are the major food. In Asia, grains provide 70 percent of the food supply, in Africa, 45 percent, and in Latin America, 50 percent of the food supply. Potatoes, yams, cassava, pulses, and peanuts are the other important items in the food supplies of Africa and Latin America.

Inadequate storage facilities and poor storage practices result in massive losses of grains from spoilage, contamination, and deterioration. Surveys in India show minimum storage losses from all causes of 10 percent for cereals and oil seeds, 30 percent for pulses, and 12 percent for rice.[10] [11]

If only half of the estimated world loss of food grains was prevented, it would represent an additional 55 million tons or enough to make the diet of 500 million people in developing countries adequate in total calories.

Good storage practices could reduce these losses to 5 percent or less.[12] Further reduction could be accomplished by prevention of spillage, better harvesting procedures to prevent grain breakage, and more prompt delivery of grains to storages.

From a study of thousands of storage sites, the United States Department of Agriculture found that proper storage could maintain

[10] Rice in India, a techno-economic review. Mysore, Central Food Technological Research Institute, 1965. 27 pp.

[11] Food and Agriculture Organization of the United Nations. Regional Conference for Asia and the Far East.

[12] Faukner, Reed and Brown. Increasing milling returns of rice from paddy in India. The Ford Foundation, New Delhi. September 1963.

grain quality at a high level at a cost of one cent per bushel loss in shrinkage, handling and deterioration per year. To keep losses at this level required an expenditure of five cents per bushel per year for maintenance, operation and fixed expenses. These data illustrate the cost and the effectiveness of proper storages and probably are indicative of the results that might be achieved in developing countries. A simple system for bean storage in jute bags fitted with a plastic film liner and treatment with ethylene dibromide would cost less than 2 percent of the value of the beans stored.

Another source of loss in developing countries is the use of primitive processing techniques. Primitive cane crushers leave up to 50 percent of the sugar in the bagasse. Hand-pounded rice has a high percentage of cracked kernels. In some areas of India a third more rice could be secured by replacing antiquated rice mills.[13]

One of the most commonly quoted estimates of world-wide losses for all cereals, pulses and oilseeds is the 10 percent figure provided by FAO.[14] A United Nations estimate gave losses as high as 35 percent in six Latin American countries from insects in stored cereals and pulses.[15] An AID report from Brazil indicated losses of 15 to 20 percent in stored grains.[16] Storage experts familiar with conditions in Africa indicate that one-third of the harvested cereal is lost to pests.[17]

The shortage of suitable transportation and lack of refrigeration leads to poor utilization of locally produced fruits and vegetables. In developing countries as much as 50 percent of the harvested fruits and vegetables are lost from spoilage in market channels. Losses of meat, poultry, fish and dairy products are not adequately reported, but indications are that they amount to 15 to 25 percent.[18]

In one state in India where losses of fruits and vegetables range from 25 to 60 percent, utilization of the material produced would supply an additional 3 ounces of fruits or vegetables per person per day.[19]

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[13] Faukner, Reed and Brown. Increasing milling returns of rice from paddy in India. The Ford Foundation, New Delhi. 1963.

[14] FAO Expert Committee, 1946. Report Nu/Wa. WP 3.

[15] Joint ECLA/FAO Working Party. Agricultural requisites in Latin America [Rev. 1]. Lake Success, United Nations Dep. Econ. Affairs, 1950. 156 pp. (U.N. E/CN. 12/83, U.N. publications. 1950. II. G. 1.)

[16] Weitz-Hettelsater Engineers. Economic and engineering study-marketing facilities for grain and tuberous crops (an economic survey for ETA). Weitz-Hettel-sater, 1963. 2 volumes.

[17] Hall, D. W. FAO. Informal Working Bulletin No. 24. 1963. Jordan, R. C. U.N. Conference on the application of Science and Technology for the Benefit of the Less Developed Areas. Vol. V, Geneva, 1963.

[18] Jordan, R. C., New techniques for temperature control of perishable goods in transport and storage applicable to the less developed areas. *In:* United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas. Science, technology, and development. United States papers. Washington, U.S. Govt. Printing Office, 1962–63. Volume 5. pp. 120–132.

[19] A community canning and food preservation project. Food & Agr. Org. United Nations. Expanded Tech. Assistance Program FAO Rep. No. 786, 1958.

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### *10.6.0 Discretionary Channeling of Food Resources*

In many developing countries there are modern marketing systems being used to assemble, process, and distribute food products for export. The development and maintenance of export markets required that valuable land, food, and processing capacity be allocated to produce for exportation. Such markets play a key role in a developing economy by generating foreign exchange with which essential purchases can be made.

In Argentina, grains are diverted to livestock production to support large meat exports. A number of tropical countries use land that could produce food for domestic consumption to produce coffee, tea, cotton, sugar cane, and other crops for export. During the past few years, Taiwan has developed an industry for canning pineapple, mushrooms, and asparagus. Exports from this industry are expected to produce approximately $71 million in foreign exchange in 1966.

While export use of a developing country's food production potential may limit domestic food supplies, there are important advantages inherent in the practice. One very obvious advantage is that it encourages specialization in production of crops that are suited to the local soils and climate. A second advantage is that it earns foreign exchange with which to further develop the economy. A third advantage is that the competition in world markets encourages the introduction and use of modern methods for production, transportation, packing, processing, and distribution.

Another discretionary use of food is the avoidance of certain foods because of customs or traditions. In India a segment of the population has religious objections to the use of meat or animal products except milk and dairy products. Nearly 10 percent of the bovine population is unproductive because of these local mores.[20] There is strong sentiment against either use or destruction of such animals despite their contribution to the scanty food supply. Such traditional prohibitions against certain foods are not likely to be overcome easily even though starvation threatens.

### *10.7.0 Food Protection Technology*

#### *10.7.1 Importance of Food Preservation*

Preservation of foods that are now lost because of spoilage or waste would very significantly increase world food supplies. It is believed that the technology of food production that exists presently is adequate to meet world needs for many years. These techniques will need to be adapted to local conditions and special situations. Forceful programs

[20] Patel, J. S., Agriculture in India—needs & prospects. *In:* World Food Congress. Summary of proceedings on agriculture. Washington, D.C., 1963. 387 pp. pp. 59–76.

will need to be initiated promptly if the available technology is to be used effectively.

Rural populations can subsist at some level on food produced locally, but urban populations depend upon the market place for their food supplies. The larger the urban population and the farther such populations are from primary sources of food, the greater the need for modern food protection techniques.

About 73 percent of the rural population in India and 16 percent of the urban population live at a subsistence level.[21] For these large segments of the population, processed foods now represent an unimportant share of their food purchases. Thus, for roughly three-fourths of the population of India there is no immediate prospect for use of processing methods if they increase food costs.

### *10.7.2 Methods of Food Protection*

Foods are preserved by creating a physico-chemical environment wherein spoilage organisms cannot grow or by sterilizing the foods in sealed containers so that they cannot become recontaminated. A number of methods are used to establish an environment in food products that is unfavorable to spoilage organisms.

*10.7.2.1 Dehydration.* Sun drying and artificial dehydration can reduce moisture in foods to levels below which microorganisms cannot grow. Dry foods are relatively stable and provide a major part of the stored food supply throughout the world. Those preserved by natural field curing in the sun (for example, cereal grains and legumes) will constitute a major food resource in the future as they do now. Immediate attention must be given to preventing losses of such foods in storage and distribution by protecting them from rodents, insects, microbial spoilage, and spillage.

Where dry foods are held in numerous small stores rather than in large centralized storages, application of technical knowledge is difficult. Grain-handling practices vary from conditions in the Yaqui Valley of Mexico, where there is substantially no farm storage for wheat, to the subsistence-level rural economy of India, where grains and pulses are kept on the farm in quantities amounting to as much as 70 percent of India's entire food supply. Traditional knowledge for keeping grain and legume supplies dry has been passed on by generations of populations requiring such knowledge to survive.

Dry food products can be preserved more efficiently in larger storages operated by the private sector of commerce, by cooperatives, or under government control. The value of larger holdings of food can justify the cost of training skilled operators and technicians in good handling practices and the use of pesticides. Capitalization of

[21] Unpublished FAO data.

storage facilities and costs of rodenticides, fumigants, and other supplies must be met.

Suitable packaging for distributing food from storage centers to consumers involves further costs, ultimately borne by consumers or governmental subsidies. Grain and other dry foods in developing nations are distributed to many small outlets. Small quantities are sold from open sacks or bags to be carried away by consumers in their own containers. Bulk handling of dry foods may be cheaper than handling food in individual packages if physical losses in transport can be minimized. Handling dry foods in bulk and distributing them to the ultimate consumers in inexpensive paper or film packages are steps that might be taken to improve distribution of foods in urban areas, thus reducing spoilage and spillage and controlling adulteration and pilferage.

*10.7.2.2 Refrigeration.* Fruits and vegetables, animal and dairy products, and sea foods are more perishable than dry foods. Refrigeration extends the shelf-life of these foods and the distances over which they can be conveyed to markets. Refrigeration inhibits development of microorganisms and also prevents insects from damaging foods. Mechanical refrigeration is used for temporary protection of foods at reduced temperatures and for preservation of foods by freezing. The knowledge required to preserve most types of foods by freezing has been well worked out and can be applied where appropriate.

Refrigerated warehouses in the producing areas, refrigerated train and truck transport, and refrigerated storage facilities and display cabinets in the marketing areas could prevent substantial spoilage of perishable foods. Unfortunately, the development of a refrigerated marketing chain for such products would be extremely costly and is applicable only in limited areas in the developing world at this time.

Refrigerated transport implies improved highways and rail systems. Maintenance of refrigeration systems for trucks requires skilled mechanics whose availability in the near future is doubtful. Refrigerated trucks traveling on roads that are poorly maintained will require extra attention for maintenance. Liquid nitrogen refrigeration, under such circumstances, would have an advantage over mechanical systems because of an inherently simpler maintenance requirement but its present high cost would preclude its use. In one area in Brazil where the market can be reached by an overnight haul, frozen beef carcasses are shipped in insulated trucks without refrigeration. While this method is obviously much less expensive than shipping by refrigerated truck, it restricts severely the distance that can be reached from a food-producing area.

As urbanization increases, refrigeration will become more widely used and economic forces will be brought to bear to reduce its cost.

For example, in an important potato-growing area in India when only one cold storage unit was in operation in the early 1940's, rental of refrigeration space was $51 per metric ton per season. A second unit was introduced in 1946 and rental dropped to $45. Continued addition of more cold storage units reduced the cost to less than $23 in 1960.[22]

*10.7.2.3 Heat Sterilization.* Heat preservation in hermetically sealed containers (canning) provides a major means for food preservation. Costs, however, may be high. In many parts of the world, metal containers are beyond the economic resources of a large fraction of the population. Glass containers can be made with native materials and labor in many regions of the world and can be used for preserving foods in place of metal containers. Glass breakage, however, may be a considerable factor of cost. Some of this disadvantage might be overcome in areas where hand-labor could provide pads and bottle sleeves of native materials to cushion glass jars in shipping containers. New innovations, such as plastic containers, may prove particularly useful.

*10.7.2.4 Radiation.* Radiation treatment to prolong storage life of perishable foods under refrigeration, to control insects in exported fruits and vegetables and stored grains, and to preserve perishables in hermetically sealed containers is technically possible, but not yet an efficient commercial reality. Recent studies suggest that harmful radiation effects may be transmitted by stable, toxic intermediate products in foods. The significance of these studies cannot be ascertained until extended feeding studies are completed. These and other problems indicate that radiation is not likely to have a significant application for food preservation in the foreseeable future.

*10.7.2.5 Fermentation, Brining and Smoking.* Fermenting, brining, and smoking are techniques known in most areas of the world. They were all developed in prehistoric times and have been well advanced even in some aboriginal cultures. Modern technology has provided advances in control of these methods and an explanation of how they work.

### *10.8.0 Utilization of Food Protection Techniques*

In developed countries losses of dry food resources are kept at reasonable levels by use of well designed and effectively operated, large storage facilities. Rodents are excluded or controlled with rodenticides, insects are controlled by fumigation with appropriate insecticides, and moisture is held at levels to prevent spoilage from microorganisms. Spoilage is controlled by artificial drying, by deter-

[22] U.S. Department of Agriculture. Economic Research Service. Changes in agriculture in 26 developing nations 1948 to 1963. U.S. Dep. Agr. Econ. Res. Serv. Foreign Agr. Econ. Rep. No. 27, 134 pp. November 1965.

mining moisture content of each lot before storage, and by monitoring stored grain temperatures for evidence of heating. Processed dry food products are packaged to prevent damage from insects and microorganisms and to prevent spillage and waste in retail outlets or in homes.

In developed countries, highly perishable fruits, vegetables, meats, dairy products, eggs, etc., are refrigerated, dehydrated, canned, pickled, or frozen to minimize spoilage and to facilitate distribution. In terms of the purchasing capabilities of consumers, the costs are low because the necessary kinds and amounts of raw materials are available, and the knowledge and physical facilities are available to process goods efficiently. Moreover, competition among food storage operators and among food processors and market outlets has resulted in an efficient, high volume operation that functions with low profit margins.

In developing countries processed foods are a luxury beyond the purchasing capacity of most people. This situation exists for a number of reasons:

(*a*) The proper facilities are not available to store, prepare, and distribute processed foods in large quantities.

(*b*) Large volume markets are not available to support a large and efficient food processing operation.

(*c*) Dependable supplies of uniform and high quality raw materials suitable for processing have not been developed.

(*d*) Operational skills required to process and distribute processed foods are not available.

(*e*) High import duties designed to protect local industries result in increased costs for containers, processing equipment, etc.

(*f*) Distrust among people is so prevalent that large scale purchases of raw materials without quality standards would be impractical.

The organization of the public and private sectors in developed countries to provide grain storage, food processing, food distribution, research and education cannot be applied unchanged to the developing countries. Many of these programs and organizations involve objectives and techniques that are too sophisticated and too expensive to warrant consideration in developing nations. In the sections that follow consideration has been given to the kinds of food protection techniques that should be applied in developing countries and the sequence of developments that could be programmed.

### *10.8.1 Home and Community Storage and Processing*

For the farmer in India who subsists mainly on the grain and pulses that he can produce and store, the immediate problem is to protect these food resources in sufficient quantities to last until the next harvest. Rodent-proof storage bins are needed that will also provide pro-

tection against insects. If the stored grains are not sufficiently dry, the storage must have ample ventilation. The small operator cannot afford much of an investment in storage facilities and it may be more effective to develop better designed and efficiently operated facilities for community use on a cooperative basis.

Educational programs are needed to encourage the use of simple food preservation methods such as dehydration by sun drying, pickling, and preserving with sugar. Greater utilization of these techniques could increase the variety and amounts of food available in communities where shortages and surpluses occur seasonally. Some community canning projects have been initiated in India. In six communities in Uttar Pradesh, 45,000 pounds of preserved fruit were produced after the third year of operation.[23] While this is a trivial amount of food relative to needs, it is illustrative of the kind of educational program that would encourage food conservation and protection. Moreover, such programs could absorb surpluses that cannot be disposed of profitably at local markets.

### *10.8.2 Industrialization of Storage, Processing, and Distribution of Foods*

As agriculture changes from a subsistence to a market orientation, an opportunity is afforded for the markets to specialize and to expand. Local grain collecting stations ultimately must be established close enough to farms to permit delivery. The collecting agencies may be operated as a private enterprise or as a cooperative. In either case, management should be able to provide credit or payment for the grain delivered. The village cooperative or the trusted merchant buying the grain will need a basis for their transactions with farmers that will reflect quality and value of the commodity in larger markets. Factors such as moisture content and prevalence of insect and mechanical damage will be important characteristics to describe. The units of measurement will need to be established. The Government will be required to develop grades of grain and to describe these grades in terms of specifications that reflect the value of the grain for storage and for processing. The government will also need to adopt a system of weights and measures that can be used in regional, national, and international trade. With these services it becomes possible for grain or other products to be sold to remote markets in terms of units of measure and quality criteria established by an unbiased third party. If the buyer and seller can relate prices to objectively determined quality and quantity criteria, they can transact business even though separated by many miles.

At all stages in the post-harvest handling procedures, farm produce must be transported and stored in a manner that will keep losses and

[23] FAO Report No. 786. "A Community Canning and Food Preserving Project."

spillage at a minimum. There should be premium prices paid to farmers for premium quality produce and the storage system should permit segregation in terms of quality until it reaches the processor or consumer. Such price incentives will tend to improve quality and the adoption of better farming practices.

In areas where perishable products such as meat, fish, fruit, and vegetables can be produced, the marketing procedure will become complex. The first step in the development of such markets might involve transportation of surplus fresh produce to adjacent communities. Utilization of more distant markets for perishables would require transportation facilities and refrigeration. Local and terminal refrigerated storages can be used as markets expand to prolong the season of availability and to control the flow of produce that otherwise might cause gluts and excessive losses. Again, uniform and realistic quality criteria must be developed as a government service and utilized in a manner that permits buyers and sellers to conduct business with confidence. The same or similar quality criteria will be useful to consumers to identify superior produce at retail levels.

As economic conditions develop, commercial dehydration, canning and freezing plants can be constructed in areas where the quantity and quality of perishable products are adequate. Before industrial preservation can be developed, there must be reliable supplies of good quality raw material, adequate supplies of good water, processing equipment, packaging materials, fuel, waste disposal facilities, and proper storages for finished products. Distribution systems for the processed products must be developed and the consumer must be educated to use new and different foods. The development of fruits and vegetable varieties and better cultural practices to provide more dependable supplies may be major problems because processing quality criteria are often very different than the quality characteristics desired for fresh market purposes.

If costs of preserved foods are to be low enough to benefit a significant segment of the population in developing countries, the scale of operation must be large enough to keep unit costs low. Cost inputs that can be supplied domestically are generally inexpensive, but imported equipment and containers are usually costly. While governments may need to provide financial support or even operate processing plants in early stages, there is ample evidence that private enterprise will operate them more efficiently, particularly if there is competition for raw materials and for sales of finished products.

Food preservation operations on a large scale have an important advantage in that by-products can be utilized. For example, the slaughter of individual animals for immediate sale of fresh meat results in the loss of blood, bones, and other useful animal products.

These materials are recoverable for food or feed products in large slaughter houses. Primitive equipment for milling grain, for extracting cane sugar, or for pressing oil from seeds needs to be efficient to reduce losses and to permit utilization of byproducts.

The marketing, processing, and distribution of processed foods require specialized knowledge and experience. The development of personnel with technical training and experience needed in the developing countries for food processing and distribution may be as difficult as development of material resources. The kinds of knowledge and experiences that will be required include (a) production of raw materials for processing, (b) movement of materials from farm to factories, (c) processing procedures, (d) development of auxiliary supplies and services, (e) treatment and disposal of waste materials, (f) utilization of by-products, and (g) distribution and marketing of finished products. Such knowledge in the developing countries is mainly limited to a few firms exporting such items as coffee, tea and bananas.

Programs for technological training and institutions for basic and adaptive research must be developed if the needed expansion in food preservation and food distribution is to be accomplished. Attention also must be given to the development of mechanical skills that handicap the introduction of modern techniques on a large scale.

### *10.9.0 Development and Marketing of New Food Products*

It is generally agreed that a major nutritional problem of developing countries is the inability of pre-school children to obtain the proper quantities and quality of protein. This problem has attracted the attention of numerous public agencies and a number of high protein foods have been developed specifically for young children. The nutritional value of these foods has been established in laboratories and hospitals. Several commercial organizations have been interested in the possibilities of marketing these high protein foods. The experiences of some of these commercial efforts have been well documented and clearly illustrate the complexity of developing an entirely new food, constructing facilities for manufacture of such foods, and the development of consumer demand for such an unusual product.

High protein foods have been developed for commercial distribution in Guatemala, Colombia, Peru, Brazil, Nigeria, West Africa, Hong Kong, and perhaps other areas. A number of high protein products also have been developed by institutions in India, but these products apparently have not been used for commercial purposes. There are some situations where commercial concerns have been interested in high protein foods only if manufacturing and distribution rights for a specific product could be held exclusively in a nation. Even with ex-

clusive distribution rights it has been difficult to build distribution to a point where these foods have had an important impact on the quality of food consumed by pre-school children. Most organizations that have attempted to develop a high protein food business have been able to utilize an existing food distribution system, but there have been some attempts to develop a business with a high protein food product exclusively.

### *10.9.1 Creation of High Protein Foods*

It has been demonstrated by a number of research agencies that nutritious mixtures of certain oil seed meals and cereals can be prepared. These mixtures generally contain about 25 percent protein with the essential amino acids in proper balance. Vitamins and minerals have been added in some instances. It has been demonstrated that children fed these high protein foods to supplement their normal diet will be cured of severe protein malnutrition. In view of the great need for more and better proteins in the diets of pre-school children and the demonstrated effectiveness of the protein mixtures from vegetable sources, it would appear that foods of this sort should have important commercial possibilities.

One of the first considerations in the development of a high protein food is the local availability and quality of protein-rich ingredients. Oilseeds are particularly useful as one ingredient because a high protein residue remains after the oil is extracted. Oilseeds are commonly processed for animal feeds and are not handled with the care and sanitation considered necessary for human food. Such problems as excess fiber, toxic substances such as gossypol in cottonseed meal, or aflatoxin in peanuts, or antitryptic factors in soybeans, must be anticipated and corrected. Care must be taken to see that the methods used are consistent with domestic food regulations. Another large volume ingredient in the mixtures will generally be a locally available cereal such as rice, wheat, corn, milo, etc. Certain vitamins and minerals may be added as needed. The blended ingredients must result in a palatable, acceptable, and economical food that is not too greatly different from some important native food in appearance or form.

Most of the high protein foods developed to date have been designed for consumption in the form of a biscuit, liquid or semi-liquid formulation and similar forms resembling foods already in use in the countries involved. It is likely that formulation of high protein foods can be greatly improved by giving more emphasis to palatability, acceptance by children, appearance, and methods of preparation in the home. It is also likely that high protein foods should be made available in a variety of forms to avoid monotony of diet.

### *10.9.2 Collection and Processing of High Protein Food Components*

The principal ingredients in high protein foods are selected because of their nutritional value, availability and cost. Sources of each ingredient will need to be developed and it will need to be ascertained that the nutritional quality is reasonably uniform. Quality requirements of oilseeds and cereals as regards moisture content, varieties, insect damage and similar factors may be more rigid than local farmers are accustomed to meeting. This situation may require the processor to engage in grower education and to participate in the development of quality criteria or government grades to serve as a basis for purchases.

Some raw materials may have to be imported. There are only a few places where cottonseed meal is commonly available that has been treated to remove gossypol and soy beans can be grown only in the temperate climates. Government assistance will be essential so that these critical materials can be imported on a duty free basis.

Special equipment will be needed for ingredient handling, storage, processing, blending, and packaging. An investment in manufacturing plants and storage facilities for raw and finished products will be required. Government assistance may be obtained in the form of reduced import duties on equipment and reduced taxes on capital investments.

Without the proper manufacturing and marketing skills the food processing venture would have scarcely any prospect for survival. These production and marketing talents are unavailable in the developing countries and even in short supply in developed countries. The people who would do the actual manufacturing and marketing work must be selected and trained from available nationals. A consortium of companies from the developed countries might be able to provide the necessary management talent easier than a single company. Such a consortium would have the added advantage of greater knowledge of food processing and marketing in the event the initial venture should develop into a major food industry.

### *10.9.3 Development of Consumer Demand*

The successful commercialization of a high protein food has not yet been accomplished even though the basic technology has been available to create and manufacture the kinds of products needed, and it has been demonstrated that such foods will fulfill a prevalent need. There are several organizations engaged in marketing high protein foods in developing countries, but none of these products has had a dramatic effect in alleviating protein deficiencies on the large scale that will be necessary.

The programs followed by the different commercial concerns to develop consumer demand have been similar. These programs will be described here because they illustrate how difficult it has been to

introduce new and needed foods in developing countries. These experiences clearly show that a huge gap separates our knowledge of food formulation and food marketing and our understanding of desires of uneducated, poor people in developing countries.

Food processors interested in developing and marketing high protein foods have first secured the support of local governments. This has been done to secure duty concessions applicable to the importation of equipment and ingredients, and tax concessions for the proposed business. In several instances the governments have made bulk purchases of the high protein foods for distribution to publicly supported children's institutions. In addition to the official support of government and its institutions, the products have been widely distributed to pediatricians and hospitals for research and educational purposes. In some cases international organizations, such as UNICEF, have supported product development financially and through educational material.

Market development for the products usually has been directed to the urban areas of the developing countries where there are retail outlets and where malnutrition of children is particularly serious. Attention has been given to attractive packaging, instructions for use by illerate people, package size and the possibility of deterioration of the product after the package is opened. Care has been given to ascertain that unit costs are within the consumer's purchasing ability. All conventional advertising media have been utilized, including posters, radio, movies, and publications. Demonstrations and educational programs have been staged in mobile vans, in clinics, schools, hospitals, and other public places. Some campaigns have been purposely directed to upper or middle class segments of the population so that the product would not have the stigma of being known as food for "poor children". Changes have been made in flavors, and formulas have been modified to create a product with more appeal.

The experiences of food processors with the development and marketing of high protein foods suggest that one of the great unsolved problems is how to formulate a product for which the demand is related to need. A greater impact might have been made initially in some cases if the foods had been distributed to children by the local government. On the other hand, a successful commercial development will provide a greater incentive to continue product development and promotion. Another factor favoring manufacture and distribution through private enterprise is the possible development of a financially sound food processing industry that can also produce and market foods for other segments of the population.

A survey was conducted recently[24] in which 165 food processing

[24] Milner, M. The need for food processing industry in developing countries. Talk before Food Industry Advisory Committee of Nutrition Foundation, May 11–13, 1966.

companies were queried about their interest in a study relating to the production and marketing of a high protein food in Peru. There were 85 responses to the inquiry. All indicated no interest in supporting such a study. The reasons for lack of interest were belief that (a) a poor profit potential must exist because consumers do not have money with which to buy a special food, (b) local governments would not permit business a profit from making and marketing food for needy people, hence there would be no money for promotion, and (c) a little consumer demand and uncertain government support would be available for such a project. The survey indicated that United States industry will require some substantial encouragement before companies will enter the high protein food production field on a scale necessary to meet immediate needs.

# CHAPTER 11

# TRANSPORTATION

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## Contents

| | | Page |
|---|---|---|
| 11.1.0 | Summary | 571 |
| 11.2.0 | Introduction | 572 |
| 11.3.0 | The Transportation "System" | 574 |
| | 11.3.1 Network of Access Roads | 575 |
| | 11.3.2 Local Collection and Distribution Points | 575 |
| | 11.3.3 Intermarket and Intercity Transport | 575 |
| | 11.3.4 Overseas Transportation | 576 |
| 11.4.0 | Planning the Transportation System | 579 |
| | 11.4.1 Prior Overall Planning | 579 |
| | 11.4.2 Letting Demand Dictate Construction | 580 |
| | 11.4.3 Planning for Long-Haul Transportation | 580 |
| | 11.4.4 Planning the Network of Access Roads | 581 |
| 11.5.0 | Getting Access Roads Built | 582 |
| 11.6.0 | Financing and Operating the Access Network | 583 |
| 11.7.0 | Management and Operation of the System | 584 |
| 11.8.0 | Vehicles for Transportation | 585 |
| 11.9.0 | Integration with Marketing Facilities | 586 |
| 11.10.0 | Cooperation Between Government and Private Industry | 587 |
| 11.11.0 | Appendix | 588 |
| | 11.11.1 Proposal for a System Study of Transportation in Relation to Food Production and Distribution | 588 |
| | 11.11.2 A Suggested Transportation Program for India | 589 |



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# 11.0 TRANSPORTATION

## *11.1.0 Summary*

Because farming is inherently an activity that must be widely dispersed over the land area of a country, agricultural *development* is heavily dependent on an equally widespread transportation system, Such a system is needed to move production inputs to farms and to move farm products to ultimate consumers, domestic or foreign.

The transportation facilities of a country must be well-articulated in which each part of the *system* is efficiently linked to the next. The elements in such a system include a widespread network of *access roads* connecting farms with local collection points or market towns, *intermarket* and *intercity* highways or railways of heavier carrying capacity, major transport *connections to seaports*, adequate access to international *seaborne* trasport, and efficient terminal and transfer facilities between each of the links in the system.

In general, the proportion of public expenditures that are devoted to improving and operating transport systems is as high (20 to 40 percent) in most developing countries as it should be, but much greater effectiveness could be secured by better allocation of funds among different links in the system and by greater efficiency of administration and operation.

In almost every developing country the network of access roads between farms and local market towns is still inadequate. It is usually the absence of roads that must be corrected. Maintenance of existing roads is also a major problem but, for the time being, the efficiency with which carriers are operated over these roads is of secondary importance.

Intercity transport exists in most places and is accorded high priority in most current investments in transportation facilities, but its efficiency is usualy neglected and needs additional and major attention.

Seaborne transportation is reasonably adequate and most additional future needs will probably be met by private investment and operation.

Greater attention needs to be paid to improving terminal facilities throughout the transportation systems of developing countries.

In view of the high importance of a *complete* transportation system to agricultural development, emphasis should be placed on providing a complete network of access roads in those regions that have



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the greatest potential for increased agricultural production and on providing connecting links between such regions and major cities and seaports. The potential of a region for higher productivity depends as much on the availability of new farm technology and an adequate market demand for farm products as it does on inherent soil fertility or present production levels.

### *11.2.0 Introduction*

Four facts define the crucial importance of transportation facilities in a program for increasing agricultural production.

1. Agricultural production uses solar energy, through photosynthesis in plants. This solar energy is widely distributed over the surface of the earth and must be utilized where it hits the earth. Farms therefore, must be located wherever conditions of soil, moisture, and micro-climates are or can be made favorably and many intensive growing areas are likely to be remote from centers of consumption.

2. Only in a stagnant, wholly subsistence agriculture, do farmers limit themselves to the use of resources that are found "naturally" on their farms: the existing chemical properties of the soil, tools and equipment that can be made by the farmer out of materials produced on the farm, sources of power that can be sustained by products of the farm, and the labor of the farm family. As agriculture progresses it *must* use more and more inputs purchased from other parts of the economy. In a progressive agriculture, farms are only the "assembly lines" utilizing fertilizers, pesticides, tools and equipment, construction materials, and sources of power transported to the farm from factories, oil refineries, seed multiplication farms and other suppliers of the inputs of progressive farming.

3. If farmers are to utilize purchased inputs, they must sell farm products. These farm products must be transported to processors and ultimate consumers scores, hundreds, or thousands of miles away.

4. If farm families are to have incentives to increase production in excess of their own needs, there must be not only a market demand for their products but there must also be available, in each rural locality, desirable consumer goods that farm families would like to be able to purchase. These industrial products come largely from urban centers and must be transported to widely dispersed rural markets, within easy access of farm families, if they are to provide incentives for increasing agricultural production.

Transport *alone* is not sufficient to increase the supply of food but it is one of the essentials to agricultural progress and its neglect can nullify all other measures designed to increase farm productivity. Current plans for increasing the output of food tend to focus on fertilizers and other farm inputs without considering the need to deliver the

inputs to the farm and to distribute outputs to consumers. In regions where the food problem is most critical, the transport capacity is often least able to move the required tonnage of farm inputs and the facilities needed to move foods to markets are lacking, are too costly, or are too slow.

Most of the developing countries are allocating a very large proportion of development resources to transportation. The percentage typically ranges from 20 to 40 percent of expenditures in the public sector. But planners usually have failed to relate rural transport investments to the specific needs of agriculture. The major effort usually has been on the more obvious need for intercity movement of industrial traffic.

The relation between transportation and the ability to grow and market food has been demonstrated in many parts of the world. In Thailand, partially used jungle land was transformed into highly productive, prosperous farms along the hundred-mile course of the Friendship Highway. Travel time was reduced from eleven hours on the old road to three on the new. The production of sugar cane, vegetables, bananas, and other fruits more than tripled in three years and Thailand began to export corn to Japan.[1]

In Bolivia, the highway from Cochabamba to Santa Cruz reduced travel time in the rainy season from several weeks to fifteen hours and provided a link between the country's food supplies and its consumers. Until then, the price of Bolivian rice was 50 percent higher than imported rice simply because the cost of domestic transport was high. The highway has largely eliminated the need for imports.

In Costa Rica, before the Inter-American Highway was constructed, driving beef cattle from grazing lands to San José customarily resulted in a 40 percent loss of weight, and imports were necessary to satisfy domestic market demand for beef. With an all-weather highway, it became possible to deliver cattle by truck-trailer units overnight and Costa Rica has become self-sufficient in meat.[2]

Where transport has been included in a program containing the other ingredients needed for increasing agricultural productivity, the results have been uniformly rewarding. There are many examples, however, where lack of transport has frustrated well-intentioned efforts to produce more food. In many agricultural areas, intensification of cultivation is inhibited mainly by the poor quality and high cost of rural mobility. Where access roads became impassable for several months of the year, input costs are high, marketing possibilities are uncertain, and incentives to accelerate production are low. It has never been pos-

[1] Wisit Kasiraksa, "Economic Effects of the Friendship Highway," SEATO Graduate School of Engineering, Bangkok, 1963.

[2] U.S. Department of Commerce, "Motor Transport in Middle America," World Trade Information Service, 4, No. 55–13.

sible to change traditional methods of cultivation and patterns of production until transport is adequate because transport is a means of moving ideas and information as well as goods.

Farmers in regions lacking transport are prevented from specalizing in crops that offer the best return. In such areas each farmer, forced to meet all the needs of his family and livestock, tends to retain more food than he actually requires knowing that if supplies run short they will be difficult to replenish from other sources. Inaccessibility means that operations such as fertilization and application of pesticides are at the mercy of unreliable delivery schedules. Agricultural extension workers find it too time-consuming to visit the farms that are not on a hard-surfaced route.[3] Fruits, vegetables, and other foods that spoil readily cannot be produced because they require rapid transportation to markets.

Some idea of the magnitude of the transportation task in a modern agricultural system is illustrated by the estimate that in 1964–65 94 million tons of farm supplies and equipment were moved into the commercial farms of the United States [4] and 324 million tons of farm products moved from these farms to markets.

Storage and processing facilities may enhance marketing to a greater extent than can be accomplished by transport alone. The development planner must weigh transport along with all of the significant factors and combinations of factors capable of increasing agricultural output. This type of "systems approach" to agricultural development is essential if the problem of feeding the world's people is to be solved.

### *11.3.0 The Transportation "System"*

The critical dependence of a country's food supply upon the availability and efficiency of transport makes it important to define what is meant by a "transportation system" and the special requirements that agriculture imposes on such a system.

A transportation system is any feasible combination of transport methods that provides an adequate and continous flow of goods between producers and consumers. In an agrarian economy, therefore, the concern, in a very real sense, is with a system of physical communications to and from each individual farm-family unit—a network that

[3] A study in the Philippines revealed that visits by extension workers and personnel of other government agencies increased by 400 percent to 1,000 percent to barrios after motorable roads reached these villages.

[4] Information supplied by Mr. James Vermier, Economic Research Service, U.S. Department of Agriculture. Of the 94 million tons of supplies and equipment 5.8 percent was machinery, 28.1 percent was limestone, 33.2 percent was fertilizer, 25.4 percent was fuel and lubricants, 2.1 percent was pesticides, and 5.4 percent was building materials. The total tonnage of farm supplies and equipment represented an average of about 2,600 pounds per crop acre.

includes the interconnection of population centers but one that is far more complex and extensive.

A transporation system has three general features: (1) a fine-mesh network of low-capacity routes blanketing each food-producing and food-consuming area; (2) a scattering of focal points within each of these networks that serve as collection and distribution centers; and (3) a loose network of high-capacity routes that connects the collection-distribution centers with major cities and seaports. (Figure 11–1) Each of these is an essential ingredient of any national transportation system, and the effectiveness is no greater than the system's weakest link.

### *11.3.1 Networks of Access Roads*

The critical importance of a fine-mesh transport grid is universally recognized for the population-dense, food-consuming areas but is almost completely ignored for the rural, food-producing areas. The objectives in each type of region are the same—equal convenience in marketing or acquiring products, whether it be the commuter going to work to sell his services, or the farmer taking his produce to market and picking up his supplies. In rural or urban settings, productivity will increase with efficiency of transport—the more the individual is isolated in a time sense, the less will be his incentive to produce or to purchase more than his minimum needs.

It is this fact that makes the rural transport network of such fundamental importance in the food supply problem. Farm operations are, by their very nature, geographically widespread. Unless it is reasonably convenient for the farmer to exchange surplus crops for consumer goods, he lacks an important incentive to exploit the full potential of his land. The lack of an efficient rural transport net may be the real limiting factor in attempts to increase agricultural productivity.

### *11.3.2 Local Collection and Distribution Points*

Local collection and distribution centers in towns may be regarded as storage and transfer terminals whose basic function is to provide an efficient coupling between the rural transport network and the external urban network. The terminal, if practical, should be for *transfer* rather than storage because all primary food products are perishable through deterioration, contamination, or spoilage. Storage is necessary for seasonal carry-over of local products, to implement price stabilization schemes, or to hold imported goods until they are needed by local consumers.

### *11.3.3 Intermarket and Intercity Transport*

The final link in a transportation system requirement serves to connect a country's regional economies and to link the nation with the

avenues of world trade. In contrast to the rural network, which must consist predominantly of roads to accommodate a variety of low-density animal and vehicular traffic, the national network may consist of a relatively few routes with heavy enough traffic to justify the highly specialized equipment of modern highway, rail, air, and marine operations. There is a great tendency to view these sophisticated systems as the answers to all transport problems, with the result that developing countries often find themselves with an expensive and poorly utilized main transport network that falls far short of meeting the basic transportation requirements of a predominantly rural economy.

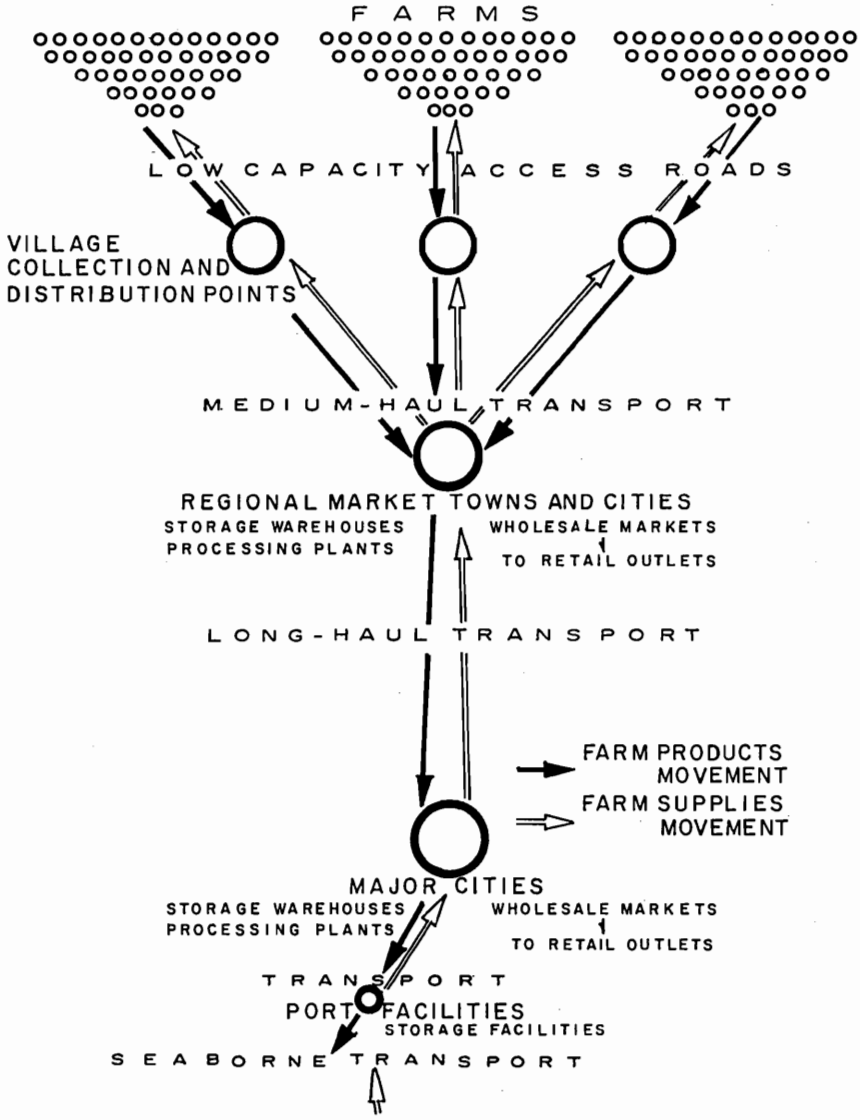
It is clear that the food transported on this primary national network will be no greater than that fraction of rural production which is marketed. The primitive state of rural transportation in most developing countries would make it impossible to market more than a small fraction of the production. Except for a few countries whose highly specialized economies are based on only one or two products which are exchanged for all other goods that are needed or wanted, the capacity of intercity networks is not likely to limit agricultural productivity in the developing nations. The critical component of these networks is the efficiency of their extension into existing and prospective producing areas. Where this efficiency is low, it will not be possible to provide the incentive for farmers to adopt improved farming techniques and to exploit the productive potentials that are possible through modern practices.

### *11.3.4 Overseas Transportation*

For those highly developed regions where agricultural production is characterized by a high degree of specialization, ocean transport is often a major and critical extension of the internal transportation system. In some cases, the whole economy of such a region may be based on sea lines of communication. It is clear, however, that this cannot be true within the context of the problem we are concerned with here. In the first place, our initial problem is how to increase the food supply within the developing countries. In the second place, the improvement of agricultural productivity within these developing countries is necessarily a two-phase process. Phase one, with which we are primarily concerned, is predicated on internal trade within the developing region—the generation and exchange of local farm surpluses for those agricultural inputs and consumer goods that make the surpluses possible and desirable. Phase two, the overseas export and import of related products, is generally a long-term result of highly successful phase-one operations under conditions where intensification and specialization have led to a fairly sophisticated agricultural economy.

Figure 11-1

ESSENTIAL ELEMENTS IN TRANSPORTATION SYSTEM SERVING AGRICULTURE



Viewed in this light, our analysis of transportation in support of agricultural development need not be vitally concerned with overseas lines of communications. The initial dependence of any program on this type of logistics will be small and can be expected to be met by existing privately financed shipping operations. Furthermore, in any areas where an increasing need for ocean transportation begins to develop, the demand trend can be anticipated far enough in advance so that again private enterprise can be relied upon to furnish the required transport capability.

The foregoing conclusion does *not* imply that one can forget about the overseas logistics problem entirely. It does have its critical components and one is the interface between the sea and land-lines of communication. Unless there is at least one good deep-water port facility that connects efficiently with the internal transportation network, a developing region is vulnerable to shortages of critical inputs no matter how much ship capacity might be available on the high seas. Vessel operators are reluctant to contract for calls that are likely to involve extensive delays; therefore, good port facilities are essential regardless of the volume of cargo to be handled.

The best way to assure a good port facility is to project shipping requirements on a continuous basis even though this means small tonnages per ship call. It is the long-term prospect of reasonably frequent *calls* that provides the business incentive necessary to attract capital and labor into port facilities and operations. There is no reason that this kind of scheduling should not be done as part of an agricultural development program. It would be much more efficient to partially subsidize regular vessel calls and thus stimulate port, terminal, and trade development than it would be to try to conduct sporadic supply operations on an as needed basis through inadequate terminal facilities. This latter procedure is often responsible for the difficulties encountered in fixing spot charters for emergency shipments because vessel operators know their ships will have to spend an inordinate time in port. On the other hand, the economic opportunity presented by a regular schedule of reasonably frequent future calls creates an environment where adequate terminal facilities can develop naturally.

A final critical factor in overseas supply to developing countries relates to the form of the cargo. Distribution to the ultimate consumer is often frustrated because the cargo is not packaged in the manner and quantity in which finally it must be handled and used. For example, a ship-load of grain or fertilizer in bulk form would be an awesome thing if it were to appear suddenly in a port that had neither bulk handling and storage facilities nor bulk transporters for inland distribution. By the time the material could be hand-sacked and taken

to individual farmers by whatever means available, its value in a physical or a time sense could well have disappeared.

Difficulties of this kind can be minimized by pre-packaging commodities in units that are compatible with the manner in which they must be transported during the final phase of the journey to the farmer's door. Whatever the characteristics of the rest of the transport system, the whole process breaks down if this ultimate requirement is not met. Containerized operations, where truck bodies can be hoisted on or off the truck to and from rail cars or ships, is an ideal method for accomplishing the desired purpose in those areas where the final road link can accommodate the operation. This method has the added virtue of eliminating much of the handling difficulty, cost, and delay usually associated with cargo transfer at the interface between different transport modes. Where the final transport link to the farmer's door is not suitable for containerization, many of the same benefits can still be realized by careful pre-selection of unit loads that are compatible with the final mode of transport, whether it be A-frame, burro, or ox-cart.

## *11.4.0 Planning the Transportation System*

There are essentially two methods of planning an adequate transportation system. One is to specify a complete system within the framework of general economic development goals and the other is to build transport facilities as demands arise.

The specification of a "complete" system is undertaken with limited knowledge of the eventual agricultural and industrial mix in the country. It is unlikely, even in a developed country, that one can predict the locations of future industrial plants, the demise of the old, or the exact location of various kinds of agricultural production. Over the years, plant locations and several types of agricultural production may shift among regions. One can anticipate rather accurately, however, (1) that certain areas will continue to yield agricultural products, and (2) that industrial complexes will continue to produce industrial goods and services even though the products may change. These two general pieces of information should allow reasonable overall planning of routes to meet a country's minimal transportation requirements.

### *11.4.1 Prior Overall Planning*

A long-range planning approach has two great advantages. First, it provides a definite national transportation goal; albeit, this may require periodic revision. It should minimize the local and regional political pressures that are inherent in almost any development program. Second, a long-range "comprehensive" transportation plan, with a specific program of projects, can bring "ordering" to economic development. A reference to current experience in the United States is

illustrative. New and adequate highways almost always induce the location of light industry and major service industries in the adjacent area. This reduces the total transportation resources required in contrast to a situation in which haphazard location of industrial plants might determine the need for and routing of new roads.

### *11.4.2 Letting Demand Dictate Construction*

On the other hand, there is something to be said for simply allowing demands to specify the location of transport routes. This is true for both heavy industry and agricultural production since these involve the use of geographically fixed facilities that associate transportation requirements with specific locations.

But there are at least two important limitations involved in allowing demand to determine the structure of a developing transportation system. First, in the under-developed regions, the supply and location of transportation is likely to be based upon existing demands without consideration of future needs. In many countries, footpaths and beasts of burden determined the original transport routes. To locate a modern road along such lines is generally a mistake. Second, to use present demand to determine transportation priorities disregards the fact that availability of transportation is itself a potent stimulus to development.

### *11.4.3 Planning for Long-Haul Transportation*

The choice of transportation systems for long-haul transportation from collection points of raw agricultural products to processing centers and major distribution centers will depend on a country's geography and economy as well as the kinds of agricultural products involved. No general rule can be laid down for the optimal mix of rail, road, and waterways in developing nations.

In Brazil, for example, the major roads linking agricultural and industrial areas are not uniformly all-weather roads, leading to frequent delays en route due to floods. Water transportation is inadequate for lack of fast, efficient, and dependable service. Decisions on the establishment of satisfactory long-haul transportation are very important because costs are high and, once built, these links influence development for many years.

Since there are many uncertainties in the process of socio-economic development, it is important to find ways to make the requisite large investments in transportation facilities while retaining a degree of flexibility to accommodate unforeseen eventualities. Long-haul transportation links must be versatile enough to accommodate different cargoes, initially agricultural, perhaps, and later a variety of manufactured products. The long-haul links must also be capable of adjustment to seasonal or other variations in demand. They must also pro-

vide for timely transfer of goods with a minimum of transshipment and delay.

These requirements suggest the need for more attention in planning for two technologies of modern transportation: containerization and centralized rapid telecommunications. Recent experience with unitized cargoes and containers indicates that large savings can be achieved in transfer and turn-around time. Centralized monitoring of transport demand and vehicles can result in substantial economies and faster overall transportation, reducing unused capacity per vehicle, and making cargo capacity available where and when needed.

Thus, while the choice of long-haul transportation links may vary from country to country, it is possible to build flexibility into any system and thereby greatly increase its utility, both for the immediate needs of food production and distribution and for still undetermined requirements stemming from future economic development.

### *11.4.4 Planning the Network of Access Roads*

A system of transportation that connects only major cities, or extends only from cities to major rural market towns, is wholly inadequate for agricultural development. The final linkage between each farm and rural market town is as important as the rest of the system. The frequency with which this link is the last to receive attention or is overlooked entirely is an important element in the world food problem.

In developing transportation within food-producing areas, the concentration points must first be determined so that a suitable system of roads can be provided to connect them with the farms they serve. Such concentration points are both the end of the first transfer and the beginning of the second. If the second means of transport is by water, it is just as important that the terminal be located on water as that it be accessible to farms. If other methods of long-distance transfer are to be used, concentration points must be on a railroad or highway or where a plane can land or depart. The important objective is to integrate the network of rural roads with long haul transports. Similarly, products brought into a consuming area must arrive at a distribution point that is suitable for distributing products to retail outlets.

Development and integration of the different stages of transportation are necessary as a first step. It is also essential to coordinate services. Supplies must be at the concentration points in producing areas when the train or ship arrives to take them on the second leg of their journey and, conversely, the second means of transportation must be ready when the products are available. All transportation services should be so coordinated in timing, operations, and equipment that a shipper can negotiate with a single carrier (regardless of the variety of transportation methods involved between origin and destination)

with assurance about rates, safe delivery, and reasonable adherence to schedules.

### *11.5.0 Getting the Roads Built*

Altogether, the size of the roadbuilding task in developing countries is staggering. In agriculturally advanced Western countries, there are from 3 to 4 miles of farm-to-market roads per square mile of cultivated land. The mileage is smaller in grain-producing areas where fields are large and higher where farms are smaller and the topography difficult. In Britain, France, Japan, and the United States, the average is about 4 and in Taiwan and Denmark it is closer to 3. In India there is only about 0.7 of a mile of road per square mile of cultivated land. In Malaya it is about 0.8 mile and in the Philippines about 1 mile. None of the developing countries that are most dependent on agriculture has sufficient rural access roads.

The magnitude of the problem emphasizes the need for concentrating efforts on local roadbuilding in areas that show the greatest promise of increased productivity. In India, for example, it is estimated that a million miles of roads will have to be built to satisfy the access needs of 580,000 villages throughout the country. Only 11 percent of these villages now have reasonably adequate roads and one out of three is more than five miles from a satisfactory road.

Few, if any, regions which have a settled agriculture are wholly without transportation facilities. Existing facilities may be limited to footpaths along which persons carry headloads and along which laden beasts of burden—bullocks, burros, horses, llamas, or camels—may move. These paths may be adequate for the relatively small amounts of marketed produce and purchasable consumer goods that characterize traditional, self-sufficient, subsistence economies. If the amount of marketed produce is to increase, and increased amounts of farm supplies and equipment are to be moved to farms, other cheap and efficient means of transport will be needed to link individual farms to market centers.

Few regions of the world are as fortunate as the American Middle West where at the outset, before most of the land was settled for cultivation, the right-of-way for a public road was established at one mile intervals along survey lines running east and west, and north and south. In the beginning, only the rights-of-way were established. At an early stage these were fenced, not by the government, but by each farmer where his land touched a right-of-way. This was done to define his boundary, to control his livestock, and to keep other animals off his farm. Establishing a total grid of rights-of-way put every farm on what could eventually become a serviceable access road.

Over the years, farmers joined together to maintain a road along the right-of-way between their own farms and the nearest market town. Later, local governments improved and maintained the roads, aided by grants-in-aid from state governments, in return for adhering to established standards of road construction and maintenance. A regular program of national grants-in-aid was established later for intercity and interstate highways.

The first step in achieving an adequate grid of access roads is to determine where these roads should be and to secure the rights-of-way for them. Too frequently, roads are established where heavily traveled footpaths already exist without regard to present and future needs, current roadbuilding technology, or later costs of transport. These factors are usually considered for major highways but they are equally important for access roads.

Another frequent determinant of the location of access roads is the willingness of present owners to "give" their land for the right-of-way. Access roads are so important that a poorly located one is almost always better than none. A system of access roads, however, is so important to future development that it is worthwhile to give early consideration to a total plan for access routes throughout a region, and to use the right of eminent domain to locate roads properly rather than to locate them haphazardly along old trails or where landowners are willing to donate a route.

Departments of public works in developing countries tend to adopt minimum standards and requirements based on intercity needs or on similar standards in developed countries. As a minimum requirement, a road should allow the passage of wheeled vehicles during enough of the year to meet the anticipated minimum transport needs for five years. In the beginning, a right-of-way of 10 or 12 feet may suffice. Streams that can be forded need not be bridged at first, although culverts to prevent disturbing normal drainage and to prevent the formation of mud holes are important from the beginning. Surfacing the road can be accomplished gradually and piecemeal as local interest and requirements dictate. Establishing rights-of-way and opening even poor roads is preferable to waiting until a more advanced modern type of road can be financed and constructed.

### *11.6.0 Financing and Operating the Access Network*

Although constructing and maintaining a grid of access roads to service an expanding agriculture involves considerable expense over a long period, in the beginning it requires more thought and policy-making than expenditure of funds. Subsequently, the rising productivity associated with better access roads can contribute substantially to financing future road improvements.

Some financing is necessary even in the beginning apart from costs of survey, road location, and the acquisition of rights-of-way.

The major expenses of developing access roads, before surfacing is attempted, are the purchase of materials for culverts and bridges. In many "community development" programs, the government will provide part or all of these costs if the local populace provides the necessary labor.

Eventually, substantial costs will be incurred for maintenance, road improvement, and for surfacing. While local communities may be able to help in the early stages of establishing roads, it is unrealistic to expect them to assume all of these later expenses. Since a constantly improving grid of access roads benefits manufacturers and distributors of farm inputs and consumer goods, as well as farmers, state and national grant-in-aid participation in improving and maintaining rural roads is justifiable.

Even where most of the labor for building access roads is provided by local people, technical aid is required for surveying, specifying gradients, and locating and constructing culverts. Such technical aid by avoiding faulty design and construction in the beginning can result in substantial savings later.

The principle that government is responsible for the maintenance of major highways is well established. Governments usually do not accept this responsibility for access roads as soon as they should. Local people can be mobilized to build roads much more readily than to maintain them. Once established, roads are a general public asset and proper maintenance of all roads, minor or major, should be a public responsibility delegated to an appropriate technical agency.

### *11.7.0 Management and Operation of the System*

The trained management that is required at all levels for any transportation system may be even more scarce than capital in developing countries. As a matter of fact, the degree of sophistication of available management may largely determine the mode of transportation and hence the investment decisions.

Adequate management is required at three levels: (1) planning, (2) operation, and (3) maintenance. The same individuals may be involved at all levels, especially where a central government is responsible for both construction and operation. To give priority to roads rather than railroads is consistent with a scarcity of trained personnel since it is generally agreed that the operation and maintenance of roads require less sophisticated management than railroads. The operation and maintenance skills required for roads are closely connected, and a relatively low level of technical training is required for the construction and maintenance of a rural road system.

There is a choice to be made between low and high axle load specification in developing major roads. To increase the load limit from 10 to 13 tons can increase costs (depending upon climate and soil conditions) by as much as 40 percent. The lower limits are to be preferred for "major-secondary" roads. These lower limit roads have three distinct advantages: (1) construction costs are minimized, thereby conserving limited capital; (2) smaller trucks are generally more available and at lower initial outlays; and (3) given enforcement of capacity limits, initial maintenance costs will be reduced. Low load limit roads will require more rolling stock to move a given volume of goods and the variable costs per ton of goods moved would probably be higher than for high limit, larger vehicle roads, but the initial capital requirements would seem to dictate the lowest possible load limit road in the beginning.

### *11.8.0 Vehicles for Transportation*

Developing countries frequently lack adequate numbers of trucks to distribute food products and bring supplies to the farm. A long-range plan for developing major and secondary roads must incorporate estimates of likely traffic, with the estimates based as much on the availability of vehicles as on the quantities of food and other products to be transported. It may be that the successful development of a system of major-secondary roads is contingent upon a "vehicle assistance program."

Successful development of major-secondary road systems requires investment in more than the roads and vehicles. Trucks need fuel; distribution facilities must be established (including import facilities in many nations); service stations must be built; and mechanics have to be trained. All of these factors must be considered in a long-range plan if its goals are to be attained.

Because of the bulkiness and relatively low value of most agricultural products, air transportation cannot be a major means of moving agricultural products in the developing nations. But airfields designed for use by small planes can be built with minimum capital requirements wherever there is level land. Where the distances are great, where traffic does not justify investment in roads or railroads, or where the climate and geography make road or rail construction difficult, airplanes can provide an economically sound supplemental means of transportation. Airplanes can be used to move critical supplies such as pesticides, animal drugs, and medical supplies. They are used now in the Andes to transport limited food, especially meat.

Railroads offer an economical form of transportation, especially if a single railroad line is used to connect two major cities or to connect a major raw material region with a processing location. Railroads are particularly well suited for the transportation of bulky products.

### *11.9.0 Integration with Marketing Facilities*

At the concentration points in producing areas, storage facilities may be required to accumulate products brought from the farms to assure their availability in proper quantities and condition at the right time for further shipment. For some grains, milling or other facilities for processing may be essential. In short, these terminals must provide a method and place for transferring products from the first haul to the second and must maintain the condition and form of products for the second movement. (Figure 11–2)

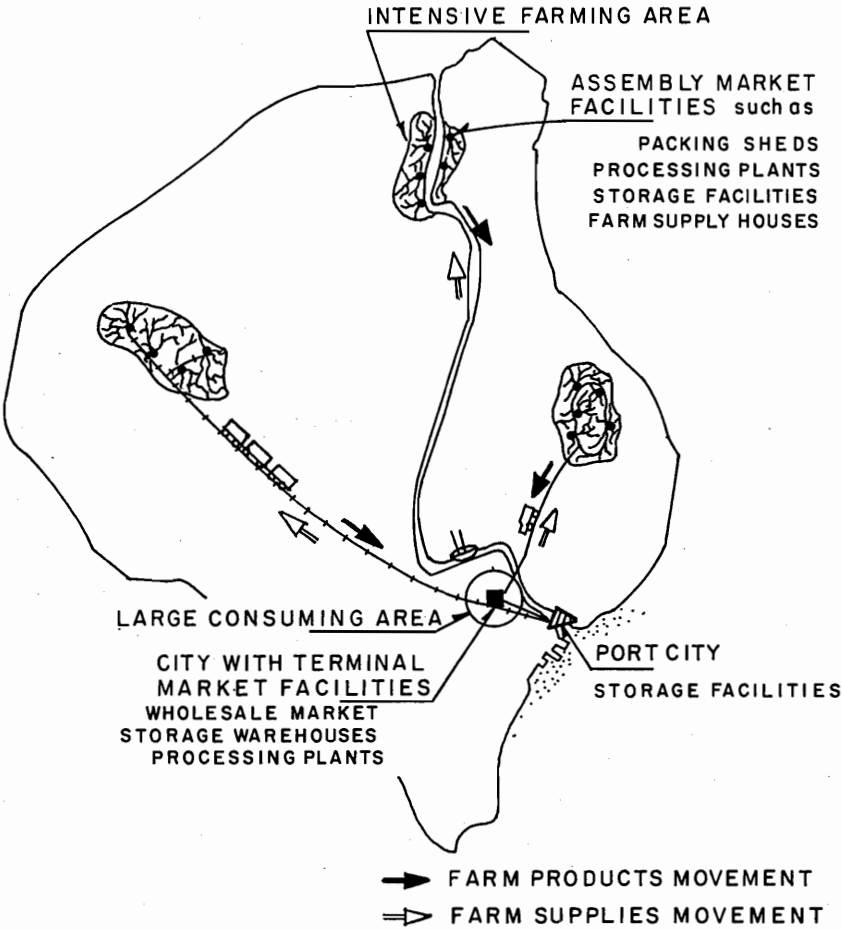
In consumer areas, food distribution centers and warehouses are needed to receive the products delivered by the long-haul agencies of transportation and, with or without further processing, to deliver the products in smaller lots to the retail points where they will be available to consumers. At each place where products are transferred from one method of transportation to another, the marketing facilities must be of suitable type and size, properly equipped and operated, and appropriately located for efficient transportation and marketing.

Transportation requirements are greatly affected by the form in which the product goes to market. If livestock and poultry are shipped live, different equipment with more capacity is required than that needed if animals are slaughtered in producing areas. Dressed meat shipments must be refrigerated which requires equipment that is also suitable for transporting other perishables. There are few alternate uses for vehicles designed to transport live animals and poultry. Canning or freezing reduces the need for speed in handling so losses from spoilage become negligible. Processing sugar cane and beets into syrup for bulk transport simplifies transportation. Fertilizer in liquid form can be moved in tanks or by pipeline. Phosphate rock can be converted to phosphoric acid to reduce bulk.

Recently an enterprising man wanted to ship meat from a livestock producing area in Africa to city consumers hundreds of miles away. A van container similar to a truck trailer, with liquid nitrogen for the refrigerant, was used to ship the meat by road to a river where the trailer was loaded onto a boat and moved to a dock terminal near the market and hauled by road to the city. The meat was retailed at a price which paid all costs. This illustrates that modern technology can be utilized to advantage in developing countries. Storage, refrigeration, and two methods of transportation were combined to accomplish the job and at a profit!

Containerized vans facilitate the movement of products from one part of the transportation system to another—the van can be moved by road, rail, water, or air, and a constant environment can be maintained, making it unnecessary to handle the cargo itself at transfer points. These vans also serve as places of storage. The same container

INTEGRATION OF TRANSPORTATION WITH MARKETING AND PROCESSING




can be used to haul refrigerated products in one direction and non-refrigerated in the other. It can be used for bulk goods, for packaged goods, or for liquids. Multi-purpose containers make it possible to haul a wide variety of products, even those requiring different temperatures, at the same time. "Unitizing" loads by means of pallets or pallet boxes is another important method for integrating transportation and simplifying handling of cargo.

### *11.10.0 Cooperation Between Government and Private Industry*

To develop and operate an efficient, integrated transportation system is a major undertaking which must be planned jointly by government and industry.

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Government agencies must be responsible for building roads, airports, and port facilities; they must regulate rates and services; and they must establish safety regulations. They can assist greatly by standardizing shipping documents, simplifying customs procedures, and obtaining and disseminating information. In many situations, governments may join with industry in financing portions of the system.

Despite this indispensable role of government in the development of an efficient transportation system, there remain many activities which all experience to date indicates are better performed by private initiative. The total job of developing and operating a transportation system that will maximize economic growth in the developing countries is so great and challenging that it will require the combined talents of government and industry. If left alone industry is likely to develop good parts of a transportation system, but not an integrated system. With complete government domination, initiative may be stifled. The job is too big and important to be left to either to accomplish alone.

## *11.11.0 Appendix*

### *11.11.1 Proposal for a System Study of Transportation in Relation to Food Production and Distribution*

The Subpanel has stressed the importance of transportation in food production and distribution. Transportation is a necessity although by itself it will not suffice to solve the food problem. Qualitatively, the dimensions of the transportation problems are clear but from a planner's or investor's practical viewpoint, it is desirable to obtain an estimate of the gains in terms of increased production and improved distribution that might be expected from different investments in a transportation system.

The Subpanel believes that a systems analysis study of transportation in relation to the food production and distribution problem is feasible and urgently required. The feasibility of a quantitative approach is suggested by previous statistical and analytic work dealing with parts of the overall problem. For instance, the minimum daily human requirements for calories and proteins can be calculated by age and sex; the yield from agricultural crops under different combinations of soils, fertilizers and farming techniques can be estimated accurately; and reliable figures are available on the feasibility and costs of developing, operating and maintaining transportation networks for a variety of environmental conditions.

In approaching the food transportation problem as a systems question, it will be necessary to devise a methodological framework, to define alternative systems design, and to define appropriate objective functions. Regional characteristics will have to be obtained for the

particular geographic areas considered. The Subpanel urges that not one, but perhaps two or three, such systems studies be undertaken in order that a variety of conditions and issues may be considered which may be used for generalizations about the problem.

Among the issues to consider are: (1) the establishment of numerical measures for the potential amounts and kinds of food shipments from a particular area; (2) the trade-offs between single and multiple mode transportation networks, each transportation mode having different vehicular characteristics; (3) the trade-offs involved in additional storage points along the transportation network from production to consumption areas as compared to direct by-pass transportation; (4) the comparison between food processing at source of production and remote centralized processing; and (5) the trade-offs between investments for higher yield food production through improved fertilizer and irrigation, and investments in high cash yield, non-food production from which purchasing power for food importation can be derived.

It is clear that a large number of factors, including population density, enter into this problem; they need to be carefully sorted out through sensitivity analyses. It is noted also that transportation can serve many economic and social functions, hence, design optimization and cost allocation present complex problems. For the purpose of the suggested studies, transportation is treated as a single-purpose, two-way system for the conveyance of farming inputs and farm products.

### *11.11.2 A Suggested Transportation Program for India*

The most important transport program for Indian economic development in the Fourth Plan would be to concentrate on the agricultural sector to permit the distribution of necessary farm supplies and to make possible the marketing of surplus foods.

Efforts have been made in the past to build rural roads to the villages through the Community Development Program, but the limited results of this program are understandable. Road construction is only one of many requirements for rural development and until recently the other elements did not exist. There was no fertilizer or other inputs for intensive cultivation and no guaranteed prices to provide incentives for growers to buy and use these inputs. Even where roads were built, it was often the case that the roads were not useful and the roads fell quickly into disrepair because there was no compelling economic reason for their maintenance.

The insistence of most Indian policy makers that improving rural transport was not important to food production was, strictly speaking, correct until now. Building roads is futile without the capability of producing for the market and without the market centers or price supports for making commercial farming feasible.

The situation has changed. Farmers have reasonable assurance of enough return to enable them to invest in seed and fertilizer. Supplies of these inputs are more available.

It is now time to begin in earnest to get the roads built, the vehicles rolling, and the market centers established. The question is how to do this quickly and on a large enough scale to obtain results.

India's local transport poses a problem of such magnitude and urgency that improvements will have to be concentrated where agricultural prospects are best. Highway funds and vehicle supplies need to be made available specifically for market roads in the Intensive Agricultural Areas. In addition, help may have to be obtained from the outside for the foreign exchange cost of road machinery and motor trucks and to help defray the local costs of materials and labor.

The total amount of foreign assistance required over a five-year period might be approximately $200 million. This sum, combined with matching funds, would make it possible to build 250,000 miles of basic roads needed in the Intensive Agricultural Areas. Access roads could be improved to higher standards as traffic demands warranted. Further improvements and maintenance could be financed by increased motor vehicles tax revenues and local resources generated by the economic activity resulting from the breakdown of rural isolation.

The first step in the conduct of the transportation for food program would be for the Government of India to use foreign exchange for the importation of motor trucks, road machinery, and the parts and materials needed to increase India's vehicle production capacity (Figure 11–3). The rupee equivalent of aid money for trucks, road machinery, and parts would then be credited to the Central Road Fund for rural road development. The Center would be expected to match these funds out of its own revenues in an amount equal to 25 percent of the grant. Matching funds could be financed by allocating to the Road Fund part of the diesel tax and other motor vehicle tax revenues levied by the Central Government.

These funds would then be distributed among the states on the basis of population and area and augmented by a 25 percent state contribution. Other stipulations for receipt of local road aid would include the designation of access roads eligible for aid as certified by Agricultural Development Boards and Public Works Departments.

Local governments would contribute to the cost of the program from their own resources in an amount equivalent to 10 percent of the aid received, or by the donation of right-of-way in lieu of local cash contributions.

Local governments would have to take the responsibility for market road planning and for the actual construction work. At the local level, groups of villages could initiate planning and established priori-

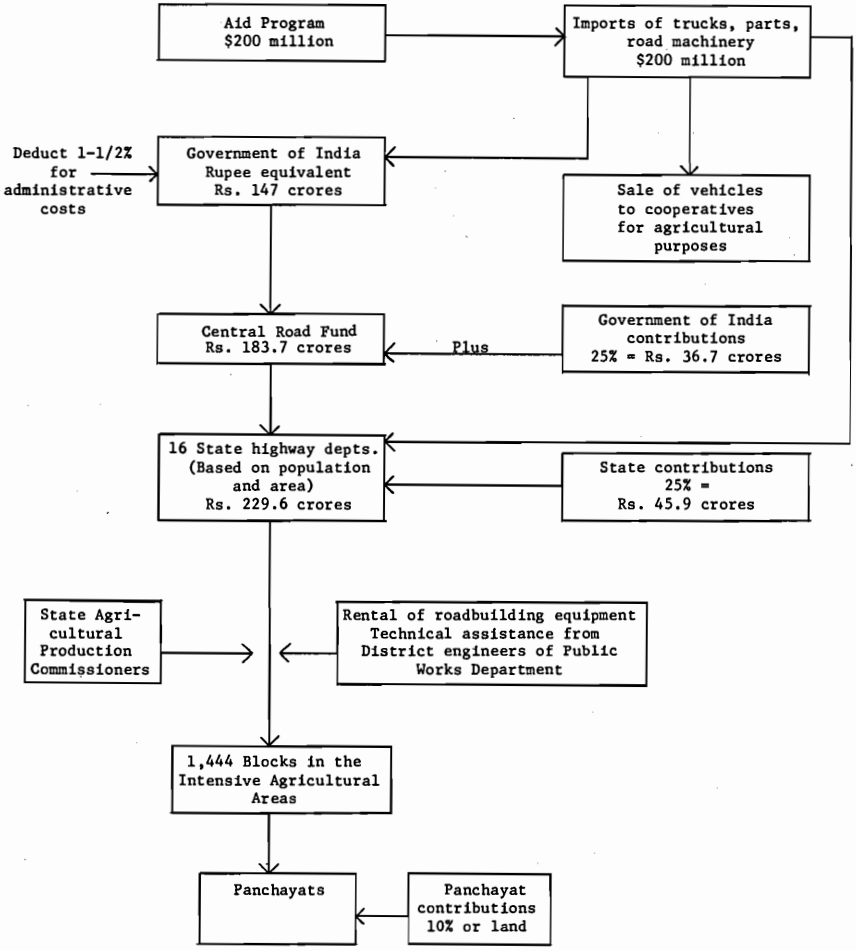


Figure 11-3

A Schematic Diagram of Transportation for Food Program

ties under the village councils, or panchayats. These community development blocks could be brought together into a coordinated program with the districts providing technical and logistical services and supervision of the work.

An important side effect of a local road program to support agriculture would be to provide jobs and income for workers who are only partially or seasonally employed. Much of the construction and later the maintenance of the roads could be accomplished by labor-intensive methods. The program would provide some of the purchasing power needed to buy inputs for intensive cultivation and to pay for consumer goods. This purchasing power, added to the reduction in transport costs resulting from road improvements, could provide both the means and incentives for introducing commercial agriculture.

The high priority given to agriculture in the Fourth Plan makes it essential to improve rural transportation as part of the package. Efforts to increase food output cannot succeed without parallel steps to provide access to farm and market.

# CHAPTER 12

# RESEARCH AND EDUCATION

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## Contents

| | | Page |
|---|---|---|
| 12.1.0 | Summary | 595 |
| 12.2.0 | Introduction | 598 |
| 12.3.0 | Education in Developing Areas | 601 |
| 12.3.1 | Development of Human Resources | 601 |
| 12.3.2 | Formal Education | 603 |
| 12.3.3.1 | Primary Education | 605 |
| 12.3.3.2 | Secondary Education | 606 |
| 12.3.3.3 | Higher Education | 607 |
| 12.3.3.4 | Overseas Education and the "Brain Drain" | 609 |
| 12.3.3 | Manpower Needs | 611 |
| 12.4.0 | Food Related Research in Developing Countries | 614 |
| 12.4.1 | National Commitments to Research on Food Supply and Nutrition | 615 |
| 12.4.2 | Organization and Administration of Research | 616 |
| 12.4.3 | Resources to Carry Out Research | 616 |
| 12.4.3.1 | Trained Manpower | 616 |
| 12.4.3.2 | Facilities | 617 |
| 12.4.3.3 | Financial Support | 617 |
| 12.4.4 | Program Content and Orientation | 618 |
| 12.4.5 | Relationship to Formal and Extension Education | 620 |
| 12.4.6 | Relationship to Industry | 620 |
| 12.5.0 | Extension Education | 621 |
| 12.6.0 | Contributions of Developed Nations | 623 |
| 12.6.1 | Contributions of the United States | 623 |
| 12.6.1.1 | Federal Agencies | 623 |
| 12.6.1.2 | Foundations | 625 |
| 12.6.1.3 | United States Universities | 626 |
| 12.6.2 | Contributions of Other Developed Countries | 626 |

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Page

12.7.0 Examples of Progress ..... 627
12.7.1 Foundation Participation ..... 627
12.7.2 University Participation ..... 629
12.7.3 Family Planning ..... 629
12.7.4 Educational Programs ..... 631
12.7.4.1 Educational Television ..... 631
12.7.4.2 Agricultural Education ..... 631
12.7.5 Nutrition ..... 632
12.7.6 Pilot Extension-Type Projects ..... 633
12.8.0 Requisites for the Future ..... 634
12.8.1 Recognition and Commitment ..... 634
12.8.2 The Load Must Be Shared ..... 634
12.8.3 Innovation—The Key to General and Extension Education ..... 635
12.8.4 Continuity and Longevity ..... 635
12.8.5 Production Plus ..... 636
12.8.6 Indigenous Institutions ..... 636
12.8.7 Three-Component Team ..... 637
12.8.8 A Mechanism for Coordination and Implementation ..... 637

# 12.0 RESEARCH AND EDUCATION

## *12.1.0 Summary*

Greatly expanded research and educational programs are vital if the world's hungry people are to be fed. Only through research is it possible to use United States scientific technology to produce new techniques, processes, and biological materials for developing nations. Only through vastly broadened educational programs will these nations be able to use this converted know-how.

Vital research and education programs not only provide the basis for increasing food production and nutritional quality of food but also are mandatory for effective family planning. Many environmental and social factors must be evaluated before effective programs relating to food supply and quality, and family planning can be implemented. Each society has different forces which affect the outcome of such programs, and these forces must be understood. Also, people must be taught the elements of family planning lest long-range programs fail to balance population and food supply.

Leaders of the developing countries are seemingly unaware of the importance of research and education. This is also true of leaders in some countries higher on the development scale. Inadequate programs of technical assistance and lack of sufficient funds from more advanced nations reveal this lack of understanding. Support of research and education is therefore hampered by shortsighted national policies and lack of national commitments.

One reason some developing nations have failed to recognize research needs is that in the past the cultivation of new lands has provided them with new sources of food. For most of the world's population needing food, especially those in Asia, new lands are scarce or non-existent. These people must now turn to research and education to provide the technology for increased yields on the land now in use.

Some of those concerned with the world food problem reason that high-level technology of developed nations can be applied directly to developing areas. In a few cases they are correct. In most cases the plant varieties, animal breeds, and farming practices must be tailored to fit the environment. Most of the developing nations have climates, soils, cropping systems, and harvesting, processing, and marketing techniques vastly different from those in the United States and Europe. Under these circumstances, United States technology cannot be transferred without extensive adaptive research.

The misconceptions of "know-how, show-how" must be erased. The developing nations cannot be "shown how" until the "know-how" is suited to particular needs in terms of the social structure, the physical environment, and economic relationships.

Although educational levels in the developing countries are quite diverse, there are certain common deficiencies among them. First, populatons are highly illiterate. Most of the rural and farm populace cannot read nor write, and primary education facilities, although inadequate, are not being utilized fully. The dropout rate among the few children who start school is high.

Little direct help for problems related to food, agriculture, and nutrition comes from secondary and university educational programs which are highly academic and attract mostly non-rural students. Important as this academic orientation is in training agricultural students, it is inadequate when it fails to focus on the food-population problems of these developing coutries.

Students sent abroad to the United States and Europe are interested mainly in traditional academic subjects rather than those relating to food and agriculture. Similarly, most United States scientists and students sent to the developing countries seem to be motivated by intellectual curiosity rather than a desire to help the people.

The net result of all these educational deficiencies is a near void of trained and educated manpower in many of the developing countries. The shortage is at all levels. Illiteracy limits the masses to the simplest of tasks and greatly reduces their opportunity to learn. A shortage of teachers, technicians, and other vocationally trained people is common. Scientists and engineers often must be imported from the more developed areas.

Research is among the activities greatly handicapped by manpower shortages. The level and quality of research on food, nutrition, and population control are closely related to the quality of education. Low salaries, inadequate support, and poor facilities are contributing factors to the limited quantity and quality of research.

Research on nutrition and on food processing, marketing, and disdistribution is especially lacking in the developing countries. Animal production and socio-economic factors affecting food production and marketing are also slighted as is research on family planning. Even the crop production research, which has received most attention, has been insufficient to produce few real breakthroughs in agricultural technology.

During the past 25 years, the United States and other developed countries have invested time and money trying to help these developing nations to improve their food production. In general, technological and scientific inputs have been woefully inadequate. Programs

have lacked continuity, organization, and long-range planning. Because of these and other deficiencies, help from the devoloped world has had little effect on crop yields or food quality.

Intensified extension efforts have been made in recent years to motivate cultivators in the developing areas to accept new and improved practices. In some cases, these efforts failed because research has not developed practices which farmers are willing to adopt. In others, farmers lacked confidence in extension specialists or were not given social or economic incentives for change. There are notable exceptions which give hope for the future and provide guidelines for adaptation to other areas.

In a pilot program in Italy, television has been used to teach large numbers of illiterates to read and write at a fraction of the cost required for the formal classroom approach. In other countries, films, radio, and comic strips are being used to communicate information on food, nutrition, and family planning. Initial successes suggest that these innovative techniques deserve extensive trial and could provide the needed tools for breakthroughs in general and extension education.

The importance of developing regional or international research and training centers has been demonstrated. The International Rice Research Institute in the Philippines, the International Maize and Wheat Improvement Center in Mexico, and the Institute of Nutrition in Central America and Panama are examples of productive programs. These successes should be used as the bases to establish programs in selected problem areas elsewhere in the world.

The need to first understand the social patterns through which the people who till the land can be motivated has been demonstrated in pilot programs such as those in Peru and East Pakistan. One of the most successful efforts to bring a social and technological change is best illustrated by the extension program among farmers in Taiwan. Lessons from these innovative programs can and should be used elsewhere.

The development of indigenous institutions for education and research should continue to receive high priority. Long-range funding must be available to permit universities in the United States to work effectively with their overseas partners. Selected indigenous institutions in the developing countries should be improved to provide education and training for surrounding countries with similar ecological and problems. This should minimize the need to send students to the United States or Europe.

Industry can make a significant contribution to the research and educational efforts in the developing countries. Experience in the United States and Europe has demonstrated the essentiality of industry involvement. Every encouragement should be given to couple the

efforts of public institutions and private industry in both research and education.

The ultimate, long-term success of research and education rests with the countries in which these activities are carried out. The United States and other developed nations must of necessity contribute significantly in the initial stages of cooperative research and educational programs. As rapidly as the competencies and capacities of the indigenous nations improve, they should be utilized in order that the developing countries can assume the responsibility and leadership for their own research and educational programs.

### *12.2.0 Introduction*

The problem of world hunger is large and very complex, requiring concerted efforts on many fronts including strong, viable programs of research and education.

Research provides the basis for improved technology in food production, preservation, and utilization. Research is essential if effective, inexpensive, and socially acceptable means of limiting population growth are to be developed and utilized. These factors are basic to all other efforts to solve the problem of world hunger. Education is needed to convert the products of research into action.

Education serves three main functions: (1) it eliminates illiteracy; (2) it disseminates research findings on which improvement in per capita food supplies depend; and (3) it provides skilled personnel to reinforce public and private institutions on which agricultural improvement and family planning rely.

Most nations facing serious food deficits have high levels of illiteracy. This greatly restricts use of printed material as a means of communicating information on food production and population control. Experience has shown, however, that information on family planning and on food supply can be disseminated effectively even where the population is illiterate, if there are other motivational forces.

Furthermore, the urgency of the world food crisis dictates that mankind cannot wait for long-range general education programs to solve this problem. More immediate benefits are likely to result from intensified educational programs relating specifically to family planning and the supply of nutritionally balanced foods.

Research and education have contributed substantially toward increasing food supplies in the developed nations. For example, a study made by Dr. Z. Griliches, a University of Chicago economist, showed an annual return of at least 700 percent from investment in research which led to the development of hybrid corn in the United States.[1] Dr.

[1] Griliches, Z., Research cost and social returns: hybrid corn and related innovations. J. Polit. Econ. 66: 415–431. 1958.

Griliches also reports an annual return of some 1,300 percent for each additional dollar invested in agricultural research and extension education within the United States.[2] Few investments in the public sector have returned such handsome dividends.

Such success has motivated the United States to share its research and educational experiences with other nations. Through the Agency for International Development (AID) and its predecessor agencies, the Federal Government has supported educational and institutional development programs in developing countries for more than 20 years. More recently, it has supported research efforts in the fields of agriculture, nutrition, and family planning. Certain United States foundations have been involved in similar efforts for even longer periods. Some European nations also have made substantial investments in agricultural research and education in the developing nations during their colonial periods. Several of the United Nations agencies have continuing programs to support research and education on food supplies and nutrition. They, too, are now giving attention to family planning.

All these efforts have contributed substantially to a better understanding of the potential of research and education relating to food, nutrition and population in the developing countries. Some excellent opportunities now are available to build on these experiences if bold and imaginative programs can be supported adequately.

Experience has shown, for example, that some technology from the more developed nations can be used in those developing countries whose climates, soils and crops are similar. The main problem is to test the technology and to have it accepted by the indigenous population of the developing nation, which is often steeped in tradition and unaccustomed to ready acceptance of new practices.

Many persons assume that those countries to whom our help is directed can boost their food production, processing, and marketing simply by adopting our technology. Experience proved this a mistaken assumption. As much technology cannot be transferred directly; some, not even with the aid of adaptive research.

There are vast areas in the wet, humid tropics where the potential for food production is unknown. Expanded research and educational efforts may reveal that they are the world's major areas for increasing food production.

Past experience has shown potential opportunities for regional cooperation in obtaining needed research knowledge. Nations in similar geographic areas have common food supply problems, but each cannot support sufficient research to solve these problems. Cooperating teams

[2] Griliches, Z., Research expenditures, education and the aggregate agricultural production function. The American Economic Review, Vol. LIV, pp. 961–974, 1964.

of scientists located at well-equipped centers of specialization should be considered to meet these regional or area problems.

These centers also would provide excellent opportunities to develop productive educational programs, particularly at the graduate level. Thus, they would serve the dual purpose of acquiring new knowledge and of providing the training needed by agricultural scientists.

Universities in more developed nations have trained thousands of students from developing countries. For example, up to one-third of the graduate students studying in some fields of agriculture in the United States are from outside this country. Unfortunately, the orientation of their training often does not prepare them well for the type of research and educational programs needed in their home country.

Educating and training foreign nationals in more developed nations has led to another serious problem, the "brain drain" from developing countries. Many of the better students, whose original intentions may have been to help their own countries, do not return home, or, if they do, they do not remain there. They become dissatisfied at home because of low salaries, inadequate support, or failure on the part of their superiors to recognize their potential. Eventually they return to Europe or the United States. These scientists contribute to the more developed nations where they obtain employment, but their abilities are lost to their homelands.

Other important lessons have been learned from past experience with technical assistance programs in food-deficit nations.

Successful research and educational programs must have continuity of objectives, funding, and personnel. There are no effective shortcuts in building research and educational institutions, training indigenous manpower, and mounting coordinated research programs to develop new varieties, better breeds of animals, or improved practices.

Institutions in the more developed nations which participate in international food research and educational activities must make long-term commitments. These commitments must go beyond "lending" staff for a six-month temporary assignment or admitting a few foreign students to take the same courses of study and research as students of the developed nations.

Perhaps most significantly, the United States has learned that the developing countries, as well as those which are more advanced, must support research and educational efforts relating to population and food at far greater levels than has been in the case in the past. In developing countries, inadequate attention has been given to research and education. Furthermore, political interference, low salaries of teachers and scientists, and the low image of agriculture in these countries have drastically limited the potential contribution of research and education.

Our experience has demonstrated that research and education are basic links in the continuum which starts with new knowledge and ends with advanced technology. Such technology can result in marked increases in the supply of quality food. The United States, through its scientists, educators, and institutions, is being challenged as never before to help struggling nations develop manpower and institutions needed to feed themselves.

The objective here is to identify the problems, needs, and potentials of research and education in food, nutrition, and population growth in the developing countries. Examples are given of contributions being made by agencies, foundations, and institutions of more developed nations toward solving the world food supply problem. Suggestions are made for needed action in achieving long-term, enduring solutions to problems of increasing the food supply and controlling population growth in the developing nations.

## *12.3.0 Education in Developing Areas*

### *12.3.1 Development of Human Resources*

There is wide variation from country to country in development of human resources. Educational systems are in different stages of evolution or development and meet their countries' needs with varying degrees of effectiveness.

Illiteracy characterizes the developing countries where of the 1.3 billion people living in these areas, an estimated 750 million of school age or older cannot read or write.[3] Thus, the written word is essentially eliminated as a means of communicating with nearly three-quarters of a billion people. Our present efforts are obviously inadequate as there are 20 million more illiterates today than there were five years ago.[4]

Harbison and Myers [5] grouped 75 countries in terms of four levels of human resource development: Level I, underdeveloped; Level II, partially developed; Level III, semiadvanced; and Level IV, advanced. References to these levels are made throughout this report.

Table 12–1 groups countries by the four levels with their populations. Table 12–2 compares certain characteristics of countries on those levels. For example, it shows relationships between human resource development and characteristics such as the gross national product (GNP), median literacy, and the percent of population involved in agricultural pursuits.

Level I countries, comprised mostly of African nations, are charac-

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[3] Hoffman, P. G., World without want. In: Britannica Book of the Year, 1962. pp. 32–33.
[4] What is UNESCO? Published by UNESCO, Paris, France, 1966.
[5] Harbison, F., and Myers, C. A. Education, manpower, and economic growth; strategies of human resource development. New York, McGraw-Hill, 1964. 229 pp.

terized by having an extremely small trained manpower force. In most of these countries, less than 1 percent of the indigenous population has a secondary education or its equivalent. Most of the educated and trained indigenous personnel in Level I are employed in government services and in education. Foreign scientists and educators fill more than half of the high-level manpower positions. Educational conditions are underdeveloped at every level.

Level II, which includes such countries as Indonesia, Pakistan, mainland China, and parts of Latin America, is comprised of what Harbison and Myers call partially developed countries. Among the developing nations, they may also be called relatively advanced.

As in Level I, there are wide differences among countries within the category. In general, however, they still depend on more advanced countries for much critically needed scientific and engineering manpower. With some assistance from advanced countries, they are able to supply most of their nontechnical high-level manpower such as teachers, managers, and supervisors.

Though Level II countries are progressing toward economic and political maturity, they have not reached a climax in this development. They are still unable to develop enough strategic high-level manpower such as engineers, scientists and highly qualified teachers to progress satisfactorily on the road to economic development.

Nations in Level III comprise those termed semiadvanced by Harbison and Myers. In human resource development they are approximately midway between the partially developed (Level II) and advanced countries (Level IV).

With the possible exception of scientific and technical manpower, Level III countries can provide practically all needed high-level manpower. Shortages persist, but there are enough scientists and engineers available for the countries to import and adopt modern technology successfully without substantial external help.

In education, Level III countries have progressed beyond those of Level II in quantity and quality of primary education. Principal problems are at the secondary and higher education levels. The system of higher education, however, brings Level III countries into the semiadvanced group. Noteworthy universities are in Mexico, India, Egypt, and Chile.

The United States, United Kingdom, U.S.S.R., or any other typical Level IV country have an advanced industrial economy. Such countries make major scientific, technological, and organizational discoveries and innovations. They have strong commitments to education and to human resource development generally. A significant characteristic is the relatively large supply of high-level human resources.

TABLE 12-1.—*Countries grouped by levels of human resource development according to composite index* [1]

| Country | 1964 population (millions) | Index |
|---|---|---|
| (Level I, underdeveloped) | | |
| Niger | 3.3 | 0.3 |
| Ethiopia | 22.2 | .75 |
| Malawi | 3.9 | 1.2 |
| Somalia | 2.4 | 1.55 |
| Afghanistan | 15.2 | 1.9 |
| Saudi Arabia | 6.6 | 1.9 |
| Tanzania | 10.3 | 2.2 |
| Ivory Coast | 3.8 | 2.6 |
| Northern Rhodesia | 4.1 | 2.95 |
| Congo | 15.3 | 3.55 |
| Liberia | 1.0 | 4.1 |
| Kenya | 9.1 | 4.75 |
| Nigeria | 56.4 | 4.95 |
| Haiti | 4.6 | 5.3 |
| Senegal | 3.4 | 5.45 |
| Uganda | 7.4 | 5.45 |
| Sudan | 13.2 | 7.55 |
| (Level II, partially developed) | | |
| Guatemala | 4.3 | 10.7 |
| Indonesia | 103.0 | 10.7 |
| Libya | 1.6 | 10.85 |
| Burma | 24.2 | 14.2 |
| Dominican Republic | 3.5 | 14.5 |
| Bolivia | 3.7 | 14.8 |
| Tunisia | 4.6 | 15.25 |
| Iran | 22.9 | 17.3 |
| China (Mainland) | 686.0 | 19.5 |
| Brazil | 78.8 | 20.9 |
| Colombia | 15.4 | 22.6 |
| Paraguay | 1.9 | 22.7 |
| Ghana | 7.6 | 23.15 |
| Malaya | 7.8 | 23.65 |
| Lebanon | 2.3 | 24.3 |
| Ecuador | 4.9 | 24.4 |
| Pakistan | 100.8 | 25.2 |
| Jamaica | 1.7 | 26.8 |
| Turkey | 30.7 | 27.2 |
| Peru | 11.4 | 30.2 |
| Iraq | 7.0 | 31.2 |
| (Level III, semiadvanced) | | |
| Mexico | 39.6 | 33.0 |
| Thailand | 29.7 | 35.1 |
| India | 471.6 | 35.2 |
| Cuba | 7.4 | 35.5 |
| Spain | 31.3 | 39.6 |
| South Africa | 17.5 | 40.0 |
| Egypt | 28.9 | 40.1 |
| Portugal | 9.1 | 40.8 |
| Costa Rica | 1.4 | 47.3 |
| Venezuela | 8.4 | 47.7 |
| Greece | 8.5 | 48.5 |
| Chile | 8.5 | 51.2 |
| Hungary | 10.1 | 53.9 |
| Taiwan | 12.1 | 53.9 |
| South Korea | 27.6 | 55.0 |
| Italy | 51.0 | 56.8 |
| Yugoslavia | 19.3 | 60.3 |
| Poland | 31.2 | 66.5 |
| Czechoslovakia | 14.1 | 68.9 |
| Uruguay | 2.7 | 69.8 |
| Norway | 3.7 | 73.8 |
| (Level IV, advanced) | | |
| Denmark | 4.7 | 77.1 |
| Sweden | 7.7 | 79.2 |
| Argentina | 22.0 | 82.0 |
| Israel | 2.5 | 84.9 |
| West Germany | 56.1 | 85.8 |
| Finland | 4.6 | 88.7 |
| U.S.S.R. | 227.7 | 92.9 |
| Canada | 19.2 | 101.6 |
| France | 48.4 | 107.8 |
| Japan | 96.9 | 111.4 |
| United Kingdom | 54.1 | 121.6 |
| Belgium | 9.4 | 123.6 |
| Netherlands | 12.1 | 133.7 |
| Australia | 11.1 | 137.7 |
| New Zealand | 2.6 | 147.3 |
| United States | 192.1 | 261.3 |

[1] The composite index, developed by Harbison & Myers op. cit., is the "arithmetic total of: (1) enrollment at second level of education as a percentage of the age group, 15 to 19, adjusted for length of schooling, and (2) enrollment at the third level of education as a percentage of the age group, multiplied by a weight of 5." pp. 31-32.

### *12.3.2 Formal Education*

Human resources are nurtured in many ways. Formal education is the most obvious way, starting with primary or first-level education, continuing with secondary education, and then higher education including colleges, universities, and higher technical institutes.

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TABLE 12-2.—*Certain educational and other characteristics of nations by level of human resource development*

| Characteristic | Classification of countries [1] | | | |
|---|---|---|---|---|
| | Level I, 17 underdeveloped countries | Level II, 21 partially developed countries | Level III, 21 semi-advanced countries | Level IV, 16 advanced countries |
| Population (millions) | 182 | 1,123 | 834 | 771 |
| Gross national product per capita (US$) | 84 | 182 | 380 | 1,100 |
| Percent of population active in agriculture | 83 | 65 | 52 | 23 |
| Median illiteracy [2] | 89.5 | 59.5 | 23.5 | 2.8 |
| Scientists and engineers per 10,000 population | .6 | 3 | 25 | 42 |
| Percent of total population: [3] | | | | |
| All students | 6.01 | 13.58 | 16.30 | 21.79 |
| 1st-level students | 5.59 | 11.90 | 10.80 | 13.35 |
| 2d-level students | .36 | 1.39 | 4.64 | 5.51 |
| 2d-level students (vocational) | .041 | .15 | .51 | 1.44 |
| 3d-level students | .015 | .14 | .34 | 1.48 |
| Total 2d and 3d levels | .42 | 1.68 | 5.49 | 8.43 |
| Public expenses on education as percent of national income | 3.7 | 2.1 | 3.1 | 4.2 |

[1] See Table 12-1 for country listing.

[2] Generally, literacy is reported for persons 15 years of age and older. The illiteracy figures are the latest reported by UNESCO and are for 9 countries in Level I; 18 in Level II; 19 in Level III; and 7 in Level IV.

[3] 1st, 2d, and 3d levels approximate elementary, secondary, and college education in the U.S. system.

Source: From Harbison, Frederick and Charles A. Myers. Education, manpower and economic growth; strategies of human resource development. New York, McGraw-Hill, 1964. p. 38, and from United Nations Educational, Scientific and Cultural Organization Statistical Yaerbook, 1965. Paris, 1965.

In developing countries, the modern knowledge gap, overall low student enrollment, low enrollment and graduation of agricultural students in universities, and low rate of literacy are all concerns in formal education.

The extent of problems is further emphasized when one considers a country's individual deficiencies as well as lack of qualified teachers, wide variations in curricula and standards, lack or shortage of textbooks and teaching aids, high percent of student dropouts, overseas education, and the "brain drain". All are important factors strongly affecting the countries' food and population problems.

The modern knowledge gap vividly portrays the present vastness and increasing complexity of the problem of education. With the rapid developments of knowledge in all disciplines, the educational lag of the developing versus developed nations widens. The less fortunate nations need the products of education, but, first and foremost, their people need an education. As stated by Channing: "He is to be educated, because he is a man, not because he is to make shoes, nails or pins".[6]

[6] Channing, William Ellery, "Works of William Ellery Channing," New Edition, American Unitarian Association, Boston, 1890, p. 19.

*12.3.3.1 Primary Education.* Terms such as "meager" and "poor quality" best describe education in Level I (underdeveloped) countries and Level II (partially developed) areas. Not only is there a shortage of qualified teachers, but textbooks and teaching materials are poor or do not exist. Furthermore, there are wide variations in curricula and standards since varied voluntary agencies or missionary groups operate many schools. Pressure of rapid expansion in the number of schools and pupils at primary level make it hard to maintain, let alone improve, quality.

Amid this situation is a high dropout rate. For example, enrollment in Brazil's primary schools in 1957 [7] was:

| | *Percent of 1st-year enrollment* | |
|---|---|---|
| | *In state capitals* | *Outside state capitals* |
| Grade: | | |
| First | 100. 0 | 100. 0 |
| Second | 61. 1 | 35. 4 |
| Third | 47. 2 | 22. 8 |
| Fourth | 35. 1 | 12. 7 |

The figures for Brazil typify the dropout problem in most countries in Levels I and II. They also emphasize the higher dropout rate among children who live in smaller cities or in rural areas.

Even in Level II countries, few rural children are among those in primary school, for many live too far from the nearest school. Full primary education is available, in reality, only to those from larger towns and cities.

Principal efforts have focused on increasing the number of classrooms and teachers, but there has been too little concern with training teachers, improving standards, or developing instructional materials.

For example, universal primary education of six years is near achievement in Eastern and Western Nigeria (Level II). Yet these efforts are seriously hampered by poorly educated teachers. Even today, probably only 10 to 15 percent of all primary teachers in Nigeria have studied beyond primary school.

In most of the developing countries there is a similar, though not always as severe, teacher qualification problem. Moreover, in Level I and II countries this situation will likely become worse rather than improve as governments push to extend primary education rapidly to all children in the compulsory school-age group. Amid high rates of population growth, numbers in this age group are increasing sharply.

Compared with Levels I and II, countries in Level III offer primary education of better quality and quantity. In particular, effective

[7] Inter-American Committee for Agricultural Development. Inventory of information basic to the planning of agricultural development in Latin America, Brazil, Washington, Pan American Union. 1964. 156 pp.

schooling in these areas is geared to varied needs of the maturing society in which rural areas and agriculture still play important roles. For example, special educational programs for rural areas have been underway for some time in India, Mexico and other Latin American countries. Others have been started more recently in several African countries. Though many teachers still are not fully qualified, the percentage of primary education teachers who are trained is said to have risen from 58 percent in 1949–50 to 65 percent in 1961.

Most Level III nations have legal compulsory primary education for at least six years. Published enrollment figures show less than this, however, because of the unavailability of schools and teachers in rural areas.

*12.3.3.2 Secondary Education.* Like primary schools, secondary schools in Level I and II countries generally charge fees and are mainly used by persons with above-average incomes. They are commonly run by missionary organizations or private groups, the same as are primary schools.

Typically, the secondary enrollment for Level I countries is only 2.7 percent of the age group, 15 to 19. Comparable figures for Levels II and III are 12.4 and 27 percent. In all three levels, the demand far exceeds the supply of available secondary schools. This is true, despite deficiencies which in Level II, for instance, are even more serious than in primary education.

Deficiencies in Level II are due, in part, to governments giving first priority to building primary schools and high priority to development of universities. Secondary education, in contrast, is largely offered by private, fee-charging institutions. As a result, nearly all countries on this level have woefully inadequate secondary education systems which are among the chief obstacles in the path of economic and social progress.

However, some countries in Level II offer rather high-quality secondary education designed to prepare students for higher education within and outside the country. In general, the curriculum is so academically oriented as to provide little help or motivation for students concerned with food supply. Moreover, the stress is on foreign rather than local cultures and conditions, and few students can be accommodated.

The teachers are usually expatriates with fairly good teaching training and as members of the "intellectually elite", they tend to move rapidly into high, government positions. The result is an acute shortage of indigenous teachers—a situation that will long remain.

Level III countries also are afflicted with a shortage of competent teachers, many of whom are still narrowly academic and mainly university-oriented.

The shortage of secondary school graduates is a giant obstacle to progress in food production and distribution. Technicians for laboratory and field research often are lacking. Likewise, field men for agricultural and food industries are scarce due to the shortage of secondary school graduates.

*12.3.3.3 Higher Education.* As one scales the educational heights in developing countries, the student population appears especially minute in relation to the nations' manpower needs. In terms of these needs, the proportion of students studying agriculture in higher education is abysmally low as shown in Table 12–3.

TABLE 12–3.—*Students enrolled in higher-level institutions by field of study*

| Item | Level I, 15 under-developed countries | Level II, 20 partially developed countries | Level III, 21 semi-advanced countries | Level IV, 14 advanced countries |
|---|---|---|---|---|
| Total (thousands) | 29 | 991 | 2,922 | 2,802 |
| Percent enrolled in: | | | | |
| Humanities and fine arts | 20.2 | 14.9 | 26.7 | 23.3 |
| Education | 9.3 | 13.0 | 6.8 | 6.9 |
| Law | 16.9 | 9.2 | 6.2 | 8.1 |
| Social sciences | 15.5 | 11.7 | 16.0 | 16.7 |
| Natural sciences | 13.0 | 7.6 | 16.8 | 11.2 |
| Engineering | 8.2 | 24.3 | 13.3 | 14.5 |
| Medical sciences | 9.7 | 12.7 | 8.4 | 11.2 |
| Agriculture | 4.9 | 6.0 | 5.0 | 2.3 |
| Not specified | 2.3 | .6 | .8 | 5.8 |

Source: United Nations Educational, Scientific and Cultural Organization. Statistician Yearbook, 1965. Paris, 1965.

College graduating classes in six Level I countries with a combined population of 116 million in 1964 included only 144 agricultural students.[8] Moreover, the entire college student body in these six countries as well as the other nine in Level I includes only 5.6 percent studying agriculture. In contrast, about 20 percent are studying humanities and fine arts. Obviously, food supply has not been accepted as a problem worthy of their study at the college level.

Whatever one studies, costs per student are relatively high for college-level education in Level I countries as shown in Table 12–4. Contributing to this cost is the necessity of employing a high proportion of foreigners on the faculty and of importing teaching equipment and laboratory supplies. High costs lead qualified students to study in the United States, Europe, or in a neighboring country instead of pursuing third-level schooling at home.

Most developing countries consider their own universities essential to national prestige. They also cite drawbacks to students' studying

[8] United Nations Educational, Scientific and Cultural Organization. Statistical Yearbook, 1965. Paris, 1965.

TABLE 12-4.—*Recurring Expenditures for Primary, Secondary, and Higher Education in different development groups*

| Category of education | Annual costs per student (US$) | | | |
|---|---|---|---|---|
| | Level I, 5 under-developed countries | Level II, 10 partially developed countries | Level III, 12 semi-advanced countries | Level IV, 10 advanced countries |
| Primary | 19 | 45 | 101 | 170 |
| Secondary | 229 | 155 | 235 | 263 |
| Higher | 1,576 | 797 | 1,162 | 1,127 |

Source: United Nations Educational, Scientific and Cultural Organization. Statistical Yearbook, 1965. Paris, 1965.

abroad; namely, students face readjustment at home after studying in a foreign environment, and some, lured by fine positions, remain abroad. Furthermore, in Africa which contains most Level I countries, a major purpose of local universities is to stress importance of African studies and national needs. So they continue to maintain them despite great expense.

In Level II countries, higher education is perhaps relatively more advanced than is either primary or secondary education. There are universities, higher technical institutions, and higher teacher-training colleges in most of these countries. Quality is often sacrificed for quantity, however, though there are exceptions such as Ghana, Jamaica, and Nigeria.

In contrast to universities in India, Egypt, and other countries in Level III, the institutions normally are not yet overcrowded. The lack of students moving up from the secondary level holds back the pressure of students for entrance into universities.

High enrollments in law, humanities, and art partly reflect the orientation of students toward employment in these professions and, to a lesser extent, toward the cultural traditions of the countries. However, the major reason for expansion of law, arts, and humanities faculties is that places for students in these fields are the cheapest to provide. For example, education costs per enrolled student are probably one-sixth to one-fourth of those in medicine, the natural or biological sciences, and engineering.

One notes distinguished universities in countries such as Mexico, India, Egypt, and Chile. More than any single factor, the system of higher education brings these and other countries into the semi-advanced group, Level III. Yet quality of education in the semi-advanced group of nations is uneven and still far below the average in advanced countries, Level IV.

*12.3.3.4 Overseas Education and the "Brain Drain".* In 1963–64, about 107,000 college students from Levels I, II, and III were engaged in studies abroad in 15 countries (Table 12–5). Approximately half were studying in Europe.

TABLE 12–5.—*Numbers of 3-level (college) students from different areas studying overseas in 15 countries compared with the numbers studying at home (1963 or 1964)*

| Area providing college training | Area of student origin [1] | | |
|---|---|---|---|
| | Level I countries, underdeveloped | Level II countries, partially developed | Level III countries, semiadvanced |
| Europe (9 countries) | 6,031 | 20,790 | 22,626 |
| United States and Canada | 4,664 | 22,423 | 18,314 |
| Other (4 countries) | 2,092 | 6,742 | 3,069 |
| Total | 12,787 | 49,955 | 44,009 |
| Number receiving college-level training at home (thousands) | 28 | 1,554 | 2,840 |

[1] See Table 12-1 for listing of nations in the 3 development levels.

Source: United Nations Educational, Scientific and Cultural Organization. Statistical Yearbook, 1965. Paris, 1965.

Level I countries had about one-half as many students studying abroad as studying at home. Ratios for Levels II and III were 1 in 30 and 1 in 64 studying abroad.

In 1966, only 3,064 (3.7 percent) of the 82,709 foreign students in the United States studied agriculture. Engineering and the humanities were the leading fields of study (Table 12–6). The students' lack of emphasis on agriculture is probably related to their individual backgrounds. It certainly is not related to the food and agriculture needs of their respective countries.

TABLE 12–6.—*Fields of study of foreign students in the United States (1965–66)*

| *Field of study* | *Percentage distribution* |
|---|---|
| Engineering | 21.9 |
| Humanities | 20.0 |
| Natural and physical sciences | 17.6 |
| Social sciences | 14.9 |
| Business administration | 9.6 |
| Medical sciences | 5.0 |
| Education | 5.1 |
| Agriculture | 3.7 |

Source: Institute of International Education. Open doors 1966, report on international exchange. New York, 1966. Reference p. 13.

Table 12–7 lists the numbers of foreign students studying in the United States from countries having different levels of human resource development. The percentage studying agriculture declines as the level of development increases (from Level I to III). Likewise, of those studying agriculture, the percentage who are graduate students is greater in Level III than in Level I, a reflection of the differences in university opportunities at home. United States institutions have contributed for many years to the education and training of foreign nationals concerned with the world food supply. Most likely, our contributions will be needed and wanted for some time.

Two problems are inherent in United States-based training of foreign nationals, especially graduate students. First, the environment in which the student studies differs markedly from that in his own country. Frequently, research equipment is more modern than what the student will have when he returns home. Also, his thesis research problem may have little or no application to the solution of food, nutrition, or population problems at home. Social and economic environments also are rather different from his home country.

TABLE 12–7.—*Foreign students studying agriculture in the United States from countries varying in human resource development, 1965–66*

| Foreign students in the United States | Region of students' origin [1] | | | |
|---|---|---|---|---|
| | Level I, 17 under-developed countries | Level II, 20 partially developed countries | Level III, 21 semi-advanced countries | Level IV, 15 advanced countries |
| Number in all fields | 5,215 | 13,948 | 26,087 | 22,081 |
| Number in agriculture | 404 | 640 | 960 | 609 |
| Percent in agriculture | 7.7 | 4.5 | 3.7 | 2.7 |
| Number of students specializing in agriculture: | | | | |
| Graduate students | 106 | 340 | 750 | 332 |
| Undergraduates | 277 | 265 | 172 | 196 |
| Others | 21 | 35 | 38 | 81 |
| Percentage distribution of students specializing in agriculture: | | | | |
| Graduate | 26 | 53 | 78 | 55 |
| Undergraduate | 68 | 41 | 18 | 32 |
| Other | 6 | 6 | 4 | 13 |
| Total | 100 | 100 | 100 | 100 |

[1] See Table 12-1 for list of countries. Mainland China excluded from Level III group.

Source: Institute of International Education. Open doors 1966, report on international exchange. New York, 1966. Reference p. 13.

A second problem is the "brain drain". Many graduates do not return to their homeland after completing their academic work abroad. Instead, they obtain employment in the United States or other developed countries. While contributing to the total world scientific manpower force, they make little impact on the food supply prob-

lems in their native countries. The brain drain has been called "one of the great and neglected problems of our time" which robs developing countries of the professional and skilled manpower they need to bring hope to their peoples.[9]

The significance of the "brain drain" in disciplines related to population and the world food supply is not well established. In one agricultural field (agronomy) a study[10] showed that 39 percent of the foreign students graduating from United States universities with a B.S. degree remained in the United States. During the same period, 43.5 percent of those receiving an M.S. and 32.9 percent of those earning the Ph. D. in agronomy remained here. The number from developing countries was not reported separately, but it is likely that many of them were included among those who remained in this country.

President Johnson has endorsed a proposal that multinational institutions be developed for advanced training in science and technology. Such institutions could provide prestigious centers for training and reduce the "brain drain" associated with students coming to the United States and other developed countries for their training.[11]

### *12.3.3 Manpower Needs*

Progress of a developing nation depends upon development of its people. Among the factors involved in economic growth, none is more important than the development of the human resource. Problems of building on human resources fit into two broad categories: (1) those related to shortages of high-level manpower with critical skills and competence, and (2) those related to under-utilized manpower.

Underdeveloped (Level I) countries are unable to meet even minimum needs for local high-level manpower, and the needs on this level are critical. For the immediate future, underdeveloped (Level I) countries need to train 1,000,000 persons as top-level administrators, professional personnel, management and business executives, and middle-level technicians for building and industrial programs, health services, education and supervisory positions in government and industry.[12]

Foreigners also hold strategic technical positions in public services, top posts in private industry and commerce, and most higher positions in education. Non-native farmers produce most of the agricultural exports. In East Africa (Kenya, Tanzania, Uganda), for example, the 67,000 persons currently holding positions in the high-level category

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[9] Mondale, W. F., The International Brain Drain Act of 1966. U.S. Congr. Rec. 112: 25438–25441. Oct. 13, 1966.

[10] Seif, R. D. Correspondence. College of Agriculture, University of Illinois, Aug. 30, 1966.

[11] Rowan, C. T., "Brain drain" hurts alliance for progress U.S. Congr. Rec. 112: 25649. Oct. 13, 1966.

[12] Harbison, F., and Myers, C. A. Education, manpower, and economic growth; strategies of human resource development, New York, McGraw-Hill, 1964, 229 pp.

include nearly 23,000 Europeans and 31,000 Asians.[13] Europeans comprise 50 percent of the total in the senior category—top personnel, administrators and managers and university graduate teachers. Asians make up 38 percent; Africans only 12 percent.

In varying degrees, manpower needs also face countries at other levels of development. India, for example, a semi-advanced country (Level III), had less than 10,000 agriculture graduates of the 273,000 holders of technical university degrees in 1961. During the next 15 years this number will need to be increased to 125,000, according to Revelle[14] who also suggests that there would be one agricultural university for every 5 million farmers. This means a total of 20 such institutions instead of the present seven.

Table 12–8 provides an indication of India's manpower needs for food and agriculture. Revelle contends that the chief problem in building to levels shown in the Table 12–8 is the present acute shortage of potential faculty members.

In addition to the estimates in Table 12–8, Revelle projected that the number of persons with a diploma level of training should be at least one to two times the number of persons with university degrees. This ratio would require 300,000 to 600,000 diploma holders.

In addition to the above information, it has been suggested in Chapter 6 of this report that, if 50 percent of the agriculture acreage in developing countries were sown to improved varieties, an estimated

TABLE 12–8.—*Manpower needs for agricultural development in India (includes persons with B.S., M.S., or Ph. D. degrees)*

| | |
|---|---|
| Agriculture (including animal husbandry and veterinary science) | 127,500 |
| Engineering | 28,000 |
| Nutrition and food technology | 15,700 |
| Agricultural economics | 10,200 |
| Public administration | 7,500 |
| Mass communications | 4,200 |
| Sociology, anthropology and law | 7,500 |
| Resource conservation | 11,700 |
| Forestry | 16,500 |
| Fisheries | 8,500 |
| Earth science | 2,700 |
| Basic science | 15,000 |
| Humanities | 1,000 |
| Total | 256,000 |

Source: Revelle, R. Notes on education for agriculture. New Delhi, Education Commission, 1966.

[13] Harbison, F., and Myers, C. A. Education, manpower, and economic growth; strategies of human resource development. New York, McGraw-Hill, 1964, 229 pp.

[14] Revelle, R. Notes on education for agriculture. New Delhi, Education Commission, 1966.

44,550 scientists and technicians would be needed for Latin America, Asia, Africa, Europe, and Oceania in the work related to such development.

The additional trained manpower needs for pesticide production, formulation, and research are given in Table 12–9. This excludes technically trained manpower needed in extension, sales and distribution. Even so, the total number required is in excess of 11,000.

The human resources needed to build a strong fertilizer industry in developing nations is predicted to be 51,000 skilled and 85,000 unskilled workers by 1977; 66,000 skilled and 110,000 unskilled workers by 1980.[15]

Using Revelle's figures for India (Table 12–8) as a basis, the estimated needs for college-trained manpower (Table 12–10) were calculated. These calculations are based on the assumption that the needs for college trained manpower in relation to the size of the population in agriculture was the same in other developing nations as in India. This would indicate a need for more than a million college graduates.

Reliable estimates of the numbers of college trained individuals currently working in developing countries are unavailable. In Level I countries, however, it is likely that less than 5 percent of the needs for college graduates are met. Assuming that comparable estimates for Levels II and III are 30 percent and 50 percent respectively, the total *unmet* college trained manpower needs are 438,000 persons. Using

TABLE 12–9.—*Estimated requirements for technical manpower to implement expanded pesticides programs*

| | Asia | | Africa | | Latin America | | Oceania | |
|---|---|---|---|---|---|---|---|---|
| | R & D [1] | Other | R & D | Other | R & D | Other | R & D | Other |
| Manpower for production of pesticides (for 50 percent production increase) | 1,023 | 1,116 | 264 | 288 | 275 | 300 | 165 | 180 |
| Manpower for formulation of pesticides (for 50 percent production increase) | 108 | 324 | 28 | 84 | 30 | 90 | 18 | 54 |
| Adaptive pesticides research program (for 50 percent production increase) | 952 | 1,904 | 609 | 1,218 | 504 | 1,008 | 168 | 336 |
| Total | 2,083 | 3,344 | 901 | 1,590 | 809 | 1,398 | 351 | 570 |

[1] Research and development.

Source: Ennis, W. B. Correspondence. Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Md.

[15] Nelson, L. B. Correspondence. Office of Agricultural and Chemical Development, Tennessee Valley Authority, Muscle Shoals, Ala., Nov. 18, 1966.

TABLE 12–10.—*Manpower needs for agricultural development in 3 human resource groups*

| Region | Population in agriculture (millions) | Manpower needs [1] (thousands) | | Total |
|---|---|---|---|---|
| | | In agriculture | In other disciplines | |
| Level I, underdeveloped | 151 | 62 | 62 | 124 |
| Level II, partially developed [2] | 248 | 102 | 102 | 204 |
| Level III, semi-advanced | 434 | 178 | 178 | 356 |

[1] Includes persons with B.S., M.S., or Ph. D. degree calculated using the same ratio of manpower needs per million agricultural population as used by Revelle op. cit.

[2] Excludes Mainland China.

Source: Harbison, F., and Myers, C. A. Education, manpower, and economic growth; strategies of human resource development. New York, McGraw-Hill, 1964. 229 pp. Revelle, R. Notes on education for agriculture. New Delhi, Education Commission, 1966.

Revelle's "College to Diploma" ratio of 2 to 1, twice this number of additional sub-college trained people will be required.

Trained personnel are needed to support family planning programs as well as those concerned with food supply and nutrition. Researchers, doctors, nurses and technicians will be required as well as formal and extension educators.

### *12.4.0 Food Related Research in Developing Countries*

There is great diversity in food and nutrition research programs of developing nations and in the progress that has been made in recent years. Some nations have made giant strides in developing long-range, sound research and teaching programs. Others have progressed little or have regressed due to civil strife, economic difficulties, or other internal problems.

The size and quality of research programs are closely related to the number and quality of trained scientists. In Level I, for instance, Africa's emerging countries have woefully inadequate research underway on population and food supply problems. Some research stations formerly manned by Europeans now operate at low-quality levels, while others have been abandoned. Most of the countries in Level I have virtually no native scientists. This void requires continued employment of foreigners which, in turn, gives rise to an unstable and politically unpopular situation. Under these conditions, continuity of high-level research programs is impossible.

In contrast, some countries classed in Level III in terms of human resource development (Table 12–1) have made significant progress in expanding and improving their agricultural research efforts. For example, Mexico initiated a well-coordinated research effort under the administration of the National Institute of Agricultural Research.

This program has a central research group as well as a number of regional research stations.

Likewise, India has made important progress in food and nutrition research. The Indian Council of Agricultural Research provides a nationwide coordinating body. The Indian Agricultural Research Institute in New Delhi and seven newly created state agricultural universities have excellent potential for research accomplishment and for supplying trained manpower.

Both Mexico and India have a significant number of qualified scientists to organize and implement new research efforts. An increasing number of these scientists have received at least part of their university training at home. These nations and others in Level III depend less on assistance from scientists in more developed nations than do countries in Levels I and II.

Nevertheless, nations in Level III have serious population-food problems that need research. India, for example, has a population increase rate which demands extraordinary increases in food production. Research inputs at levels greater than in the recent past will be required to help these nations meet their food needs. Research on family planning has had little emphasis in relation to need. This has been due, at least in part, to social and religious constraints on birth control. The possibility of widespread famine has led to a reconsidera- of these constraints and increased interest in research and education relating to family planning.

### *12.4.1 National Commitments to Research on Food Supply and Nutrition*

Most developing countries fail to recognize the potential contribution of research to a balanced population and food supply. The small allocations of national resources to research seem discordant with the serious nature of the problem.

Low economic and social status of farm people may account for national policies which have not encouraged the well-being of farmers. Inadequate research and extension to help these people is a consequence.

There is a great misconception about the time lag between research discovery and applying technology to the production and marketing of food. Likewise, there is misunderstanding as to nutritive requirements of people in developing areas.

Some governments have used research to meet food supply problems. For instance, the farsighted Mexican Government established a joint agricultural development program with the Rockefeller Foundation in the early 1940's. Other Latin American countries are participating in demonstrations of nutritionally superior foods. These examples are

encouraging and similar actions are being planned by other governments in the developing nations.

### *12.4.2 Organization and Administration of Research*

Many of the developing nations were formerly ruled by colonial powers, and their research organizations reflect the pattern of the nation which ruled them. For example, food production research usually is directed by a ministry or department of agriculture. Often there is a central research organization with a number of inadequately staffed field stations. Some larger nations have state as well as national institutes whose activities may or may not be coordinated with the national organization.

Compared with the more advanced nations, developing countries assign relatively little importance to university research, especially that related to food production, processing and marketing. The system involving a coordinated research program of government agencies and universities, so common in the United States, is virtually non-existent in developing nations. In fact, universities may be discouraged or forbidden to conduct applied research. In countries where university research programs exist, they often must compete with those of government agencies for operating funds.

In some countries, the organization of subject matter and discipline-oriented research affects the overall coordination. For example, in some Latin American and in most Asian countries, animal science research is commonly under the direction of veterinarians in government agencies or veterinary colleges. As a consequence, there is little work on animal breeding, physiology, and nutrition.

Political instability in several countries and consequent changes in organization and administration result in programs directed by poorly qualified persons. This discourages well-trained scientists and often leads to frustration or even abandonment of scientific careers.

### *12.4.3 Resources to Carry Out Research*

*12.4.3.1 Trained Manpower.* Lack of trained and educated manpower is the most serious limiting factor to effective research on food-population problems. There is a need for scientists with advanced training to organize and plan effective research programs and for project leaders to guide their implementation. Supporting personnel, technicians, and field foremen who are sufficiently well-trained to carry out scientists' instructions are lacking.

Manpower estimates for research personnel needed are greater in many cases than the entire output of indigenous agricultural colleges. The following data from a survey taken in 1959 in Brazil emphasize the trained manpower need.[16]

[16] Inter-American Committee for Agricultural Development. Inventory of information basic to the planning of agricultural development in Latin America: regional report. Washington, Pan American Union, 1963. 202 pp.

| | Persons now employed | Additional persons needed |
|---|---|---|
| Agronomists | 3,004 | 2,922 |
| Veterinarians | 1,448 | 1,344 |
| Social workers | 1,455 | 2,069 |
| Home economics workers | 365 | 264 |
| Total | 6,272 | 6,599 |

The number of additional professionally trained people needed was more than that employed in 1959.

Attracting competent personnel into the food and agriculture professions will continue to be difficult so long as salaries and support for research scientists remain low. Those with training to do research are often forced to take second or even third jobs to earn a livelihood. For example, on the faculties of five agricultural schools in Mexico there are 75 full-time professors and 114 part-time professors, most of whom have jobs elsewhere.[17] This situation limits not only their productiveness but their commitment and loyalty to their profession and mission.

*12.4.3.2 Facilities.* Developing areas lack research laboratories with modern scientific equipment so essential for effective research. The facility problem is especially critical in the tropics. To cope with high temperatures and high humidities special laboratory and storage rooms must be available.

Equipment maintenance also is a serious problem. Effective commercial maintenance services are not available locally. Research budgets permit little or no equipment repair and replacement. Consequently, expensive equipment may lay idle for months, if not years.

*12.4.3.3 Financial Support.* Generally, insufficient funding is the underlying cause of inadequate research, manpower, and facilities. Since the return from research investment is not immediate, research is less likely to get government funds than are highways, industries, or other publicly supported projects. In the developing countries, a lower percentage of the gross national product ordinarily is spent for research than in nations more advanced industrially and technologically. This is unfortunate since the relative needs for food and nutrition research in developing countries are greater.

The budget and staff for Research Institutes in India (Table 12–11) and for Latin America (Table 12–12) show relatively low financial support for research. The budget for India in 1960 was less than that currently supporting agricultural research in the State of New York. After taking into account differences in currency values, it is obvious that research efforts must be greatly expanded if India is to feed her

[17] Ibid.

470 million people. Similarly, agricultural problems facing Brazil and other Latin American countries need support far in excess of that currently available.

Certainly, some types of research are more costly in developing than in developed nations where goods, services, and indigenous manpower are more readily available. There are many cases where the cost of research will be less expensive than if it were done in the United States or other developed nations. In most cases, it would be inappropriate to do the research any place except in the environment where results are to be applied.

### *12.4.4 Program Content and Orientation*

Perhaps the greatest deficiency in program content and orientation is lack of concentration on problems of food supply and quality. Investi-

TABLE 12–11.—*Budget and staff for agricultural research institutes and stations in India (1960)*

| Item | Type of research units | | |
|---|---|---|---|
| | 13 national research institutes | 91-State research stations | Total |
| Budget in 1960 (US dollars—thousands) | 7,184 | 3,061 | 10,245 |
| Staff: | | | |
| Ph. D. degree holders | 226 | 63 | 289 |
| M.S. degree holders | 704 | 384 | 1,088 |
| B.S. degree holders | 284 | 1,123 | 1,407 |
| Others degree holders | 356 | 198 | 554 |
| Total | 1,570 | 1,768 | 3,338 |
| Foreign assistance research staff | 91 | 34 | 125 |

Source: Food and Agriculture Organization of the United Nations. Regional Office for Asia and the Far East. Directory of agricultural research institutes and experiment stations in Asia and the Far East. Bangkok, 1962. pp. 1–12. Supplement, Bangkok, 1963. pp. 13–107.

TABLE 12–12.—*Annual budgets of major national agricultural research institutes or agencies in several Latin American countries*

| Country | Year | Research budget (US$—thousands) |
|---|---|---|
| Argentina | 1961–62 | 9,225 |
| Colombia | 1962 | 4,146 |
| Brazil | 1962 | 3,950 |
| Venezuela | 1962 | 3,488 |
| Mexico | 1963 | 2,100 |
| Peru | 1962 | 777 |

Source: Inter-American Committee for Agricultural Development. Inventory of information basic to the planning of agricultural development in Latin America: Regional report. Washington, Pan American union, 1963. 202 pp.

gators often are engrossed in problems which personally interest them but which have little direct bearing on food problems faced by their countrymen. This is true especially in fields where increased food production might logically be a major objective of the investigator.

The reasons for inappropriate orientation are many. Few personnel in research have had any practical experience in producing, processing, or marketing food. They may share the antipathy of their countrymen toward manual labor and toward practical aspects of food production and distribution. They have probably received their graduate training in the United States or Europe and have done research projects irrelevant to their local problems. They may be unable to apply principles they learned as students to solving applied problems in their home countries.

Some research phases concerning practical problems relating to food and agriculture such as crop and animal breeding have received more attention than others. Researchers have recognized that genetic characteristics of food plants and animals have great potential for affecting national production levels.

Much less work has been done to develop food production systems involving crop culture, fertilizers, and protection from pests. Although there has been some research on animal diseases and their control, there is relatively less information on animal husbandry, nutrition, and physiology.

Areas in which research work is virtually lacking include processing and marketing of food crops and the socio-economic aspects of production, marketing, and consumption of various food products. Likewise, information on nutritional quality of various local foods and the nutritional status and requirements of the people is grossly inadequate.

Little farm management research has been done to determine the best farm production and marketing systems that give greatest yields of high-quality farm products at lowest cost.

Until recently, support for family planning and population control research came largely from private sources. Now developed nations have taken the lead. Some developing countries are strong proponents of this type of research. India, for example, has been rather aggressive in pushing research and education on family planning.[18] There is need for increased interest in population planning by indigenous scientists from other developing countries. At least two major researchable aspects exist—one in demography and socio-psychology and another in the physiology of reproduction.

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[18] Stycos, J. M., The outlook for world population. Science 146(3650) : 1435–1440. Dec. 11, 1964.

263-888 O—67——41

The climatic regions about which we know least are the humid tropics. The theoretical potential for food production is greater here than in temperate regions which currently produce most of our food. Long-term research is needed to realize this potential. Man must learn how to manage tropical soils and how to grow crops on a sustained basis where rainfall rates are 5 to 10 times those of Europe or the United States. And he must learn to protect crops before and after harvesting from a myriad of pests. He must identify and expand the production of crop or animal foods with proven nutritional value.

### *12.4.5 Relationship to Formal and Extension Education*

One of the most serious food and nutrition problems is the difficulty of getting research information to those who should use it. A closely related problem is informing research personnel of practical field problems which need solutions. These requirements necessitate coordination and frequent communication between research and extension staffs.

In most developing countries, this kind of coordination is seldom demonstrated. Extension programs often do not have research information as their bases. In turn, research scientists do not relate to the practical field problems so well known to extension personnel.

Undoubtedly, the fact that research and extension programs are in general administrated through separate agencies accounts for some of this lack of coordination. Some have argued that a system similar to that of the Land Grant Colleges in the United States must be followed to obtain coordination. There is evidence that this is not necessary; as an example, the rapid dissemination of research information relating to new wheat varieties in Mexico was done where extension programs are not administered through universities.

India has taken steps to coordinate some of its agricultural research and university teaching and extension programs. Seven agricultural universities have been established on a regional or state basis. They have some responsibilities for research and extension as well as for educating and training agricultural scientists. Five American universities with financial assistance from AID have assisted the Indian institutions in their development.

### *12.4.6 Relationship to Industry*

Industries allied to production, processing, and marketing of food have made little impact on developing new technologies in food-deficit countries. Largely lacking is the close working relationship between research scientists in public institutions and those who develop and distribute goods and services to food producers. Furthermore, there is not the confidence between farmers and those who supply fertilizers, seeds, and pesticides as in developed countries. New research findings are

not as likely to be used by industry, and growers' acceptance is much slower than in the United States.

There is great potential in coordinating efforts among researchers, educators, and industry personnel. Many examples can be cited where this cooperation has been highly productive; one is the relationship among plant breeders, certified seed cooperatives, and commercial seed companies.

Likewise, the personnel in the food processing industry working with research staffs in government and university laboratories have improved processing methods and the nutritional quality of the food. Exploring the possibility of such relationships in developing nations is imperative.

### *12.5.0 Extension Education*

Since World War II, remarkable progress has been made in establishing extension education in the developing countries. At least 11 countries have set up extension organizations since 1945.[19] Developed nations, including the United States, have strongly backed this expansion through such organizations as AID and FAO.

Generally, the newly formed extension programs have been disappointing. In most cases, they have had little impact on adoption of improved practices.

Two major limitations have been: (1) an insufficient number of well-trained extension personnel, and (2) lack of effective means of communicating with and motivating native populations.

Numbers of extension workers (Table 12–13) are woefully inadequate but numbers tell only part of the story. Lack of success also may be attributed to the over rapid initiation and expansion of extension education programs. In manpower-deficient nations not only were the initial staffs inadequately trained but also the urgent nature of some programs forced them to cope with ill-planned activities.

Desire for maximum impact in minimum time encouraged the establishment of new extension agencies which generally were administered independently of research institutes and agricultural colleges. This was not conducive to good coordination.

Extension services have suffered from the misconception that all that is needed is to give technological knowledge to a populace eager to learn. This conclusion assumed that adequate research information was available to solve the food supply problem. It also assumed that existing extension techniques were adequate and that they could be applied effectively. Experience proved these assumptions wrong.

The desire for a quick, easy solution to the problems of food, nutrition, and population may have led to the emphasis on the "Extension

[19] Proceedings of the International Conference of Extension Administrators. (Summary of Status), Brookings, South Dakota, July 22–August 23, 1965. p. 88.

TABLE 12-13.—*Number of extension workers and farms served per worker*

| Country | Number of extension workers (1959) | Farms served per worker |
|---|---|---|
| India | 48,579 | 913 (1954) |
| Japan | 13,566 | 445 (1960) |
| Argentina | 392 | 1,395 (1952) |
| Philippines | 1,623 | 1,010 (1948) |
| Thailand | 328 | 6,438 (1950) |
| United States | 15,100 | 218 (1966) |

Source: Asian countries: Extension Education for Agriculture and Rural Development, FAO, Bangkok, Thailand, 1963. Argentina: Informe del Cento Sudamericano de Extension Agricola, FAO, Rome, 1959. United States: Federal Extension Service, U.S. Department of Agriculture.

Way"—to the neglect of other avenues of approach. There are no quick, easy solutions. Solidly based, long-term programs take years to develop.

Extension has failed to meet its goals partly because of major obstacles in the developing countries. They include:

(1) Traditions impeding progressive change.

(2) Low status of agriculture and farm people.

(3) Lack of appropriate credit institutions and farmer incentives.

(4) Little representation of farmers in the political power structure.

(5) Lack of understanding by national leaders of extension's potentials and requirements.

(6) Inadequate protection from political interference.

(7) Human resource deficiencies including illiteracy and poor facilities.

(8) Inefficient transportation and communications with isolated farm and rural families.

(9) Lack of complete packages of improved production practices.

(10) Extension personnel with insufficient training in crop and animal management.

The "know-how, show-how" concept has been no more successful in extension than in research. Extension methods so successful in developed areas have often failed in the developing areas. Too often, the gross concepts of extension have been borrowed in toto from the United States or Europe. No adaptive research is done to discover and refine effective teaching and communicating methods for the developing countries.

Experience has shown a number of characteristics which a farmer

education program must have if it is to succeed. Mosher has outlined these as follows:[20]

1. It must go to farmers where they are.
2. It must be specific to farmers' present interests and needs.
3. It must respect the fact that farmers are adults.
4. It must be fitted into times when farmers are not too busy.
5. The unit of instruction for teaching and learning must in most cases be a particular new or changed practice.
6. It must be accompanied by immediate opportunities for farmers to try out the new methods taught.
7. Each new or changed practice proposed must be technically sound and economically profitable.
8. Farmers need encouragement to experiment.

This set of guidelines, adapted to local conditions, will need extensive trial.

### *12.6.0 Contributions of Developed Nations*

Since the onset of formal country-to-country relationships, the developed nations have contributed to the economic development of developing areas. During the past 20 years, this technical assistance which has supported research and education programs on world food supplies has been expanded. Also, institutional support has helped establish and improve universities and, to a lesser extent, research units of agricultural agencies.

#### *12.6.1 Contributions of the United States*

The United States has contributed to research and educational inputs on the world food problem for more than two decades through (1) Federal agencies including AID and its predecessors; (2) universities; and (3) private foundations.

*12.6.1.1 Federal Agencies.* AID and its predecessor agencies have contributed to overseas institutional development and programs utilizing research and education. Through direct agency projects as well as contracts with universities, they have helped establish and improve universities. Such institutional development is one of AID's most significant contributions.

Federal agencies have also provided training for foreign nationals. For example, during 1953–63, about 72,000 persons received some training outside their own countries.[21] Some 2,500 were in programs under the auspices of universities that had contracts to assist in overseas

[20] Mosher, A. T. Getting Agriculture Moving. Frederick A. Praeger, New York. 1966.
[21] U.S. Department of Agriculture. Yearbook of Agriculture 1964. Washington, D.C., U.S. Govt. Printing Office, 1964. 592 pp.

institutional building. In 1966, 70 universities had 110 contracts to aid institutions in 37 countries.

Since 1962, AID has supported research through grants to universities and through participating service agreements with government agencies. From the program's inception through June 30, 1966, a total of $37.2 million was obligated.[22] (This was 2.4 percent of the $1.5 billion of technical cooperation funds spent during this period.) Some 40 percent of these funds aided projects in agriculture and rural development. Research on human nutrition and on family planning also received support.

Unfortunately, funds for research sponsored by AID have been very meager, especially in light of the critical problem of world hunger. In 1966, some $12 million was allocated for all AID supported research. Of this amount, less than $5 million was provided for agriculture and related programs. In fiscal year 1967, only $9 million was allotted for AID's central research program of which less than $5 million was applied to agriculture and related activities. The allocation for fiscal year 1968 has been reduced further to less than $7 million for AID's central research fund. With such a meager allotment, any marked impact from AID sponsored research is impossible.

While AID-supported projects have made noteworthy contributions, many have had serious limitations. The greatest limitation has been the lack of continuity in programs, policies, and personnel. To be effective, an individual scientist should be able to devote more time to a project than the two–three years' service so common on AID-sponsored contracts. Uncertainty of funding and lack of institutional commitments by the cooperating university or government agency in the United States accounts for much of this program weakness.

The coupling of technical and capital assistance within AID has been especially detrimental to research and educational programs. Disruption of technical assistance because of political considerations has in specific instances greatly hindered programs.

Recent Federal legislation gives AID authority to support United States universities in their international agricultural activities. Appropriations for this purpose would greatly expand the potential of United States universities to help increase the world food supplies.

Other United States agencies are making significant contributions to the solution of world food problems. For example, in 1966 the Department of Agriculture had 300 professional people working on 84 projects in 39 countries.[23] In addition to AID-sponsored projects,

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[22] Moseman, A. H., Science and Technology in AID as related to the War on Hunger, statement prepared for this subpanel, October 18, 1966, p. 5.

[23] Drosdoff, Matthew. "A Century of Technical Assistance to Other Nations." International Agricultural Development, November 1966, No. 25, p. 11.

the Department of Agriculture is involved in continuing research efforts relating to pest control, plant breeding, and soil management which have applications in foreign nations. Unfortunately, the Department of Agriculture has been restrained by Congressional direction from working on food crops in foreign countries which may be in direct competition with those in which the United States has a strong export position.

The Department of Agriculture research contracts supported by P.L. 480 funds make little direct impact on food supplies of recipient countries. This is due to restrictions on the use of these funds for research on problems of some benefit to United States agriculture.

The 1966 Food for Peace Act has provisions for expanding research and educational programs to help developing nations feed themselves. The allocation of funds on a continuing basis could provide the long-term support for Department of Agriculture and university commitments.

The Department of Health, Education, and Welfare has cooperated in carrying out nutrition studies and has supported family planning programs. Also, it has allocated funds for overseas research grants to support studies relating to food and nutrition.

*12.6.1.2 Foundations.* The major philanthropic foundations have made noteworthy contributions to research and education in developing countries. The Rockefeller Foundation, for instance, has an outstanding record of more than 20 years' participation in overseas food and nutrition programs. In cooperation with local governments, substantial progress has been made in carrying out research projects, developing institutions, and educating and training indigenous manpower. Among countries helped most by this Foundation are: Mexico, Colombia, India, Chile, the Philippines, and Nigeria. The Mexican success story related later in this report is evidence of the Foundation's contribution.

The Ford Foundation also has a sizable program to assist in food and nutrition work.[24] During 1952 to 1965, grants amounting to nearly $100 million were made for projects in agriculture, rural village development, and home economics.

An interesting dwarf wheat project is sponsored by the Ford Foundation and the Government of West Pakistan. Stiff-strawed wheats developed in the Mexican-Rockefeller undertaking are being increased in an accelerated, seed multiplication program.

In recent years, the Ford and Rockefeller Foundations have joined in initiating and supporting such innovative programs as that of the International Rice Research Institute in the Philippines which is recognized as the best equipped and staffed research institute in the

[24] See Ford Foundation annual reports of recent years.

tropics. This institute also trains young scientists interested in the various phases of rice culture.

The Kellogg Foundation [25] has supported the training of students from the developing areas and has aided nutrition research in several Latin American countries.

*12.6.1.3 United States Universities.* United States universities have long had an interest in food and nutrition in the developing countries. In recent years, they have contributed greatly to overseas university development programs and have included research and educational projects throughout the world.

The weaknesses of these programs are almost entirely related to the lack of long term funding. In some cases, the short period has been dictated by the cooperating country; in others, by the supporter which is usually AID or the university.

Dr. F. F. Hill, former vice president of the Ford Foundation, has suggested improvements in United States university overseas programs.[26] There must be a joint institutional commitment with a cooperating institution overseas "to mount sharply focused, long-term research programs" designed to improve the technology of food production. The arrangement should be adequately financed and sufficiently long-term to produce significant results.

Research efforts should be concentrated on one or two food crops by teams of scientists of closely allied disciplines. Continuity of research efforts should be maintained throughout the project.

*12.6.2 Contributions of Other Developed Countries*

During colonial occupation of newly emerging countries by European nations, some food and nutrition research work was done in the overseas countries. Several well-equipped and well-staffed research stations were initiated and operated. European universities commonly accommodated selected students from developing areas.

Collectively, France, Belgium, the Netherlands, Britain, and other European nations are currently training more foreign students than the United States. Scientists from these countries also participate in overseas research institutes and universities. Where political stability permits, some of the former colonies receive technical aid.

The United Nations offers research and educational assistance on food nutrition and population. It makes its contribution through agencies such as the Food and Agriculture Organization (FAO); World Health Organization (WHO); United Nations Educational,

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[25] W. K. Kellogg Foundation. Annual report, 1965. Battle Creek, Mich., 1965. Rererence pp. 26–30.

[26] Hill, F. F. *U.S. Land-Grant Colleges and the World Food Crisis: A Suggested Program of Action.* Paper presented before the Division of Agriculture, National Association of State Universities and Land-Grant Colleges, Washington, November 15, 1966.

Scientific and Cultural Organization (UNESCO); and United Nations International Children's Emergency Fund (UNICEF). The developing nations benefit from programs of these agencies without having to make proportionate financial contributions.

The United Nations organizations commonly cooperate with recipient countries or groups of countries. They have helped establish regional laboratories or institutes and field stations relating to food production and nutrition. They also provide mechanisms for coordinating much of the research and educational assistance.

For many years, FAO has taken international leadership in programs to increase food production and has made significant contributions to country and regional research and training programs.

In the field of nutrition the interests of several United Nations agencies coincide. WHO, FAO and UNICEF support research and development programs to determine where nutritional deficiencies exist and how they might be alleviated.

UNESCO has the major responsibility in all areas of education. During the past 15 years, 101 countries have benefitted from UNESCO's assistance. Besides participating in the development of national educational programs, this agency has helped establish and support regional centers of education and research. It has also sponsored special conferences on topics of worldwide interest such as the extensive use of television, radio, and new classroom techniques for general and adult education.[27]

One major advantage of the United Nations agencies as supporters and organizers of research and educational activities is their international "acceptability." Recipient nations can seek assistance from the United Nations agencies without fear of political alignments. United Nations-sponsored projects are not apt to be disrupted by purely political considerations. This permits greater continuity of program and personnel which are so essential to teaching and research.

## *12.7.0 Examples of Progress*

Examples of successful methods and projects in research and education clearly show that the steps to achievement must be taken little by little, bit by bit. Patience, painstaking effort, and perseverance are the active ingredients in the success stories which follow.

### *12.7.1 Foundation Participation*

The first example, the research and development program of the Mexican Government assisted by the Rockefeller Foundation, has made a most significant contribution to agriculture since it was initiated in the mid-1940's.

[27] *Science and Technology for Development*, Vol. VI, *Education and Training*, United Nations 1963.

The joint effort contributed to Mexico's unprecedented rate of increase in agricultural production—average wheat yields grow from 11 to 37 bushels per acre in 20 years. It supplied a pattern for developing viable agricultural research programs in other countries. It still furnishes varieties of wheat, corn, and other crops now used advantageously in other Latin American and Asian countries. A cadre of trained agriculture scientists have been developed to carry on a well organized, national research program.

Some key elements that contributed to the success of the program are: [28]

1. The program was initiated on request of the Mexican Government but carried out jointly by Mexican and Foundation scientists.
2. The program, including services of most of the scientists, has had continuity. It has been underway since 1943.
3. The educating and training of young Mexicans was an integral part of the program. Specialized and university training was given in the United States but practical experience was obtained on the job.
4. The Foundation recognized American technology could not be transferred directly to solve Mexican problems. United States scientific techniques and knowledge were used in the development of new plant materials and practices needed in Mexico.
5. The joint Mexican-Rockefeller program has served as a regional center to provide new plant varieties and cultural methods to scientists in neighboring countries.
6. With leadership from Rockefeller scientists, the program became the prototype for similar ones in other countries.
7. The Mexicans devised means to hasten farmer adoption of new varieties and cultural techniques resulting from research efforts.
8. Team approach was used to cope with significant problems facing researchers. As a result, a "package" of plant materials and cultural practices was developed.

Appraising the cooperative program, Dr. J. George Harrar, president of the Rockefeller Foundation, has said: "Perhaps its greatest dividend has been the development of outstanding young Mexican scientists and leaders. These men, drawn from every economic and geographic sector of Mexico, trained over a period of years in Mexico and abroad, have again and again demonstrated the high quality of their abilities and their selfless dedication to national needs." [29]

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[28] Shaplen, R. Toward the well being of mankind; fifty years of the Rockefeller Foundation. Garden City, N.Y., Doubleday, 1964, 214 pp.

[29] The President's Review, The Rockefeller Foundation, December 1964.

### *12.7.2 University Participation*

Another noteworthy program is underway at the University of the Philippines College of Agriculture on whose campus the International Rice Research Institute is located. It is a graduate research and education program that receives financial support from the Ford Foundation and has the cooperation of Cornell University (Figure 12–1).

Its unique feature is that all graduate students, Asian as well as American, conduct their thesis research in the Philippines. This gives the Americans experience in a tropical environment working with Asian and American professors. It also assures Asian students that their research will be done in environmental conditions comparable to those they will meet after graduating. In this case, the opportunity for indigenous development is emphasized.

Turning to AID-sponsored university contracts, experience shows that short-term commitments have often impeded progress toward goals to develop indigenous institutions.

An exception is the North Carolina State University-AID contract. Its 12 year continuity has made a significant impact on both training and research through institutions it assists; the Agrarian University in Lima, Peru, and that country's cooperating Ministry of Agriculture. Since 1961, the University's enrollment and budget have doubled and more than 150 Peruvians have earned M.S. or Ph. D. degrees. Capabilities exist for concerted efforts to further improve agricultural development.

Another sign of progress at Agrarian University is the research financed partly by UNESCO, on fish and cottonseed meals. These substances are now being used successfully in edible flours and as food supplements.

Through other AID contracts, the Universities of Missouri, Illinois, Tennessee, Kansas, and Ohio State are helping establish new agricultural universities in India. This is a stepping-stone toward founding such colleges in each Indian state. It is also an example of the potential of several universities working together in coordination on a problem too large for any one of them.

### *12.7.3 Family Planning*

India was the first nation to set up a national program in the field of family planning.[30] Funds for this program were increased from $1.4 million in 1951–56 to $56 million in 1961–66. Supporting research was allotted 25 percent of the first five-year allotment and 10 percent for the second period. Future plans call for a community "extension" approach to gain public acceptance of program goals.

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[30] Stycos, J. M., The outlook for world population. Science 146(3650): 1435–1440. Dec. 11, 1964.

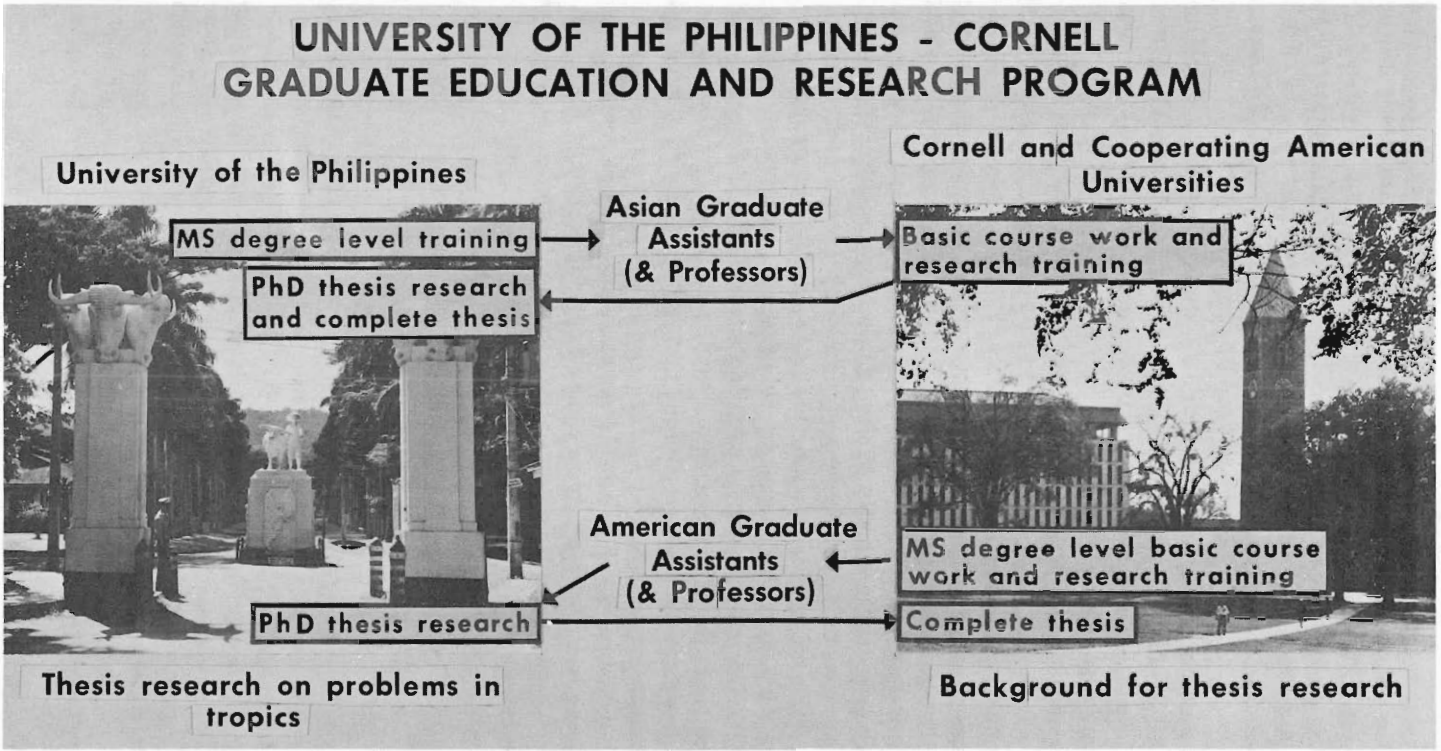


Figure 12-1 A Cooperative Program Which Requires That Part of the Graduate Eduaction and Research be Done at the Overseas Institutions.

Support of family planning has also increased markedly in the United States. Federal funds, for example, rose from $2.36 million in 1965 to $25.3 million in 1967.[31] A portion of these funds will be used to expand United States research on human reproduction, biology, contraceptive methods, and social and demographic factors in family planning.

AID, the recipient of one-third of the 1967 fund allotment, is using much of its share for research and education in the developing countries. In December 1966 its help in family planning encompassed some 20 countries.[32] Hopefully, this is only the beginning of a greatly expanded program.

*12.7.4 Educational Programs*

*12.7.4.1 Educational Television.* Television offers an excellent media for combating illiteracy in the developing nations. This means of mass communication will soon be available throughout most of the world or could be provided. The following story illustrates the tremendous potential of television for educating people to read.

An earnest, Italian teacher [33] has awakened nearly a million of his fellowmen from the sleep of illiteracy. His alarm clock? Ingenuity.

Alberto Manzi, 42, still is "waking up" illiterate children and adults via his daily television show on Italy's state-run facilities. Daily he reaches some 200,000 persons who are "enrolled." However, three to four times that number follow the program regularly, according to estimates. Six lessons a week are now given—double the number since the project began six years ago.

Students are taught reading, writing, simple arithmetic, and geography. 200,000 enrolled followers have been organized in groups around the country. In the countryside and in small towns, the local groups gather at TV sets in stores, coffee bars, or small factories. And they learn.

Teacher Manzi has taught more Italians to read and write than any other teacher in history. Ironically, he is probably the lowest paid teacher per pupil in the world. His salary of $235 a month is that of an ordinary grade school teacher, but he gets a bonus of $3.20 per lesson.

*12.7.4.2 Agricultural Education.* Recently expanded and intensified programs of agricultural education also show signs of progress. For example, in 11 African countries the number of universities offering

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[31] *Population Crisis.* Newsletter issued by the Population Crisis Committee, Washington, Jan.–Feb. 1967, pp. 2–3.

[32] *Assistance for Family Planning Programs in Developing Countries.* AID, Washington, Jan. 1967.

[33] Long, James M. "Thousands learn to read, write via Italian TV" Associated Press. 1966.

degrees in agriculture rose from none in 1952 to 17 in 1965,[34] and the number of agricultural graduates climbed from 3 in 1955 to 249 in 1964.

There is similar progress in Latin America.[35] In 1939 there were 25 faculties of agriculture teaching 2,750 students, 365 of whom graduated annually. By 1962 there were 54 faculties and 1,113 annual graduates. In Mexico, the number of professionals and technicians working in agriculture had increased from 1,197 in 1950 to 8,072 in 1960.[36]

These figures and those from India and other Asian countries give reason for optimism. In contrast, lack of solid progress in balancing food supplies and population growth suggests the rate of increase in education and manpower training is still too slow. The challenges of human resource development are just beginning.

### *12.7.5 Nutrition*

Like Mr. Manzi, K. S. Lo [37] of Hong Kong used his ingenuity and talents to help his country develop—but in the business world of food, rather than education.

Through his initiative, a milk substitute much cheaper than milk was formulated and marketed in Hong Kong in 1940 to bring better nutrition to the poor. The mission was accomplished, despite problems such as public prejudice against soy milk, lack of marketing information, and a three-year cessation of business operations which resulted from both problems. The two main problems were solved when the "milk" was marketed as a soft drink (Vitasoy), replete with metal crown instead of paper-cup-and-hood, and the final product was subjected to high heat sterilization making it unnecesary for use of refrigeration for months.

Spurred by the success of Vitasoy, private enterprise in Singapore, Malaya, and Thailand established soybean milk plants. In Indonesia, the Vitasoy firm helped UNICEF train technicians to operate a soybean milk powder plant.

The Institute of Nutrition for Central America and Panama (INCAP) in Guatemala City has conducted research for more than ten years on increasing protein intake where animal protein is scarce and expensive.[38] This research has resulted in a number of vegetable

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[34] Food and Agriculture Organization of the United Nations. The state of food and agriculture 1965. Rome, 1965. Reference pp. 139–142.

[35] Chaparro, A. G. Un estudio de la educacion agricola universitaria en America Latin. Rome, Food & Agr. Arg. United Nations, 1959. 208 pp. Reference pp. 24–25. (FAO estudios agropecuarios, no. 48).

[36] Venezian, E. and W. K. Gamble. *A Review of Mexican Agricultural Development 1950–65.* Cornell Int. Agr. Dev. Mimeo 16. 1966.

[37] Lo, K. W. "Pioneering Soy Milk in Southeast Asia." *The Soybean Digest,* Vol. 24, No. 7, May 1964, p. 18.

[38] Industrial Research and Development News, Vol. II, p. 27, 1967. United Nations Industrial Development Organization.

mixtures called "Incaparina" which are comparable in protein value to animal protein. "Incaparina" is used in a number of products such as hot beverages, soups, puddings, and biscuits.

The vegetable mixtures have been distributed by UNICEF for children's food and are available commercially in the five Central American countries and Panama and in Brazil, Colombia, Peru and Venezuela. Acceptance on a massive scale, however, has not met early expectations. This emphasizes the need for consumer preference studies along with basic nutrition and food technology research.

*12.7.6 Pilot Extension-Type Projects*

Amid unsuccessful ventures, extension has had a few marked successes. They include: (1) the program of the Academy for Rural Development at Comilla in East Pakistan and (2) an agricultural development project at Vicos in the Peruvian highlands.[39]

For its accomplishments, the first received worldwide recognition. In 1959 the Academy faced problems similar to those in hundreds of other rural regions. Cooperatives and extension service efforts had not been effective. Though improved practices were available, farmers were unwilling to accept them. A general hopelessness, a feeling that "nothing can be done", pervaded both farmers and bureaucrats.

Farmers—the Academy learned—preferred the advice of village leaders to that of extension agents. Because of agents' ineffectiveness, a new technique was used to reach the people. Village organizers and model farmers were enlisted for a continuing, part-time training program at the Academy. When the leaders returned home, they taught their neighbors.

The Comilla project motivated farmers to produce more efficiently. It recently has been expanded into other fields, including family planning and educational reform.

The second example of a successful extension venture is the agricultural development project on an 18,940-acre hacienda at Vicos in the Peruvian highlands.

Cornell University anthropologists, in 1952, found 1,800 Indians living on a hacienda under true, traditional, feudal conditions. The University rented the hacienda, became the "patron" of the Indians and gained their support. The group of Indians was given some decision-making opportunities which led to the appearance of new leadership. The new leadership accepted and promoted innovations such as modern methods of pest control.

Economically, the project is a success. In 10 years the per capita income at Vicos rose from $40 to $259; the average for Peru as a

[39] *Policies for Promoting Agricultural Development.* Report of an AID-sponsored Conference on Productivity and Innovation in the Under-Developed Countries, Center for International Studies, Massachusetts Institute of Technology, Cambridge, pp. 139–142.

whole is $179. The project is also a social success. Local initiative and self-government now prevail.

Methods in the Vicos and Comilla projects are different but there are at least two common elements: (1) farmers were involved as much as possible in decision-making, and (2) the projects were distinct from bureaucratic structures.

Extension should face its problems with confidence, armed with modern tools such as transistor radios, television and other new techniques. Extension workers should be encouraged by the potential for accomplishments in the enormous tasks that lie ahead.

## *12.8.0 Requisites for the Future*

Past successes help establish guidelines for the future. Projects such as those described in the previous section give some idea of the requisites for future research and educational efforts to meet the impending food-population crisis.

### *12.8.1 Recognition and Commitment*

All nations, their leaders and institutions must recognize that the food-population battle cannot be won without research and education. This recognition must lead to greatly expanded commitments for research and education on a high priority long-term basis.

The United States should move on two fronts to obtain a greater world-wide sense of urgency relating to food-population problems and the need for research and education to solve them.

First, in its dealings with the developing countries, the United States should help educate and orient their leaders to the critical need for long-range research and educational programs. In jointly sponsored economic development projects, the United States should make certain that adequate financial support is given to these programs. Further, it should use its influence with international and regional development banks and credit agencies to encourage loans for facilities and equipment needed to carry on food-related research and educational projects.

Second, the United States must greatly increase its own commitment to food-related research and educational programs. This can be done only if there is a national recognition of the long-term nature of the world food supply problems and of the need for massive and continuous efforts to solve them. With appropriate long-term commitments, United States universities, government agencies, foundations and industry can make research and educational contributions far in excess of the efforts of the past.

### *12.8.2 The Load Must Be Shared*

The burden of helping the developing nations increase their food production and balance their food and population increases cannot

be assumed by the United States alone. Through the United Nations and other international organizations, the more advanced countries of the world must increase their participation proportionately to increases from the United States. Similarly, the recipient nations on a "self-help" basis must contribute to the fullest possible extent whatever their resources will permit.

The United States must continue its efforts to increase the contributions of other developed nations for the support of research institutes, universities and innovational education projects concerned with the food-population problem. Also, continuing steps must be taken to coordinate United States efforts with those of other developed nations as well as with the United Nations.

*12.8.3 Innovation—The Key to General and Extension Education*

Time is running out on the population-food supply squeeze. This prevents complete dependence upon conventional educational programs to erase illiteracy and to motivate farmers and consumers to change habits, customs, and methods, even if financial resources, teachers, and facilities were available.

New, cheaper and more quickly adaptable educational and communications techniques must be developed and applied. Present tools such as television, radio and programmed learning must be tried more extensively.

There is need for more research on methodology. We know, for example, that extension methods used so successfully in the United States have decided limitations in the developing countries. Research and pilot projects will be needed to test extension teaching methods which fit more appropriately into the cultures of the developing areas. Likewise, innovative techniques must be developed to communicate with and motivate the illiterate.

*12.8.4 Continuity and Longevity*

The gaining of new knowledge through research, and its transmission through education, requires continuity of program support and manpower. Furthermore, biological research takes time; five to ten years often being minimum periods before given projects begin to produce useful results. These facts dictate the situations and conditions under which research efforts are to be initiated. If there is no reasonable assurance of longevity and continuity, the chances of any particular project's succeeding are slim.

There are several ways that greater continuity and longevity of United States efforts can be obtained. For example, in initiating specific United States supported projects, realistic estimates should be made of the total time needed to implement the project. Insofar as practicable, initial contract arrangements should recognize this total

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time requirement. Where fiscal or other restrictions prevent obligating funds for the entire life of the project, a statement of intent to provide such support should be made at the project's initiation.

Continuity of personnel concentrating on research and education programs must follow continuity of funding. There are marked limitations to the contributions which short term assignees can make to overseas programs. A major part of the United States contributions must be made by personnel whose prime responsibility is the international food and population problems. Universities and United States government agencies must develop ongoing programs aimed specifically at the solution of the world food supply problem. Thus, some kind of "mission orientation" so characteristic of Land Grant Universities in the United States must be developed to attract competent personnel to implement these programs.

*12.8.5 Production Plus*

Adaptive research and educational efforts must continue to give emphasis to the production of plants and animals. Broad efforts in plant and animal breedings, cultural management and protection must be the first steps in increasing food supplies. The potentials for these increases have been demonstrated.

The greatest percentage expansion should be in research areas concerned with improving food quality, processing and marketing food, and family planning. Protecting food from damaging pests also should receive high priority.

Research on the sociological and economic aspects of the food supply must be given concentrated attention. For example, we must learn more about motivating people with different cultures to accept new farming or family planning practices. Studies are needed to determine relative profits from different farm and food management practices and to learn the most acceptable and profitable systems of farming and marketing for each area.

*12.8.6 Indigenous Institutions*

The development and improvement of indigenous institutions for research, extension, and higher education must continue to receive high priority. Universities and institutes, whenever feasible, should be located to serve an extensive region or cropping system. Support from international agencies for university development is warranted and should be possible.

Experience has shown the wisdom of cooperative arrangements whereby United States universities furnish scientists and educators to assist in the development of overseas universities. Characteristics of successful arrangements should include:

(1) An initial long-range development plan for the indigenous

institution. The basic elements of the plan should be agreed to by the two universities and the supporting agency or foundation.

(2) Sufficient assurance of longevity and continuity of funding to make possible the assignment to the cooperative project of top scientists and educators from the United States institution.

(3) A long term (3–5 year) assignment for most of the United States personnel assigned to the overseas university. The staff could be supplemented by shorter term assignees with competence in critical areas.

(4) The arrangement for opportunities for selected students and faculty from the indigenous university to obtain advanced training in the United States. However, they should obtain only that part of their training which cannot be given at home.

*12.8.7 Three-Component Team*

A three-way partnership of government, universities, and industry must be developed with coordination, cooperation, and communication among the three groups. This has been one of the biggest deterrents toward a true "partnership." A further need is for industry to increase its involvement at all levels. In many of the developing nations, the universities, government agencies and industry have completely independent and sometimes competing programs. Even communication among the personnel of the three groups is often lacking.

Obviously the United States does not have the right or the responsibility to force better working relations among overseas universities, government agencies and industry. We can assist in improving these relationships, however. Working agreements between United States institutions and agencies and their overseas counterparts should include reference to the need for a coordinated approach by the three groups. Also, there are opportunities for specific projects involving cooperative efforts of United States institutions, government agencies and industry. For example, the development, testing, and determination of consumer acceptability of new food products provides such an opportunity.

*12.8.8 A Mechanism for Coordination and Implementation*

A mechanism must be created to improve the coordination and implementation of United States efforts in food-population research and education. An example of Federal participation and funding for this total effort could be organized as shown in Figure 12–2. This would require the establishment of some kind of organizational unit through which most of the funds would be provided for research and education on world food-population problems. It would require an advisory council from other agencies and organizations.

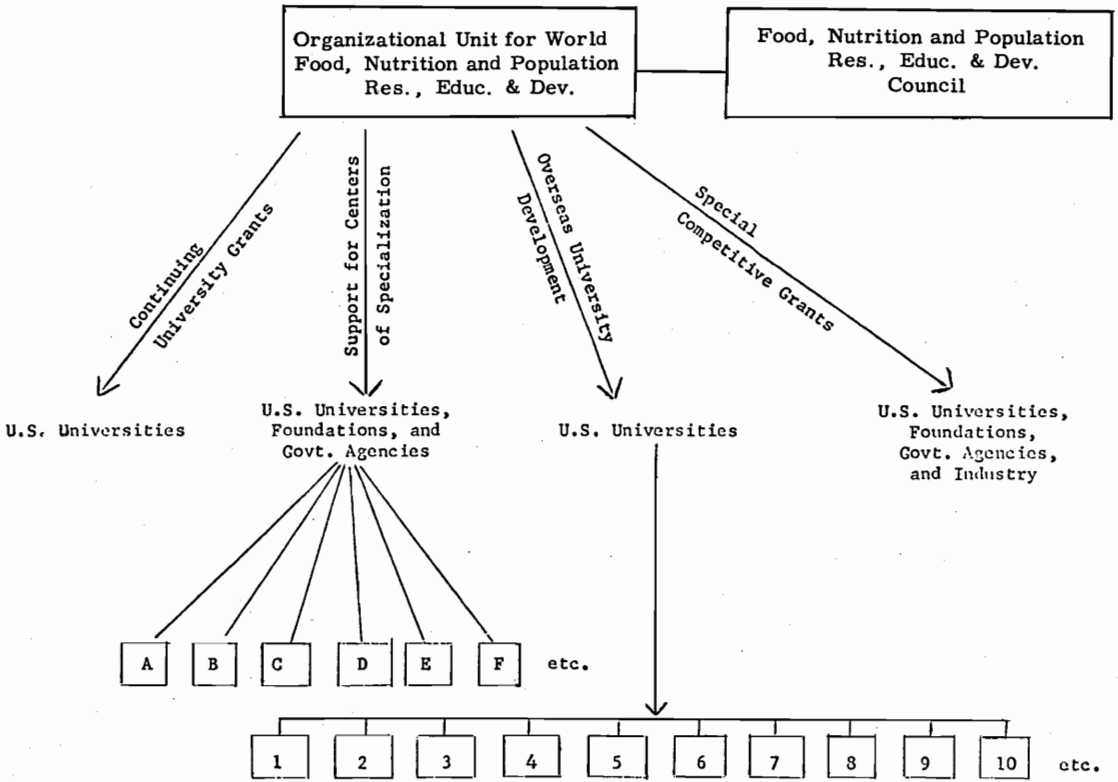


Figure 12-2 Illustration of the kinds of programs that could be handled through an organizational unit concerned with research and education.

Focus and support would be provided for the following four major kinds of research and educational efforts, most of which are already underway but are poorly supported and coordinated:

1. Overseas indigenous centers of specialization to focus on specific research and educational problems. The International Rice Research Institute in the Philippines is an example.
2. Overseas university development programs—similar in intent to those already in existence. However, financial support, continuity and longevity of program would be greatly increased.
3. Continuing support for United States universities which make long-term commitments for research and training in food-population activities.
4. Special short-term grants which would provide support for industry as well as universities and government agencies.

# CHAPTER 13

# ECONOMIC IMPLICATIONS

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## Contents

| | | Page |
|---|---|---|
| 13.1.0 | Introduction | 643 |
| | 13.1.1 Projections of Food Demand and Output in Developing Countries and Implications for Input Requirements and Overall Economic Growth | 643 |
| | 13.1.2 A Framework for Further Study | 644 |
| | 13.1.3 The International Dimension of the World Food Problem | 644 |
| 13.2.0 | Relationship Between Food Demand and Overall Growth in Developing Countries | 644 |
| | 13.2.1 Required Growth in Food Demand | 644 |
| | 13.2.2 Required Growth in Income | 647 |
| | 13.2.3 Feasibility of Required Growth Rate on the Demand Side | 649 |
| 13.3.0 | Relationship Between Food Production, Input Requirements and Overall Growth of Output in the Developing World | 652 |
| | 13.3.1 Introduction | 652 |
| | 13.3.2 The Panel's Findings | 655 |
| | 13.3.2.1 Production, Disappearance and Net Trade | 655 |
| | 13.3.2.2 Input Requirements for 3.5 and 4.0 percent Growth Rates for Agricultural Output | 657 |
| | 13.3.2.3 Land and Water Requirements | 660 |
| 13.4.0 | A Framework for Further Study | 662 |
| 13.5.0 | The International Dimension of the World Food Problem | 665 |
| 13.6.0 | Conclusions | 671 |



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## *13.1.0 Introduction*

### *13.1.1 Projections of Food Demand and Output in Developing Countries and Implications for Input Requirements and Overall Economic Growth*

There are certain relationships which exist between the demand for food and the overall demand for goods and services in any economy. In order for an "effective demand" for food to exist, the means of buying the food—the purchasing power—must be available. In other words, aggregate income must grow at a rate which will permit consumers to purchase the projected food requirements. The parameter which relates the relative change for food demand to the relative change in income (or Gross National Product) has been coined the income elasticity of demand for food. It measures the percentage change in food demand as a function of a percentage change in overall income (GNP). Thus, if food demand were to increase by 5 percent following a 10 percent rise in GNP, the income elasticity of demand for food would be equal to one-half.

Likewise, on the production or supply side, there are relationships which link food and agricultural output to overall production. The production of food crops necessitates the use of manufactured inputs such as fertilizer, pesticides and farm machinery which must be imported or produced domestically. If they are to be imported, the economy must generate sufficient exports—and/or be able to rely on a net inflow of foreign assistance and private capital—to pay for the imports. If these inputs are produced domestically or paid for by industrial exports, the non-agricultural sectors must expand at rates consistent with the needs of the agricultural sector. In the same way, various non-agricultural sectors and activities are dependent on agricultural raw materials and, in some cases, food products. For every productive sector or activity, there is a set of input-output relationships which in a technological way link the whole set of inputs (such as raw materials, foodstuffs, capital goods, labor) required for any given level of output.

Because of the interdependence which exists between food demand and overall income, on the one hand, and between agricultural (food) output and total output (GNP), on the other, the world demand and supply of foodstuffs cannot be considered independently from overall economic growth. An attempt is made below to analyze the implications of the findings of the various subpanels, first, from the demand



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side (in Section 13.2.0), and, second, from the supply (production) side (in Section 13.3.0).

### *13.1.2 A Framework for Further Study*

Because of the inherent limitations of the Panel's aggregative approach which estimated the direct input requirements on a global scale, a framework for further study is presented in Section 13.4.0. The most important recommendations are (a) that a country-by-country approach be undertaken for at least the 5 or 6 major developing countries, (b) that input-output information be used to estimate the *direct* and *indirect* input and investment requirements necessary to achieve the food targets, and (c) that explicit attention be paid to institutional, policy, and technical considerations at the microeconomic level which are eclipsed under the global approach.

### *13.1.3 The International Dimension of the World Food Problem*

A major constraint to the growth of income in the developing world is the capacity to import. Solution of the world food problem will necessitate high import requirements for both food and other commodities.

The prospects for exports in the developing countries appear rather bleak. Improvement in the "terms-of-trade" between developed and developing countries may be a precondition to achieving the desired nutritional targets. Section 13.5.0 is addressed to these questions.

## *13.2.0 Relationship Between Food Demand and Overall Growth in Developing Countries*

### *13.2.1 Required Growth in Food Demand*

The demand for food to meet certain minimum nutritional levels has been estimated in Chapter 1. On the basis of detailed demographic projections (by age distribution) and minimum nutritional requirements for calories, proteins and other nutrients, food needs to meet these requirements were projected for the period 1965–1985 for three countries (India, Pakistan and Brazil) and the world as a whole.

The "needed" food projections can be used as the basis of a demographic theory of economic development which holds that a necessary precondition to development is a reduction in the mortality rate (particularly the infant mortality rate).[1]

A causal relationship between infant mortality rates and the fertility rate is postulated; evidence is presented indicating that the number of children desired in the developing world goes down as the infant and child mortality declines. It was stated that, "We are faced with the apparent paradox that a reduction in mortality should reduce rather

[1] The nutritional requirements are based partly on the amount and kind of food necessary for lowering the (infant) mortality rates.

than raise the rate of population growth." [2] If this is the case, reduction of malnutrition among children, by increasing the quantity and quality of food supplies, may be a key factor in solving the population problem of our time.

In a sense, it is argued that a certain "critical" reduction in the mortality rate has to be achieved to lead to a reduction in the birth rate and the eventual "solution" of the world food problem. To achieve that reduction, nutritional levels must grow at a "critical" rate in the absence of which mass starvation would result.[3]

Acceptance of this thesis raises two questions: first, what is the "critical" rate of increase in food availability between now and 1985, and, secondly, what are the implications of this rate for the growth of overall demand?

Detailed estimates of caloric protein and other nutritional requirements were calculated on the basis of "high" and "low" population projections for India, Pakistan, Brazil and the world as a whole. Table 13–1 summarizes the necessary growth in calories and proteins between 1965 and 1985 to meet the nutritional targets. It is concluded that "India and Brazil will need twice as much food as was available in 1965, if similar foods are consumed, while Pakistan will need an even greater increase," [4] and that the need for protein in the developing countries will rise by 100 to 150 percent between 1965 and 1985.[5]

There are difficulties in deriving the demand for foodstuffs for the developing nations as a whole from (a) projections for the three abovementioned countries, and (b) caloric and protein requirements, exclusively. Clearly, the three countries selected account for a relatively large share of the population and of the income received by the developing Nations. In 1965 these respective figures amounted to 43.9 and 29 percent, respectively, as shown in Table 13–2.

It ought to be noted, however; that the combined per capita income of these three countries ($120) was lower than that of the developing Nations ($182). Yet, the per capita income levels of tropical Africa ($107) and of the Far East (exclusive of Japan) ($129) are of the same order of magnitude as that of the three above countries and these areas account for a total population of 489 million (see Table 13–3). The remaining parts of the developing world consist of the Near East (exclusive of Greece and Turkey) and Latin America (ex-

[2] Vol. II, Chapter 1, page 35.

[3] There is a certain analogy between the above demographic theory of development on the one hand, and Leibenstein's "critical minimum effort thesis" and "Big Push" theories which are mainly based on economic factors. The analogy is that in each of these theories a critical (infant) mortality rate, growth rate, investment ratio, respectively, must be reached to permit self-sustaining growth. Anything short of these critical levels will doom the developing world to a low-income (perhaps starvation) situation.

[4] Volume II, Chapter 1, page 9.

[5] Volume II, Chapter 1, page 57.

TABLE 13.1—*Caloric and protein requirements, India, Pakistan, Brazil, and World (growth rates required between 1965–85 to meet 1985 needs over and above 1965 needs, in percentages)*

| | Calories | | | | Protein | | | |
|---|---|---|---|---|---|---|---|---|
| | 1965–85 growth—Population projection | | Annual rate, 1965–85—Population projection | | 1965–85 growth—Population projection | | Annual rate, 1965–85—Population projection | |
| | High | Low | High | Low | High | Low | High | Low |
| India | 108 | 88 | 3.7 | 3.2 | 110 | 93 | 3.8 | 3.4 |
| Pakistan | 146 | 118 | 4.6 | 4.0 | 145 | 121 | 4.6 | 4.0 |
| Brazil | 104 | 92 | 3.6 | 3.3 | 108 | 98 | 3.7 | 3.5 |
| World | 52 | 43 | 2.1 | 1.8 | 52 | 45 | 2.1 | 1.9 |

Source: Adapted from Chapter 1.

TABLE 13–2.—*Population and national income mid–1965*

| | Gross National Product | | Population (in millions) |
|---|---|---|---|
| | Aggregate (billion 1965 dollars) | Per capita (1965 dollars) | |
| India | 49.2 | 101 | 490 |
| Pakistan | 11.2 | 97 | 115 |
| Brazil | 22.0 | 270 | 82 |
| Total of 3 above countries | 82.4 | 120 | 687 |
| Total less developed world | 284 | 182 | 1,564 |
| Total non-Communist world | 1,609 | 734 | 2,193 |
| Percentage of 3 above countries to total less developed world | 29.0 | | 43.9 |

Source: AID Statistics and Report Division.

clusive of Brazil) with per capita incomes of, respectively, $263 and $447 in 1965 and a total combined population of about 243 million. In these last two regions the main problem is not an overall food deficit but inadequate and unequal distribution.

In conclusion, the Far East, tropical Africa and the rest of South Asia are in the same stage of economic development—on the basis of per capita income—as the three [base] countries studied. In general, it can be assumed that nutritional status is reflected in the level of per capita income. Thus, as Table 13–3 indicates, the food requirements calculated for India, Pakistan, and Brazil may be considered to be representative of those of the Far East, tropical Africa and the rest of South Asia. These regions and the three key countries account for 41 percent of the income and 78 percent of the population of the developing world.[6]

[6] These percentages become 48 and 82 percent respectively, when the last group in Table 13–3 (Greece, Turkey, Spain, etc.) is excluded.

TABLE 13-3.—*Developing world: Gross national product, per capita income, and population mid-1965*

| | Gross national product (in billions of dollars) | Per capita income (dollars) | Population (millions) |
|---|---|---|---|
| 1. Near East (excluding Greece and Turkey) | 23.3 | 263 | 88.5 |
| 2. Latin America (excluding Brazil) | 69.0 | 447 | 154 |
| 3. Far East | 35.7 | 129 | 276 |
| 4. India, Pakistan, Brazil | 82.4 | 120 | 686 |
| 5. Tropical Africa | 22.9 | 107 | 213 |
| 6. North Africa | 7.0 | 225 | 31.3 |
| 7. Rest of South Asia | 3.7 | 100 | 37.0 |
| 8. Greece, Turkey, Spain, Puerto Rico, and miscellaneous | 39.9 | 534 | 78.4 |
| | 284 | 182 | 1,564 |

The selection of an aggregrate figure for the rate of growth of food demand in the developing countries necessary to meet nutritional targets is crucial to deriving the implications for overall rate of growth and in testing its economic feasibility. The evidence presented so far permits one to determine a range consistent with the projections of food requirements. From Table 13-2 and other evidence it would appear that such a range might be an annual compound growth rate of aggregate food demand in the developing world of 3.6 to 4 percent over the period 1965 to 1985. These rates imply a doubling and a 120 percent increase, respectively, in aggregate food demand in the developing world over the twenty-year period. It should be noted that *these estimates refer to final demand at the consumption level and are not adjusted for losses from time of harvest to storage, transportation, marketing, home preparation and plate waste.* It is difficult to estimate these losses but it is not unreasonable to expect them to run as high as 25 percent of farm output.[7]

### *13.2.2 Required Growth in Income*

Given the growth rates of food demand it is possible to say something about the overall (GNP) growth rates consistent with the above range. In this connection it is important to remember that economists tend to related food demand to income causally. Here the causality is reversed: a "critical" rate of growth of food demand has been estimated on demographic and nutritional grounds and the problem then is to infer the growth of income consistent with the "needed" food demand.

There are two determinants of food demand: the population effect and the income effect. At the same nutritional levels, a given rate of population growth will generate an equivalent rate of increase for food consumption. Increase in the per capita income level leads to an additional demand for food. The per capita income elasticity of

[7] See Chapter 10.

demand for foodstuffs measures the relative (percentage) change in food consumption to a relative (percentage) change in per capita income. Thus, the rate of change in aggregate food demand is equal to the sum of the population growth rate and the product of the per capita income elasticity for food and the relative change in per capita income. In symbols:

$$f = p + \epsilon y$$

where, $f$ = (annual) rate of growth of aggregate food demand
$p$ = (annual) rate of growth of population
$\epsilon$ = per capita income elasticity of demand for food
$y$ = (annual) rate of growth in per capita income (GNP)

There is empirical evidence available on the historical magnitude of $\epsilon$. During the period from 1950 to 1960, this parameter amounted to 0.51, 0.80, and 0.80 in Brazil, India, and Pakistan, respectively.[8] Of 26 developing countries surveyed by the U.S. Department of Agriculture, 11 showed a per capita income elasticity of less than 0.60 with 15 ranging from 0.60 to 0.80. It is clear that elasticity drops as per capita income increases. Given the decline in $\epsilon$ as a function of per capita income growth, a reasonable global range for $\epsilon$ for projection purposes (over the next twenty years) might be between 0.5 and 0.7.[9] The annual rate of population growth in the developing world (over the same period) is projected at approximately 2.7 percent.

It is possible to derive a range of growth rates for per capita income and for GNP consistent with the magnitudes postulated above. These can be entered into the equation which can then be solved for y, the annual growth rate in income needed to generate the level of food demand desired between 1965 and 1985. Table 13–4 indicates the per capita income levels corresponding to a given f and $\epsilon$. Thus, if the desired rate of growth of foodstuffs is 4 percent, per capita income elasticity .6 and the rate of population growth 2.7 percent, per capita income would grow at a rate of 2.2 percent between 1965 and 1985.

Table 13–4 shows clearly the sensitivity of the rate of growth of per capita income to assumptions concerning income elasticity and the desired rate of growth of foodstuffs. Thus, for example, if the latter amounts to 5 percent, the implied growth rate of per capita income would be 3.8 percent, assuming food elasticity to be .6 and population growth rate to be 2.7 percent (see Table 13–4). The difference between the implications for income growth of a target annual rate of growth

[8] U.S.D.A., Changes in Agriculture in 26 Developing Nations (1965). p. 4.

[9] This kind of prediction is, of course, quite hazardous and hinges upon all kinds of implicit and explicit assumptions. One assumption which is made explicit here is that no substantial change will take place between food and non-food prices. Two forces may operate in opposite directions to affect this last ratio. Agricultural development may be encouraged by the ratio of farm prices to non-farm prices going up as an incentive device. On the other hand, increased efficiency in farm production may tend to reduce the ratio of farm prices to non-farm prices.

of total food demand of 4 percent (the example discussed in the previous paragraph) and one of 5 percent (the case presented in the previous sentence) is dramatic.

TABLE 13-4.—*Per capita rate of growth of income ($y$) consistent with selected magnitudes of the income elasticity of demand for foodstuffs ($\epsilon$) and the rate of growth of aggregate food demand ($f$) assuming a rate of growth of population ($p$) of 2.7 percent when $f=p+\epsilon y$*

| Per capita income elasticity of demand for food ($\epsilon$) / Percentage rate of of growth of food demand ($f$) | 0.5 | 0.6 | 0.7 |
|---|---|---|---|
| 3.6 | 1.8 | 1.5 | 1.3 |
| 4.0 | 2.6 | 2.2 | 1.8 |
| 4.4 | 3.4 | 2.8 | 2.4 |
| 5.0 | 4.6 | 3.8 | 3.3 |

The first case implies a 2.2 percent growth rate in per capita income as compared to 3.8 percent in the second case. These figures are equivalent to aggregate growth rates of GNP for the developing world of 4.9 and 6.5 percent, respectively.

It should be noted that the highest alternative projection of total food consumption needs (domestic disappearance) in the developing world between 1965 and 1980 mentioned in chapter 2 assumes a rate of growth of only 3.5 percent per annum. This last figure is very close to the range of values which was derived above from the "critical" nutritional targets estimated by the Subpanel on Population and Nutritional Demands in Chapter 1.

In summary, it appears that the nutritional and demographic projection calls for an annual growth rate of food demand of about 4 percent over the next twenty years. This rate of growth, in turn, implies a growth rate of per capita income for the developing world of approximately 2.2 percent and an annual rate of increase of GNP of approximately 5 percent between 1965 and 1985. Thus, it might be concluded on the basis of the present analysis—looking at the world food problem from the overall demand side—that *a growth rate of aggregate GNP of 5 to 5.5 percent would be consistent with the "critical" food requirements.*

### *13.2.3 Feasibility of Required Growth Rate on the Demand Side*

A discussion of the feasibility of such growth rates for the developing world in terms of investment requirements, technological and institutional considerations, and balance of payments implications is undertaken in the next section. However, a few observations can already be made here.

First, the necessary growth of income (5 to 5.5 percent between 1965 and 1985) derived above is higher than the historical experience for the developing world which averaged slightly above 4.5 percent over the last decade (see Table 13–5). Yet the difference does not appear unbridgeable in an aggregate sense. The acceleration in the growth rate from about 4.5 to 5–5.5 percent which is required for, and consistent with, the food projections (on the demand side) does not appear impossible on *a priori* grounds.

TABLE 13–5.—*Percent change in GNP and GNP per capita 1957–58 average to 1964–65 average*

| Developing countries | 1957–58 | 1964–65 |
|---|---|---|
| Total | 4.7 | 2.3 |
| Latin America | 4.4 | 1.5 |
| Near East | 5.9 | 3.5 |
| South Asia | 4.4 | 2.1 |
| Far East: | | |
| Including Indonesia | 4.4 | 1.8 |
| Excluding Indonesia | 5.9 | 3.1 |
| Africa | 3.4 | 1.2 |
| Other (largely Spain and Puerto Rico) | 7.0 | 5.9 |

Source: Same as Table 13–2.

Secondly, a number of developing countries have been capable in recent times of generating enough growth of income to permit food demand to increase at the 4 percent rate that will permit the food target to be achieved in the next twenty years. Developing countries were classified into two groups, on the basis of a study by the U.S. Department of Agriculture, depending upon whether food demand had increased by more or less than 4 percent annually between 1950 and 1960. The first group consisted of 14 countries, including Israel, Mexico, Venezuela and Taiwan, all of which are well on their way to becoming developed nations. Among the remaining 12 countries which are perhaps more representative of the developing world, food demand grew at only 3.4 and 2.4 percent in India and Pakistan, respectively, over the period 1950–1960 but at 4.4 percent in Brazil.[10]

It can be concluded from these observations that the present growth of income in the developing world will have to increase from the present rate of 4.5 percent to about 5.5 percent to generate the means of purchasing the nutritionally required foodstuffs that will "solve" the "World Food Problem".

It is also clear that the GNP growth rate of 5.5 percent may be a necessary but hardly a sufficient condition to permit the attainment of the desired nutritional levels. The present very unequal distribution

[10] U.S.D.A., Changes in Agriculture in 26 Developing Nations (1965), p. 4.

of income in large parts of the developing world will have to be improved if the poorer classes are to have the economic means of purchasing more food per capita. This, in turn, will require major structural and institutional reforms in the marketing, processing, and distribution of food products along the lines suggested in Chapter 10. Likewise, as emphasized in Volume I, a proper "agri-climate" has to be achieved:

> Part of this agri-climate consists of the economic demand for farm products provided by the total non-farm industry of an economy and by export markets for agricultural commodities. It includes the efficiency of the total transportation system of the country as this affects the breadth of the market for all commodities and services and the cost of transport. Another important part of the agri-climate flows from land tenure policies, price, tax and monetary policies, general and agricultural development policies, and the degree of farmers' participation in the political process. Still other aspects of the agri-climate are the traditions, values, and social organization of the general culture as these affect farmers' freedom and willingness to adopt improved methods, and the extent and nature of general education.[11]

A final comment might be in order concerning the method used to deduce the necessary growth rate of income. The latter was derived from the "critical" food target determined on non-economic (i.e., on nutritional and demographic) grounds. As was pointed out previously, food demand is usually assumed to be causally dependent on the level of income so that a low level of income would only generate a low "effective demand" for food. On that basis no real world food gap can ever exist in a *strictly economic sense*.[12] A poor Indian earning only the equivalent of $0.28 (United States) a day[13] can spend at most about 25 cents on food considering his other consumption needs. The *economic* results of a *low* rate of growth of income for the developing world may be malnutrition or even famine and mass starvation. It is no wonder that economics has been called the "dismal science".

However, a food gap *in a nutritional sense* can—and does—exist. The Panel estimated this gap as a starting point and the above analysis is an attempt to infer the economic implications from the standpoint of overall growth of demand. Given the present demographic trends,

[11] Summary of discussion of *Agri-climate,* Vol. 1, pp. 69–73.

[12] In this connection Lars G. Sandberg has argued that, at present trends, it is extremely unlikely that the rate of growth of national income will exceed four percent in the developing world. Given this rate and assuming grain output in these countries to grow at a modest 2¼ percent, no worldwide food crisis will result. To quote him, "It seems fairly clear that while a falling rate of growth of grain output in the low income countries may create a food crisis for them, no really worldwide food crisis is likely to be forthcoming. Nor is there much chance of any pressure on the productive capacity of the high income countries." ("International Trade in Grains: Projections and United States Policy". *Review of Economics and Statistics,* May 1966, p. 161). The above study exemplifies perhaps best the difference between an *economic* approach which assumes low historical rates of growth for the developing world to continue in the future and a *nutritional-demographic* approach which sets minimum critical food targets as a sine qua non to "solving" the world food problem.

[13] This corresponds to the per capita income level in India of $101 in 1965.

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the size of this food gap could become a nightmare for humanity if proper measures on the production and population control fronts are not undertaken immediately. Since there is a limit to the contribution which population control can make to reducing this gap *in the next twenty years*, the answer lies in a supreme effort on the production side during this period.

### *13.3.0 Relationships among Food Production, Input Requirements, and Overall Growth of Output in the Developing World*

#### *13.3.1 Introduction*

Any national economy is made up of a set of interdependent productive and consuming activities or sectors. The prevailing technology, given the relative prices of the factors of production, determines the input requirements per unit of output for any productive activity. For example, the production of a ton of food grains requires specific inputs such as certain quantities of fertilizer; pesticide, seed, farm machinery, and construction (roads, irrigation). These technological relations can be made explicit through the so-called input-output table which indicates the input requirements per unit of output as well as the *final demand* components (final consumption by households, investment, government consumption and exports) for all sectors (industries). The gross output of any product can thus be broken down into one part which is used by other sectors (industries) as inputs to further production—the sum of other industries' demands for the product in question is the total *intermediate demand*—and another part which goes into satisfying the *final demand* components. Given this inter-industrial framework, an increase in the output of any single industry will entail direct as well as indirect demands on other industries. Thus, an increase in $1 million in the gross output of food grains will *directly* require a certain increase of inputs from the fertilizer industry. This increase in output of the fertilizer industry will, in turn, call for an increase in inputs from the power (i.e., electrical) industry, and the latter increase might call for additional inputs from still other industries (such as hydroelectric construction and electrical machinery). These *indirect effects* are often larger than the direct effects. (See Tables 13–10 and 13–11 and Section 13.4.0.)

Several subpanels attempted to estimate the input requirements to meet the needed increase in food output in the developing world over the next twenty years. It is estimated that food output in the lesser developed world will have to double between 1965 and 1985, implying an annual rate of growth of 3.6 percent. The subpanels calculated the *direct* input requirements for manufactured physical and biological inputs (fertilizer, pesticides, seeds, and agricultural power and equip-

ment)[14] and, in a more qualitative way, the needs for water, transportation, and some still less tangible inputs such as manpower education, and research. It is evident, of course, that the direct capital and input requirements in transportation and education are likely to be very large. An estimate of these requirements is essential to an assessment of the feasibility of any given rate of growth of agricultural output.

In addition, no attempt was made to estimate the *indirect* input requirements. It is clear that this last undertaking would have necessitated a country-by-country approach (at least for the major ones) as opposed to the global (aggregative) approach followed by the subpanels. The input-output (inter-industry) structures of countries can differ widely; hence, the need for *country* studies to estimate indirect effects. Given the paucity of reliable input-output information and the substantial amount of time and resources which would have been necessary to complete country studies, these could not be done by the Panel. It is, nevertheless, essential to keep in mind that the indirect input requirements and costs of doubling food output in the less developed world have in general been abstracted in this report.

Another limitation of the approach followed by the subpanels is that the inputs required to double food output were derived for each input relatively independently of other inputs. For example, manufactured physical and biological inputs taken as one input (because of the complementary relationships which exist on the production side among these inputs) presumed other inputs (such as transport facilities and water) to be available and vice versa. The difficulty lies in the fact that the presumed levels of complementary inputs are usually not explicitly stated. Thus, in a sense, the Panel has adopted a "partial equilibrium" approach.

It is important to understand the implications of this approach. It presupposes that—and can be strictly correct if—all inputs can be combined only in fixed proportions. While fairly strict complementarity on the production side prevails for some inputs (e.g., as between fertilizer, pesticide and seeds), there is, nevertheless, some scope for substitutability among many inputs in producing foodstuffs. Within limits, labor can substitute for capital and water for fertilizer. Furthermore, even in those instances where inputs have to be used in technologically fixed proportions in the production of food, it is clear that these proportions are variable with the scale of output.

What is needed both conceptually and empirically is a production function relating food output to the various inputs. Production functions could be empirically estimated for major developing countries using time series and cross-sectional information.[15] Clearly, such an

[14] Chapter 6.

[15] For an interesting first attempt at deriving such production functions statistically see, "The Impact of Selected Economic and Social Factors on Agricultural Output" by Ram Dayal (U.N. Research Institute for Social Development, Geneva, November 1966).

undertaking is a necessary step in deriving more detailed and concrete estimates of the economic feasibility of meeting the Panel's nutritional requirements in any given country.

In a general sense, the question of the economic feasibility of attaining the desired food targets in the developing world can only be answered with the help of a multisectorial, multiregional model. Such a model would contain, for the major developing regions, a minimum amount of input-output information reflecting the structural and technological interdependence between sectors and, more specifically, between the food-producing sector, the rest of agriculture and the non-agricultural sectors. At the same time, this model would have to incorporate functions relating imports to the growth of these developing regions. The prospects for the developing countries' exports and the net inflow of foreign assistance and private capital into the developing world will determine its capacity to import and, in turn will be a major determinant constraining the overall growth of income. A model of the type described above and including producing and consuming regions is, of course, a major undertaking requiring substantial technical resources. The Food and Agriculture Organization (FAO) is in the process of preparing such a model in its "Indicative World Plan for Food and Agriculture in 1975" (with perspectives to 1985). If completed, this World Plan should be invaluable in permitting the full economic implications for both the developed and developing world of a given food program to be evaluated.

A final problem in assessing the economic feasibility of achieving certain levels of food output in the developing countries is that the choice of the combination of inputs used in the production process will depend (a) on the state of technology; and (b) on the prices (costs) of these inputs and on their contribution to the value of food output (in turn influenced by the prices of that output). Production decisions are made by farmers at the micro level—except in centrally planned economies. It is essential, therefore, to go beyond the purely aggregative approach in evaluating the feasibility of a food program.

For example, even if yield increases from fertilizer are very large in physical terms, inappropriate prices may prevent the use of fertilizers by farmers. Given the abundance of labor and the scarcity of capital in the developing world which is reflected by very low wages and high interest rates, it will take a long time before a high degree of mechanization in agriculture will be profitable. Prices of inputs reflect resource endowment and supply considerations, but can also be influenced by government policy. The importance of appropriate policies (particularly price policies) in the agricultural sectors of the developing countries as an instrument conducive to agricultural development cannot be overemphasized.

It has been quite impossible for the Panel to cope with all of the problems and factors mentioned above. These factors, some of which are elaborated upon in the following sections, must be kept in mind when reviewing the Panel's findings and recommendations.

*13.3.2 The Panel's Findings*

The Panel's findings cover many diverse topics. In assessing the major economic implications of the food problem from the supply side, however, they can be broken down into three parts: (1) the historical, current and future production (and disappearance) projections made in Chapter 2; (2) the estimates of irrigation, manufactured and biological input requirements to raise the level of output by various multiples of current production made in Chapters 6 and 7; and (3) the subpanel reports dealing with the provision of a suitable economic (and institutional) environment and infrastructure within which these inputs can be used effectively.

*13.3.2.1 Production, Disappearance and Net Trade.* Table 13–6, showing production, disappearance, and net trade in grains for the developing world, is based on information found in Chapter 2. Grains are the major source of man's food energy supply and serve as an excellent indicator of food output and disappearance. Table 13–6 differs from that found in Chapter 2 only in that projections to 1980 have been extended to 1985.

TABLE 13–6.—*Total grains: production, disappearance, and net trade, for developing free world, 1959–61, 1964–65; projections to 1985 under alternative growth assumptions*

| | Compounded annually | | | Implied growth GNP [1] | Million metric tons | | |
|---|---|---|---|---|---|---|---|
| | Growth in grain production | Growth in population | Increase in per capita consumption | | Grain production | Grain disappearance | Net import |
| 1959 to 1961 | | | | | 199 | 212 | 17 |
| 1964 to 1965 | | | | | 219 | 244 | 24 |
| 1970 [2] | 2.7 | 2.5 | 0.5 | 3.7 | 259 | 287 | 28 |
| A1985 | 2.7 | 2.5 | 0 | | 386 | 416 | 30 |
| B1985 | 2.7 | 2.5 | 0.5 | 3.7 | 386 | 447 | 61 |
| C1985 | 3.0 | 2.5 | 0.7 | 4.2 | 403 | 460 | 57 |
| D1985 | 2.7 | 2.5 | 1.0 | 5.0 | 386 | 481 | 95 |
| E1985 | 4.0 | 2.5 | 1.0 | 5.0 | 466 | 481 | 15 |

[1] The per capita income elasticity for food implied in the Panel's projection alternatives D and E ($\epsilon$=.4) is somewhat lower than that usually found in developing nations. This same elasticity was used to derive the corresponding GNP growth rates for the other alternatives. It should be noted that the implied GNP growth rates will be lower than the figures in Column 4 to the extent that the elasticity ($\epsilon$) is higher than 4.

[2] Projections to 1970 were based on 1960–70 growth rates. Subsequent projections to 1985 use 1970 as the base period. This is consistent with the methodology of the Subpanel.

Source: Adapted from Chapter 2.

The Subpanel discussed several alternative assumptions regarding rates of production and disappearance of grains. In their judgment, increases in output of 2.7 percent and 3 percent coupled with disappearance rates of 3 percent and 3.2 percent lead to values for net imports that are within the expected capability of world grain markets. According to the Subpanel, however, these disappearance rates are too low to permit discernible progress toward better nutritional standards consistent with the targets established in Chapter 1. A minimum level of increase, in per capita consumption, given a population growth of 2.5 percent, is judged to be 1 percent or an overall disappearance rate of 3.5 percent. When this demand estimate is introduced into calculations assuming a trend in food grain production of 2.7 or 3 percent, levels of net imports are generated which the Subpanel finds excessive.

In summarizing the various combinations of production and disappearance rates, the subpanel suggests that a rate of growth in agricultural production on the order of 4 percent is possible. Such an increase would permit both the attainment of higher nutritional standards and reduction in the need to rely on food imports. For example, a 4 percent rate of increase in production coupled with a 3.5 percent rate of disappearance results in net imports in 1985 of 15 million tons, some 40 percent below current levels.

Examination of the Panel's findings suggests:

1. According to Chapter 1 a figure of 2.7 percent, which was used in Section 13.2.0 is likely to be more realistic than 2.5 percent for rate of population growth.

2. As the analysis of Section 13.2.0 indicated, it will probably require a rate of increase in per capita consumption of 1.3 percent to meet desired physiological nutritional needs instead of the 1 percent assumed in Chapter 2.

Although the increase in food demand suggested in Chapter 1 (see Section 13.2.0) appears to be small, the summed increases result in a disappearance rate of 4 percent (the sum of 1 and 2 above) annually as opposed to 3.5 percent. When the former figure is coupled with an assumed 4 percent increase in output, the result is a net import requirement of 49 million tons in 1985. According to the subpanel, this is probably within the capacity of world markets to supply, but it means more than doubling current imports to the developing countries.

It is clear that an annual increase of 4 percent in agricultural output will be almost a necessity if a 4 percent growth in food disappearance is to be realized. The above point can be dramatically illustrated by looking at Alternative D which assumes a rate of growth of grains output of 2.7 percent. In that case net imports will rise to nearly 3½ times current levels. The subpanel suggests that imports of this order of magnitude would exceed the production capacity of developed countries even if all presently idle crop land were to come back into use.

The foregoing analysis suggests a crude but fairly obvious rule of thumb for establishing necessary rates of increases in food production, i.e., *production must increase at a rate approximately equal to food disappearance.* In the long run, a divergence of even one or two tenths of a percent leads to an absolute gap between availability and consumption that is probably unmanageable.

In the following section, the Alternatives given in lines A and C of Table 13–7 have been selected for further analysis. Line A represents a level of demand that would ensure an adequate diet; it requires, however, a rather optimistic growth of food output. Line C, on the other hand, contains a somewhat more "likely" increase in output, but a demand projection that appears to be rather low in terms of meeting nutritional needs. Both A and C, however, result in levels of grain imports which appear feasible and generally consistent with the ranges of growth rates of food demand derived in Section 13.2.[16]

TABLE 13–7.—*Alternative projections on production, disappearance, and net imports of total grains in non-Communist developing world* [1]

| | Annual percentage growth rate | | | | Food (million metric tons) | | |
|---|---|---|---|---|---|---|---|
| | Food, production growth | People, population growth | Food, per capita consumption increase | Total production implied growth, GNP [2] | Production | Disappearance | Net imports |
| 1964 to 1965 | | | | | 219 | 244 | 23 |
| 1985A | 4.0 | 2.7 | 1.3 | 5.3 | 480 | 534 | 54 |
| 1985B | 3.5 | 2.7 | 1.3 | 5.3 | 436 | 534 | 98 |
| 1985C | 3.5 | 2.5 | 1.0 | 4.5 | 436 | 485 | 49 |

[1] This table used 1964–65 data as the base for growth projections.
[2] Assumed income elasticity=0.5 for food.

*13.3.2.2 Input Requirements for 3.5 and 4.0-Percent Growth Rates for Agricultural Output.* In Chapter 6, the Subpanel on Manufactured and Biological Inputs has presented its findings in the form of capital inputs required to attain various additions to current agricultural yields and not just food yields. In the following exercise, the Subpanel's figures for different levels of increase in agricultural yields have been used to obtain the rate of investment required for an annual increase in output of 3.5 percent and 4 percent, respectively (see Table 13–8). These calculations assume that the increased production is to come primarily from increased yields per acre rather than by farming a larger area.

The estimates are admittedly rough in the light of the criteria discussed in Section 13.3.1 above. Hence, it is difficult to determine exactly aggregate levels of fixed capital requirements for various time periods.

[16] Alternative C calling for a 3.5 percent rate of growth in food demand and 4.5 percent in GNP is slightly lower than the derived range in Section 13.2.

TABLE 13-8.—*Production capacity (capital stock) required to produce inputs for a 3.5- and 4-percent growth in food*

[Billion dollars]

| | Agricultural growth rate (percent) | Total increase in agricultural yield (percent) | | | | | |
|---|---|---|---|---|---|---|---|
| | 3.5 | 0<br>1965 | 10<br>1968 | 25<br>1972 | 50<br>1977 | 100<br>1985 | 120 |
| Additional capital stock: | | | | | | | |
| Fertilizer | -------- | -------- | 0.97 | 3.58 | 10.13 | 28.56 | -------- |
| Seed | -------- | -------- | -------- | .05 | .10 | .40 | -------- |
| Mechanization | -------- | -------- | -------- | .27 | .40 | .67 | -------- |
| Plant protection | -------- | -------- | .10 | .30 | .77 | 1.91 | -------- |
| Total | -------- | -------- | 1.07 | 4.20 | 11.40 | 31.54 | -------- |
| | 4 | | 1967 | 1971 | 1975 | 1982 | 1985 |
| Additional capital stock: | | | | | | | |
| Fertilizer | -------- | -------- | 0.97 | 3.58 | 10.13 | 28.56 | 34.30 |
| Seed | -------- | -------- | -------- | .05 | .10 | .40 | .48 |
| Mechanization | -------- | -------- | -------- | .27 | .40 | .67 | .80 |
| Plant protection | -------- | -------- | .10 | .30 | .77 | 1.91 | 2.29 |
| Total | -------- | -------- | 1.07 | 4.20 | 11.40 | 31.54 | 37.87 |

Source: Chapter 6 (capital required for 120-percent increase extrapolated).

Even the crude series of capacity requirements permit the derivation of the annual level of investment envisaged by the subpanel over the period 1965–1985. According to Figure 13-1, the (additional) annual rate of investment required for a 3.5 percent increase in agricultural output is approximately 300 million in the early years, increasing to over 3 billion per year by 1985. A target of 4 percent would require nearly $4 billion of investment per year by 1985.

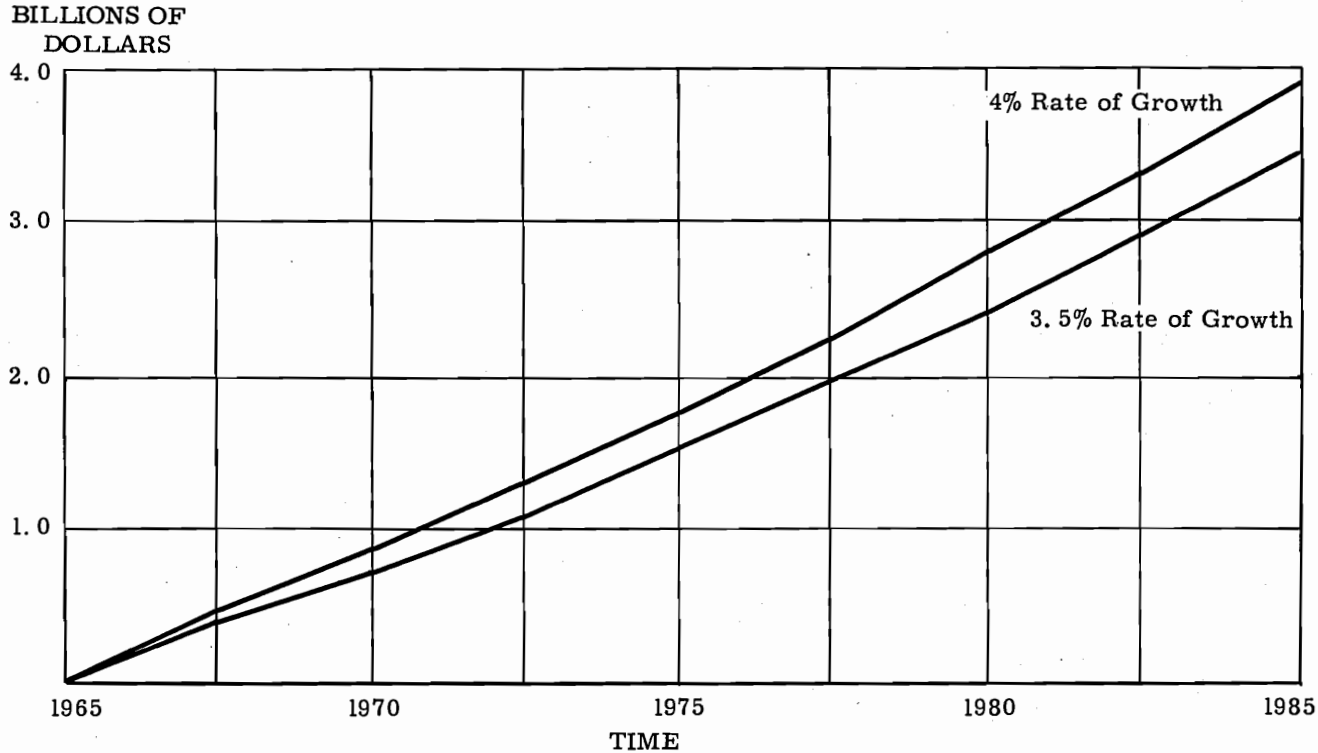
Such rates of investment may at first seem extraordinarily high, yet they are quite consistent with rates of capital formation experienced in certain sectors of developing countries where little or no capital base has previously existed. For example, India increased its production capacity in fertilizer by 264 percent during the period 1960–65; a further increase of 300 percent is anticipated by 1970.

Significantly, in the absence of detailed information on the composition of total investment in developing countries it is not possible to determine whether the estimated level of investment in fixed capital goods is feasible from an overall resource point of view. This is even truer when it is remembered that only the direct capital requirements were estimated.[17] About all that can be said is that the ratios of (1)

[17] In this connection, see the discussion of the direct and indirect input requirements in Sections 13.3.1 above and in Section 13.4 below.

Figure 13-1

APPROXIMATE LEVEL OF INVESTMENT IN FIXED PRODUCTION CAPACITY REQUIRED FOR A 3.5 AND 4.0 PERCENT INCREASE IN AGRICULTURAL OUTPUT (BASED ON TABLE 13-3)



total investment to GNP and (2) investments in input such as fertilizer and seeds, related to total investment (needed to double yields) are not altered unreasonably over the period. For example, assuming a 5 percent growth rate in GNP and an investment to GNP ratio of 15 percent in 1965 and 20 percent in 1985, the direct share of agriculturally-related industrial investment to total investment in 1965 is 0.7 percent, and in 1985, 2.2 percent (see Table 13–9).

Again, it should be reiterated that few inferences can be drawn from such global exercises. At a minimum, the analyses of investment feasibility require multisectorial, country-by-country studies. Perhaps the best that one can say of the levels of investment envisaged in this report is that *a priori* they do not appear to be impossible of achievement.

TABLE 13–9.—*Ratios of GNP, total investment, and investment in fertilizers, seeds, mechanization, and pesticides for developing countries*

[billion dollars]

| | 1965 | 1985 |
|---|---|---|
| 1. GNP | 284 | [1] 753 |
| 2. Total investment: | | |
| 15 percent of GNP | 43 | |
| 20 percent of GNP | | 151 |
| 3. Investment in fertilizers, seeds, pesticides, mechanization | .3 | 3.4 |
| Percent of share of (3) in (2) | .7 | 2.2 |

[1] Assuming a growth of 5 percent.

*13.3.2.3 Land and Water Requirements.* A second type of capital intensive input required in many parts of the developing world for a significant increase in agricultural output is irrigation water and flood control. The analysis presented in Chapter 7 indicates that, indeed, a large potential exists in a number of developing countries for increased utilization of current water supplies. For example, the subpanel estimates that in the Indian Subcontinent and Southeast and Southwest Asia alone, present surface water usage can be doubled. Coupled with substantial groundwater development, they suggest that the ultimate irrigation potential in terms of cropped acres is more than double the current irrigated acreage. Most of this increase would come from double or triple cropping. Furthermore, additional water could profitably be used to increase yields on lands now inadequately irrigated.

While giving some indication of water development potential, the Panel made no projections regarding the rate of investment required to sustain various levels of increased agricultural output over the period 1965–1985. Although some statistics on the costs of different types of irrigation projects are presented, it was not possible to develop an investment schedule that would permit an examination of the

feasibility or productivity of proposed investments in irrigation facilities. It is safe to say, however, that the full irrigation potential of the developing countries will not be realized by 1985. Even if authorization to begin all potentially feasible projects were to be given immediately, the physical and technical requirements of such an undertaking would be unmanageable. Moreover, given the gestation period of large-scale irrigation works, only a portion of the projects actually undertaken could be expected to reach fruition by 1985. Hence, the relevance of the figure of *$80 billion* for Asian water development found in the subpanel's report consistent with doubling food production by 1985 is meant to suggest a broad order of magnitude.

Although the Subpanel did not develop material by which an investment program could be formulated or judged, a number of useful points were made which bear reiteration and comment.

The Panel has stressed at great length the effect of complementarity between inputs. Important physical and institutional interactions between water and other inputs exist. Water projects without fertilizer may not pay for themselves; fertilizer without new seed varieties is only marginally profitable; establishing appropriate incentives to farmers is difficult without an adequate system of markets. What is not true, of course, is that the ease or cost of establishing appropriate complementary relationships between factors is the same for all types of inputs. For example, in an open economy if production lags behind schedule, it is always possible to import fertilizer, plant protection materials, machinery, and other required inputs. On the other hand, it is clearly impossible to import increased amounts of irrigation water. In general, irrigation projects can only be constructed at the point at which the water is to be used. This suggests that, because of the intrinsic difficulty of carrying out successfully irrigation projects compared to the acquisition of other agricultural inputs, planning and developing the country's water resources must have a high priority in any agricultural development strategy.

Secondly, the world's experience with large-scale irrigation projects is somewhat ambiguous. As the subpanel notes, investments of this type require an unusual amount of planning and followthrough in order to be successful. By contrast, ground water development and low-lift surface pumps have had a substantially better record in terms of contributing to rapid increases in output by farmers. The subpanel recommended, therefore, that highest priority in the country's water resource development program should be given to the above kinds of projects.

The rapidity with which additional groundwater supplies can be developed is indicated by the experience in West Pakistan where, from a base of approximately 5000 cubic feet per second, the yearly rate of increase in pumping capacity (public and private) averaged 45

percent during the period 1960 to 1965. This rate of increase was a highly significant factor in producing a 4.9 percent growth rate in major crops over the 1960/65 period. Current plans call for even higher investment levels during the Third Plan period (1965–1970). For West Pakistan, nearly 13 percent of the total Third Plan allocation ($0.7 billion) has been earmarked for irrigation and flood control.

But such opportunities do not exist in all areas, and generalizations based on the Pakistan experience to areas outside the northern part of the Subcontinent are unwarranted. In fact, such case studies seem only to underscore the necessity for a much more disaggregated approach to a meaningful discussion of the production side of the food problem.

### *13.4.0 A Framework for Further Study*

Much of the previous discussion in this report (and of the other subpanels') has been global in nature. It has relied upon relatively simple analytical techniques, and on numbers which can, at best, be described as first approximations. At the level of aggregation that was used, the strongest statement that could be made was that a 4 percent growth in food supply could not be judged as impossible in terms of total investment requirements. The corresponding rate of growth of GNP required to achieve the above target was found to be of the order of 5–5.5 percent which, again, appears within the realm of the possible. Nevertheless, the global approach abstracts from a host of micro considerations which could seriously endanger the actual feasibility of the type of investment program discussed above in a specific developing country.

It is clear that no definite answers on feasibility can be given without much greater attention to specific regions. Ideally, a detailed analysis should be carried out for each of the developing countries; in practice, however, analyses of 5 or 6 key countries—primarily the large Asian nations—could help to remove much of the uncertainty inherent in global estimates. We strongly recommend that this be done as a second phase of the general study.

A few additional comments will highlight why such country studies are so crucial. The global approach used above, in which national data on such items as gross national product, investment, and food requirements are all summed together for all countries, is like the familiar problem of trying to add apples and oranges. To be more explicit, India is the largest of the developing countries under review, and alone contributes about one-third of the total current world food deficit (excluding mainland China).[18] At the same time, India's per capita income and gross investment rates are among the lowest, and her balance of payments among the most constrained in the entire world. Thus

[18] U.S.D.A., *The World Food Budget, 1970.*

what may appear reasonable for the developing world as a whole may in reality be very unreasonable for one of the key countries.

In addition to the questionable procedure of aggregating over unlike countries, a second limitation (already discussed in Section 13.3.1) in the approach followed in this and other subpanel reports is that only the direct resource requirements of increasing agricultural output were considered. In addition, no division was made between the domestic and foreign exchange components of the investment bill.

Both of these factors may be extremely important, as can be illustrated with the case of fertilizer. The cost figures given in the previous discussion are based only on the necessary *direct* stocks and flows between the chemical and agricultural sectors. If fertilizer plants are to be constructed and utilized, however, there must be adequate investments (or imports) in such sectors as electric power, marketing, the transportation network, and the petroleum sector. It has already been pointed out that to analyze fully all of these requirements will necessitate some form of intersectorial analysis on an individual country basis.[19]

Two examples will illustrate the points just made. In Table 13–10 and 13–11 are shown selected data from the United States economy. Table 13–10 indicates the *direct* sectorial requirements (in terms of dollar of inputs per dollar of output) to increase the final consumption of various products by $1. Thus the $0.15 figure for crops would include items such as seeds, and the $.11, the necessary *direct* expansion of the food processing industry required to permit crop consumption to grow by $1. In Table 13–11, the *indirect* requirements have been added as well—often resulting in a doubling of input magnitudes. In the case of manufacturing inputs to crops the coefficient goes from 0.002 to 0.018. Thus, while agriculture's direct requirements for machinery may be low, a growth in agricultural output has second-order and higher-order repercussions, i.e., there must be an increase in steel production to make the lathes, to make the tractors, to produce the output.

Without going into the full intricacies of input-output analysis, one conclusion is clear. By only concentrating on the direct output and capital cost requirements, the subpanels may have significantly underestimated the total investment requirements of a 4-percent growth in agriculture. Whether the economies of the developing world can sustain both the direct and indirect investments needed for a rapid expansion in food supplies cannot be answered with the information thus far developed.

A related issue concerns the foreign exchange requirements connected with the 4 percent agricultural growth. A number of countries find themselves more constrained by the availability of foreign exchange

[19] See for instance H. Ghenery and P. Clark, *Interindustry Economics*, Wiley, 1959.

TABLE 13–10.—*Matrix of input-output coefficients, United States, 1947*

[7 interacting sectors]

| | Livestock products 1 | Crops 2 | Food processing 3 | Fibre manufacturing 4 | Other and manufacturing 5 | Energy and transportation 6 | Trade and services 7 |
|---|---|---|---|---|---|---|---|
| 1. Livestock products | 0.0692 | ---------- | 0.1915 | 0.0236 | (1) | 0.0001 | 0.0006 |
| 2. Crops | .3967 | 0.1539 | .1134 | .0659 | 0.0025 | .0004 | .0003 |
| 3. Food processing | .1210 | .0053 | .2066 | .0223 | .0163 | .0055 | .0043 |
| 4. Fibre processing | .0001 | .0041 | .0042 | .3196 | .0114 | .0013 | .0016 |
| 5. Other manufacturing | .0121 | .0587 | .0556 | .0696 | .4373 | .1342 | .0761 |
| 6. Energy and transportation | .0330 | .0147 | .0307 | .0169 | .0373 | .0873 | .0371 |
| 7. Trade and services | .0468 | .0392 | .0562 | .0441 | .0550 | .0534 | .1310 |

[1] Less than 0.000005.

Source: Karl Fox, "The Food and Agricultural Sectors of Advanced Economies" in T. Barna, *Structural Interdependence and Economic Development*, Macmillan, 1963, pp. 60–61.

TABLE 13–11.—*Inverse matrix, United States, 1947*

[7 interacting sectors]

| | Livestock products 1 | Crops 2 | Food processing 3 | Fibre manufacturing 4 | Other and manufacturing 5 | Energy and transportation 6 | Trade and services 7 |
|---|---|---|---|---|---|---|---|
| 1. Livestock products | [1] .1109 | 0.0028 | 0.2699 | 0.0489 | 0.0094 | 0.0034 | 0.0032 |
| 2. Crops | .5100 | 1.1859 | .2952 | .1444 | .0176 | .0055 | .0043 |
| 3. Food processing | .1765 | .0120 | 1.3093 | .0554 | .0411 | .0148 | .0110 |
| 4. Fibre processing | .0067 | .0098 | .0138 | 1.4751 | .0314 | .0071 | .0058 |
| 5. Other manufacturing | .1250 | .1418 | .2026 | .2294 | 1.8237 | .2800 | .1731 |
| 6. Energy and transportation | .0638 | .0282 | .0723 | .0469 | .0822 | 1.1115 | .0551 |
| 7. Trade and services | .1064 | .0656 | .1305 | .1050 | .1260 | .0877 | 1.1664 |

[1] The number greater than 1 on the diagonal should be interpreted as follows: To consume for example. 1 unit of crops, requires than unit *plus* the intra-sectoral requirement.

Source: Same as Table 13–10.

than by domestic savings.[20] This factor may be particularly important in the case of fertilizer. Given a lead time of 3–5 years in fertilizer plant construction, imports may be the only solution—at least in the short run. An optimal rate of fertilizer importation in terms of the overall economy depends on an examination of the country's export capability, of availability of foreign aid, and the net inflow of private investment. Even if countries decide to produce fertilizer domestically, there also may be foreign exchange difficulties, since the industry tends to be very capital intensive requiring a high direct and indirect foreign exchange component.[21]

[20] See H. Chenery and A. Strout, "Foreign Assistance and Economic Development", *American Economic Review*, September 1966.

[21] In Pakistan, a fertilizer industry currently based on natural gas still requires the importation of inputs equal to about 5 percent of the total value of output. See R. Soligo and J. Stern, "Export Bonus, Export Promotion and Investment Criteria," *Pakistan Development Review*, Spring 1966.

Finally, there are a number of problems concerned with projects, phasing, and policy, which are crucial to an assessment of a country's ability to increase its agricultural output. With regard to projects and their phasing, the irrigation input offers a good example. If one accepts the $80 billion figure estimated by the subpanel, for the full development of the irrigation potential, difficult questions still remain. What projects are required to sustain a 4 percent rate of growth between now and 1985? Can these projects be implemented with sufficient rapidity given planning and construction lead times? Since the $80 billion so dwarfs all other cost estimates, these are not questions to be dismissed lightly.

At the policy level there are also many unanswered questions, as was pointed out in Section 13.3.1. Given the rapid rates of farmer adoption implied by the fertilizer requirements, are subsidies either necessary or desirable? What internal price structure is required to assure that fertilizer can be used profitably on food crops? Should an individual country try to be self-sufficient, or should it trade for its food? What is the appropriate mix of inputs and outputs for a given country?

In short, only a much more detailed analysis of the larger of the developing countries can provide an adequate basis for a final judgment of feasibility on both the technical and cost aspects of the food problem.

### *13.5.0 The International Dimension of the World Food Problem*

It has been shown that the developing world may well have to grow at a rate of between 5 and 5.5 percent over the next twenty years to permit the nutritional targets to be reached. The above range would, at least, be consistent with the necessary growth of GNP on the demand side. It was not possible to derive the aggregate growth rate on the production (capacity) side consistent with the required increase in the domestic output of foodstuffs in the developing countries. The above range represents a jump over the 4.5 percent rate which prevailed in the last decade.

Furthermore, it has been shown that *even* if the developing world is capable of achieving a rate of growth of food production equivalent to the desired rate of growth of food demand (i.e., 4 percent), net imports of food grains of 54 million metric tons would still be required (see Table 13–7). This last amount is almost 2.5 times the 1964–65 level of net imports (23 million tons).

A reliable source has projected the exports (excluding petroleum) of the developing countries to grow, in the next ten years, at an annual rate of 3 percent. These projections reveal dramatically the balance of payments pressures to which the developing world is likely to be subjected.

It is, therefore, essential to examine some of the elements which are affecting the capacity to import of these countries.

Much of the discussion on the world food problem has been centered on what developing countries could do to improve their situation. This has generally been approached from the point of view of increasing each country's food production for domestic consumption, and thus either (a) raising the nutritive level of its own people, or (b) expanding its food production for domestic consumption enough to keep pace with its expanding population, to prevent further deterioration in its already low levels of nutrition, or to improve dietary adequacy and quality.

It has been recognized from time to time that as long as agriculture in developing countries is the main occupation of most of the population, it is also the major source from which developing countries can earn the foreign exchange to speed up their economic development, raise their output and standards of living, and eventually become exporters of products other than those derived from the farm. Many national development plans stress expansion of exports of farm products to help pay for increased imports of needed industrial goods.

For many countries simultaneously to try to increase agricultural exports tends to over-supply the international demand, and to reduce the prices of farm products relative to industrial products. As a consequence, the "terms of trade" for agricultural countries have shown a downward trend ever since the early 1950's.

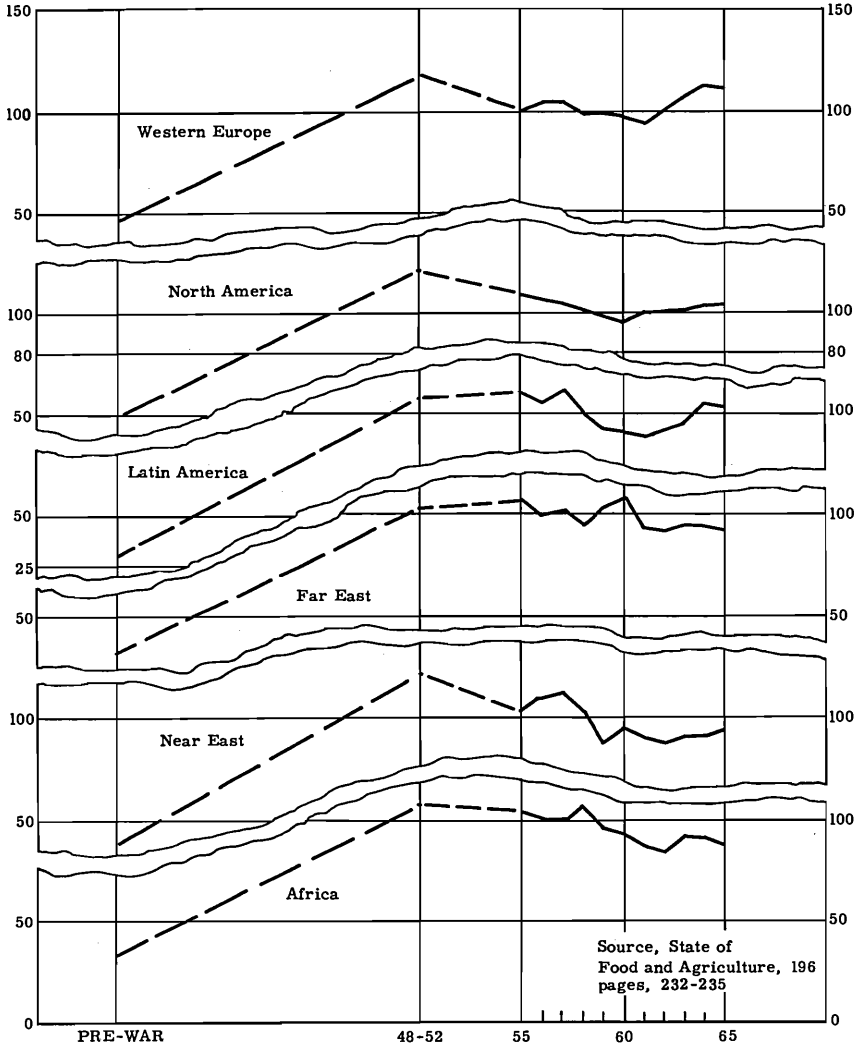
In world trade, the price index of industrial exports increased from 100 in 1948, and again in 1952, to a level of nearly 110 by 1964. Prices of agricultural exports declined from an initial average of 105 in 1948, (with a temporary rise to 120 during the Korean War) to a low of under 85 in 1962, and a rebound to about 90 in 1964. World prices of *industrial* products, compared to those of farm products, were more than 22 percent higher in 1964 than they had been a decade earlier. The short crops of 1966 and early 1967 temporarily turned up farm prices of export grains, but with normal rainfall and growing conditions the relatively low prices of farm products in international trade will no doubt reappear with the 1967 harvests.

When the prices of agricultural exports are examined regionally, however, considerable disparity in movement is seen between regions. (Figure 13–2)

With the average prices in each region for 1957–59 taken as 100, a general downward trend after 1948–52 is clear, with a tendency to flatten out from 1960 onwards in most developing regions. There were some differences between regions, however.

A continuous and almost unbroken decline occurred in average African export prices, flattening out after 1962 at an average level for 1963–65 of about 82 percent of the 1948/52 average. The Near East

Figure 13-2
AVERAGE PRICES OF AGRICULTURAL EXPORTS BY REGIONS




showed a similar decline, though with a very slight improvement from 1962 to 1965, and a 1963–65 average only about 75 percent of that in 1948/52. The Far East, with rice more important in its agricultural exports, showed a more stable export price level with a decline of only 12 percent over the same period.

Latin America had a quite different movement, with export prices in the mid–1950's about the same as in the 1948/52 period, but dropping sharply from 110 in 1958 to 88 by 1961, and then recovering in the early 1960's to nearly the 1955/57 level. (This difference in returns may reflect the greater importance of animals and meat in Latin American exports than in other developing regions.)

263-888 O—67——44

The two highly developed regions of Western Europe and North America showed substantial declines in agricultural export prices from the 1948/52 average to 1960, declining from 117 to 97 for Western Europe, and from 120 to 95 for North America. Both showed increases thereafter to 1965 back to 102 for North America, while in Western Europe the increase was to 110—possibly reflecting the effect of the European Common Market on European export prices of farm products.

Summing up: Prices of agricultural exports as a whole declined from the 1948/52 average in all regions. In 1965 they were lower than in 1948/52, except in Europe and Latin America, and also were lower in 1965 than in 1955 in every region except Europe. Part of this decline in export values, however, was due to generally declining prices for raw materials after the Korean War period and to sharply declining prices for beverages and tobacco in all the developing regions, though with some strengthening in the 1960's. In Western Europe and North America, however, prices of beverages and tobacco trended sharply upward after 1956, and by 1965 were far above any other farm product group—at 132 percent of the 1957/59 average in Western Europe, and at 112 percent of 1957/59 in North America.

In exporting regions such as Latin America, the Near East, and Africa, the beverages and tobacco group had dropped to three-fourths of the 1948/52 prices in the early 1960's, and in 1965 had recovered only to 91 percent in Latin America and the Far East, 90 percent in the Near East, and were still at 76 percent in Africa.

During the period 1956 to 1965, costs of marketing and distribution in the United States went up more sharply than did prices at the farm or in international trade; and in a number of European countries, retail costs of food went up even faster, as shown by the cost-of-living reports of the International Labor Organization. Although farm prices generally declined from 1965, *retail* prices of food in several major countries increased as follows from 1958 to 1965: [22]

| | *Percent* |
|---|---|
| United States | 16 |
| United Kingdom | 15 |
| Germany | 25 |
| France | 43 |

Coffee, an important income-earner for a number of developing countries, is an especially notable case, with marketing costs in developed countries rising so fast as to more than offset the increase in production and price declines in exporting countries. (Sources of data: Statistical Abstract of the United States 1963; 1965; and FAO State of Food and Agriculture, 1966.) Thus, while United States

[22] *Year Book of Labour Statistics, 1965,* International Labor Office, Geneva, p. 613.

imports of coffee increased considerably from 1950 onward; prices dropped so steadily that net United States payments for coffee imports had a marked downward trend after 1957, as shown below:

| Year | United States coffee imports per year (million pounds) | Average price (cents per pound) | Total value per year (million dollars) |
|---|---|---|---|
| 1950 | 2,442 | 44.6 | 1,092 |
| 1955 | 2,602 | 52.6 | 1,370 |
| 1957 | 2,773 | 49.8 | 1,376 |
| 1958 | 2,684 | 43.9 | 1,171 |
| 1959 | 3,094 | 35.7 | 1,097 |
| 1960 | 2,943 | 34.4 | 1,003 |
| 1961 | 2,984 | 32.4 | 964 |
| 1962 | 3,266 | 30.5 | 990 |

The sale of over 3.2 million pounds of coffee to the United States in 1962 brought coffee exporters only 72 percent as much income as the sale of about 2.8 million pounds in 1957, or of 2.6 million pounds in 1955.

During the post-war period, there has been a marked tendency to reduce the proportion which the farmer receives of retail prices. Particularly noticeable are products which move through international trade, but such declines are also evident in the farm-retail gap in the domestic marketing of United States farm products. With short food supplies in late 1966, United States farm prices strengthened to 107 percent of the average price a decade earlier (1957/59=100). But wholesale prices of food rose to 110 percent, and retail prices of food to 115 percent of what they had been in the same base period—an advance in prices twice as much at retail as at the farm.[23]

The short crops of 1965/66, due to unfavorable weather both in Asia and the United States, sharply reduced stocks of wheat and rice and led to a general worldwide advance in farm prices, especially marked for wheat and rice.

The temporary gains in prices due to the short crops of 1965/66 do not appear sufficient to indicate any break in the general unfavorable trend for the exports of the developing countries summarized above.

The importance of changes in the terms-of-trade of the developing countries can be illustrated by pointing out that a 10 percent decline in their terms-of-trade would be approximately of the same order of magnitude as total United States foreign economic aid in one year. In other words, such a worsening of their terms-of-trade can negate entirely the positive effects of United States assistance from the standpoint of their balance of payments.

[23] Marketing and Transportation Situation, U.S. Department of Agriculture, February 1967.

*It is of the utmost importance from the developing countries' point of view to increase exports of industrial products as well as agricultural products, for only so can they earn the foreign exchange with which to pay for the extra food they need, or to help establish or expand non-farm industries.* Such industries could help them earn increasing foreign exchange for their economic development as a whole, or for speeding up agricultural development by importing more pesticides, fertilizers, machinery, or the equipment with which to manufacture inputs needed on the farm.

If the developing countries are ever to become more highly developed, it will be in large part by increasing their manufacturing and other non-farm industries and infrastructure, reducing the heavy excess of manpower on their farms, finding markets abroad, and eventually adopting labor-saving techniques both on farms and in factories so that both output and consumption per person can be increased as it has in the developed countries. In this process they will develop the internal production and buying power to buy and use the varied technical methods of increasing farm production recommended by many of the technical panels. But if that is to happen, developed countries and their business, legislative and industrial leaders will need to recognize that worldwide industrial development can take place only if the total volume of production and trade expand, and that in that expanding trade increased exports by developing countries of both farm and non-farm products, which means increased imports by the developed countries, are an important and essential part of the development not only in world overall totals but in activities by each country concerned.

Real awareness of this principle would lead to much more readiness of business concerns and officials in developed countries to help developing countries speed up their industrial activities as well as their agricultural ones.

The meetings of the UNCTAD (the United Nations Conference on Trade and Development) have provided developing countries a forum in which to express their frustration at the box in which they are caught as a result of their difficulties in finding export markets, and have stimulated some further transfers of funds to these countries to help offset their foreign exchange shortages. But these are only palliatives, not cures. The developed countries need to face this problem squarely, admit the need of a general two-way expansion in trade to stimulate economic development, and educate their legislators and their businessmen to more positive support to increased output in developing countries, industrial as well as agricultural, and to increased mutually-beneficial trade on a global basis. Only so can the brave words

for increased food production in developing countries become a reality—when increased food production is part of a worldwide expanding economy, industrial as well as agricultural.

### *13.6.0 Conclusions*

The main conclusions which can be derived from this analysis stand out clearly.

Food consumption in the developing world will have to grow at approximately 4 percent annually over the next twenty years to meet the critical minimum nutritional targets. Since the developing world is already a large net importer of grains, balance-of-payments considerations make it imperative that the rate of growth of food production in these countries be of the same order of magnitude as that of food demand. Even under these conditions, i.e., with both food demand and production in the developing countries growing at 4 percent annually, it is estimated that net imports would amount to 54 million tons in 1985 as compared to 23 million tons in 1965. (See Alternative A in Table 13–7.) Whereas this level of net imports for 1985 appears feasible, it is clear that even a small difference between the rate of growth of food demand and that of production in the developing world could result in import requirements which could not be met even if optimistic assumptions are made with respect to the future course of (a) exports and net private capital receipts and (b) foreign assistance including food assistance.

The rate of growth of income in the developing world consistent, on the demand side, with the desired growth in food consumption is calculated to be of the order of 5–5.5 percent. It is not possible to derive the growth rate of income, on the supply (production) side, which is consistent in an input-output sense with a growth rate of food output of 4 percent. Yet, it appears probable that a rate of at least 5.5 percent might well be called for.[24]

The growth in both GNP and food production in these countries necessary to "solve" the world food problem is higher than the historical experience in the recent past. A jump from the present 4.5 percent growth rate of income in the developing world to 5.5 percent will be a very difficult but not an impossible task.

It is evident that the feasibility of such food and overall income targets can ultimately only be evaluated on the basis of a disaggregated, multisectorial framework for at least the major developing countries.

The Panel has estimated the capital investment required to achieve the agricultural production targets over the next twenty years for manufactured physical and biological inputs as well as in a more quali-

[24] It is, of course, clear that in an ex-post sense these two growth rates—on the demand and supply sides—have to be equal.

tative way for water, transportation and some still less tangible inputs much as manpower, education and research. Since only the direct (and not the indirect) input and capital requirements were calculated, and these for only *some* of the inputs, it is not possible to make a final determination of the feasibility of reaching the desired growth objectives. The most that can be said, given the level of aggregation of this study and the information available, is that a doubling of food production in the developing world by 1985 does not seem to be impossible of achievement.

In any case, gigantic efforts will be necessary in the developing countries not only on the investment front but also on the institutional front to attain the desired food and income levels. The developed world, in turn, will have to assist in the next twenty years with the provision of a high level of economic and food assistance and private capital and, perhaps even more important, with the creation of an environment more favorable to the growth of the developing countries' exports.

The World Food Supply Problem is perhaps the greatest challenge of our time. A great deal of technical information has been gathered by the Panel. It is strongly recommended that the above work be followed up by a detailed economic evaluation of the world food situation. Such study could be conceived along the lines suggested in this chapter.[25] It would have (a) to be country-oriented, at least for the major countries; (b) to use a disaggregated multisectorial approach in order to derive the direct and indirect input and investment requirements (to ascertain the feasibility of food production targets from the standpoint of the availability of domestic capital); and (c) to consider carefully and explicitly the balance-of-payments situation to estimate the import capacity.

This type of economic study of the World Food situation—outlined above—should not duplicate existing efforts (such as the FAO "World Food Indicative Plan") but *make use* of them. It is impossible to overemphasize the social importance of such a study.

[25] Sections 13.4 and parts of Section 13.3 may be particularly relevant in this connection.

# 14.0 EVALUATION OF POPULATION AND FOOD PRODUCTION PROBLEMS OF INDIA

Prepared by—

WILLEM HOLST, *Business Council for International Understanding*

## Contents

| | | Page |
|---|---|---|
| 14.1.0 | Summary | 675 |
| 14.2.0 | Introduction | 677 |
| 14.3.0 | Chart presentations | 680 |
| | 14.3.1 India's Position in the World Population Explosion | 680 |
| | 14.3.2 How Soon Will Population Controls Take Effect? | 682 |
| | 14.3.3 How Does Food Demand Relate to Population Growth? | 684 |
| | 14.3.4 Measuring the Dimensions of India's Foodgrain Problem | 686 |
| | 14.3.5 Are India's Foodgrain Production Plans Realistic? | 688 |
| | 14.3.6 The Principal Elements of Land Utilization | 690 |
| | 14.3.7 How Fast Can India's Foodgrain Yields Be Increased? | 692 |
| | 14.3.8 The Promise of Improved Seed Varieties and Fertilizer | 694 |
| | 14.3.9 Measuring the Economic Limits to High Fertilizer Intensity | 696 |
| | 14.3.10 Will the Farmer Utilize His Full Production Potential? | 698 |
| | 14.3.11 The Capital Cost of Achieving Foodgrain Self-Sufficiency | 702 |
| 14.4.0 | Appendices | 703 |
| APPENDIX I | Twenty-Year Projection of India's Foodgrain and Fertilizer Demand and Supply | 703 |
| APPENDIX II | Statistical Data Underlying Chart Presentations | 708 |

[1] Prepared by Willem Holst.

## *14.1.0 Summary*

This report and the data in the accompanying 20-year projection of India's foodgrain and fertilizer demand and supply (Appendix I) cover a wide range of foodgrain production alternatives. The Government of India targets, calling for 152 million tons in 1976, are compared with an Alternative "A," aiming for foodgrain self-sufficiency by 1971, an Alternative "B" premised on self-sufficiency by 1976, and an Alternative "C" based merely on continuation of the historical growth rate of foodgrain production. During the critical period 1964 to 1976, these alternatives show the following comparative results:

| | 1971 production (million tons) | Annual growth, 1967 to 1971 (percent) | 1971 fertilizer consumption (million tons) | Annual yield increase, 1964 to 1976 (percent) |
|---|---|---|---|---|
| Government targets | 120.0 | 8.2 | 4.10 | 5.0 |
| Alternative A | 113.5 | 6.8 | 4.25 | ---------- |
| Alternative B | 105.0 | 5.0 | 3.27 | 4.0 |
| Alternative C | 94.5 | 2.4 | 2.00 | 1.9 |

Alternative "B" calls for tripling of the historical rate of increase in yield per acre (1.32 percent per year for 1954–64), but with the advent of intensive cultivation areas, high fertilizer dosages, and improved seed varieties, it is certainly within reach technologically provided all the necessary farm inputs are made available in a balanced and timely sequence. Nevertheless, it calls for effort on a scale that has not been paralleled elsewhere in the world over so short a period. For this reason Alternative "A," even though technologically feasible, was not considered realistic. The need for 5.8 million tons of foodgrain imports in 1971, under Alternative "B," is partially offset by the 1.0 million tons per year lower fertilizer import requirement.

All data in the summary table covering the agro-industry projection to 1986 are premised on reaching foodgrain self-sufficiency by 1976, and thereafter essentially maintaining self-sufficiency for another 10 years. In the capital cost estimates shown below, it is also assumed that fertilizer self-sufficiency in nitrogen and $P_2O_5$ will be achieved before 1986. Over the 22-year period 1964–86, a rough estimate of all agro-industry capital costs (excluding infrastructure and "agri-business"),



PREVIOUS PAGE BLANK

comes to a total of $30.3 billions (an average of $1.38 billions per year), with the following breakdown:

| | *1964 to 1986 U.S. billions* |
|---|---|
| Irrigation (new and improved) | 11.20 |
| Farm machinery and equipment | 6.48 |
| Roads and truck transport | 5.30 |
| Fertilizer plants | 4.08 |
| Fertilizer marketing and farmer credit | 2.90 |
| Seed processing, pesticides, etc. | 0.37 |
| Total | 30.33 |

The summary table indicates the tremendous market potential which India's agro-industry represents, but these levels are not likely to be achieved unless:

(*a*) Sufficient foreign capital is attracted to cover the foreign exchange component of the $30 billions capital investment, roughly estimated to be $7.25 billions or $330 millions per year;

(*b*) The farmer is provided with sufficient economic motivation to increase all-India fertilizer application from 3.8 Kg/Ha to 69 Kg/Ha;

(*c*) The indicated farm inputs, and especially ever-improving seed varieties, become available to permit more than doubling of foodgrain yields, from 683 Kg/Ha to 1435 Kg/Ha.

With a population growth rate of almost 2.8 percent per year during the 1975–85 period, India's population of 854 million in 1986 will be 81 percent higher than in 1964; together with a 19 percent increase in per capita foodgrain demand (based on nutrition requirements), this results in a 115 percent increase in human foodgrain demand. For complete self-sufficiency, this requires a 136 percent increase in foodgrain production, to a level of 187 million tons by 1986; the projection falls slightly short of this goal.

As the summary table indicates, the annual population increase in India is expected to double, from 11.8 million in 1964 to 23.6 million in 1986, unless the assumed 11 percent decline in birth rate is considerably bettered.

SUMMARY TABLE

*India agro-industry projection to 1986*

| | Agricultural year, ending in June of year— | | | Percent increase, 1964–86 |
|---|---|---|---|---|
| | 1964 | 1976 | 1986 | |
| Population ... millions | 472 | 648 | 854 | 81 |
| Annual increase ... do | 11.8 | 18.0 | 23.6 | ---------- |
| Annual increase ... percent | 2.50 | 2.78 | 2.77 | ---------- |
| Gross national income [1] ... billion rupees | 139 | 230 | 349 | 151 |
| Per capita income [1] ... rupees per year | 295 | 355 | 409 | 39 |
| Human foodgrain demand ... kilograms per capita per year | 143.6 | 161.1 | 170.3 | 19 |
| Ounces per person per day | 13.9 | 15.6 | 16.5 | 19 |
| Million metric tons per year | 67.8 | 104.3 | 145.4 | 115 |
| Local foodgrain supply ... million tons | 60.1 | 104.1 | 143.3 | 138 |
| Foodgrain imports and stocks ... do | 7.7 | .2 | 2.1 | ---------- |
| Land utilization: | | | | |
| Gross area sown ... million hectares | 156.1 | 166.0 | 172.0 | 10.2 |
| Allocated to foodgrains ... do | 116.3 | 123.5 | 123.5 | 10.5 |
| Intensive food grain cultivation ... do | ---------- | 22.0 | 42.0 | ---------- |
| Harvested foodgrain production ... million tons | 79.4 | 135.5 | 184.4 | 132 |
| Foodgrain yield ... kilograms per hectare | 683 | 1,097 | 1,435 | 110 |
| Fertilizer application: | | | | |
| Intensive cultivation ... kilograms NPK per hectare | ---------- | 90 | 125 | ---------- |
| General cultivation ... do | 3.8 | 35 | 42 | 1,000 |
| Foodgrain average ... do | 3.8 | 45 | 69 | 1,715 |
| Fertilizer demand ... million tons | 0.60 | 6.81 | 11.06 | 1,740 |
| Nitrogen nutrient ... do | 0.43 | 3.88 | 6.30 | ---------- |
| $P_2O_5$ nutrient ... do | 0.12 | 1.96 | 3.17 | ---------- |
| $K_2O$ nutrient ... do | 0.05 | 0.97 | 1.57 | ---------- |
| Pesticide application ... thousand tons | 24 | 100 | [2] 154 | 540 |
| Grams ... per hectare | 149 | 600 | 900 | 490 |
| Seed requirement ... million tons | 5.0 | 5.3 | 5.5 | 10 |
| Farm machinery and equipment horsepower per hectare | 0.19 | .23 | 0.27 | 42 |
| Truck transportation ... thousands | 250 | 1,000 | 1,750 | 600 |
| Per 1,000 people | 0.53 | 1.54 | 2.05 | 287 |
| Irrigated land (net) ... million hectares | 26.4 | 37.0 | 49.0 | 86 |
| Percent of cultivated land | 19.4 | 26.6 | 34.5 | ---------- |

[1] At 1948–49 constant prices.

[2] Insecticides 50 percent, fungicides 30 percent, herbicides 20 percent.

[3] Increase equivalent to $280 million per year or 66 US¢ per acre per year.

[4] For foodgrain and fertilizer; assumes 160,000 miles new and improved roads in intensive agriculture area.

## *14.2.0 Introduction*

The subpanel reports presented in Chapters 1–12 cover a wide range of agricultural sciences and technology. They deal with these on a regional as well as on a global or macro-regional basis, particularly with Asia, Africa, and Latin America as a group. Among the regional evaluations, India, Pakistan, and Brazil have been given special attention in view of their importance in a demographic sense and, as a result, some differentiation in statistical treatment or methodology has

been introduced for these countries. By and large, the translation into specific agricultural inputs such as fertilizer, pesticides, and farm machinery is based on world-wide or United States experience factors, or on those of individual countries, where a particular technology is in an advanced stage; pesticide application in Japan is an example.

On February 2nd, 1967, President Johnson, in his message to Congress, stressed the importance of India's immediate and longer-term food supply problems, and the PSAC Panel agreed that a more specialized study of India's foodgrain problem was fully warranted. Fortunately, a twenty-year projection of India's foodgrain and fertilizer demand and supply had recently been developed for the India Committee of BCIU (Business Council of International Understanding), and it was believed that some of the technological data in the PSAC subpanel reports might be applied to this framework. This chapter is the result of this collaborative effort.

In addition to a series of graphic presentations of India's foodgrain problem, this chapter includes an up-dated (March, 1967) version of the 20-year projection or "agro-industry" model. This model attempts to portray the major variables which can affect foodgrain and fertilizer demand and supply; consequently it can be used for projection of alternative courses of action by a change in underlying assumptions. Several alternative projections have been developed, but these represent neither a forecast of what will happen, nor a Government of India (GOI) plan. They are simply premised on the assumption that Indian foodgrain self-sufficiency is a desired objective, that technology is sufficiently advanced to accomplish this in the not-too-distant future, and that the time element can vary depending on how fast the necessary policy and investment decisions can be implemented.

The agro-industry model and projection in their present form are considered adequate for broad exploratory planning and evaluation, and for illustrating a useful and consistent methodology. Further refinement is necessary, however, if they are to be used for precise cost-benefit studies or the formulation of more specific plans and policies. For example, capital costs and their associated foreign exchange components represent only rough approximations and require detailed analysis; the impact of varying rates of growth in the agricultural sector on the total Indian economy and on per capita income also deserve further and careful evaluation.

Translation of human foodgrain demand to needed farm inputs together with associated capital costs, has been limited to the "agro-industry" aspects of India's food supply problem. It does not deal with "agri-business" in the sense of processing, storing and marketing of food products or the formulation of protein and other additives; it

deals rather with the agronomic aspects, such as land and water management, and the economics of crop cultivation in relation to fertilizer response.

Many of the charts which follow should prove helpful in measuring the degree of progress being made, while at the same time permitting a comparison with past performance. They should be instructive for those in the United States who are interested in following India's agricultural achievements.

*14.3.0 Chart Presentations*

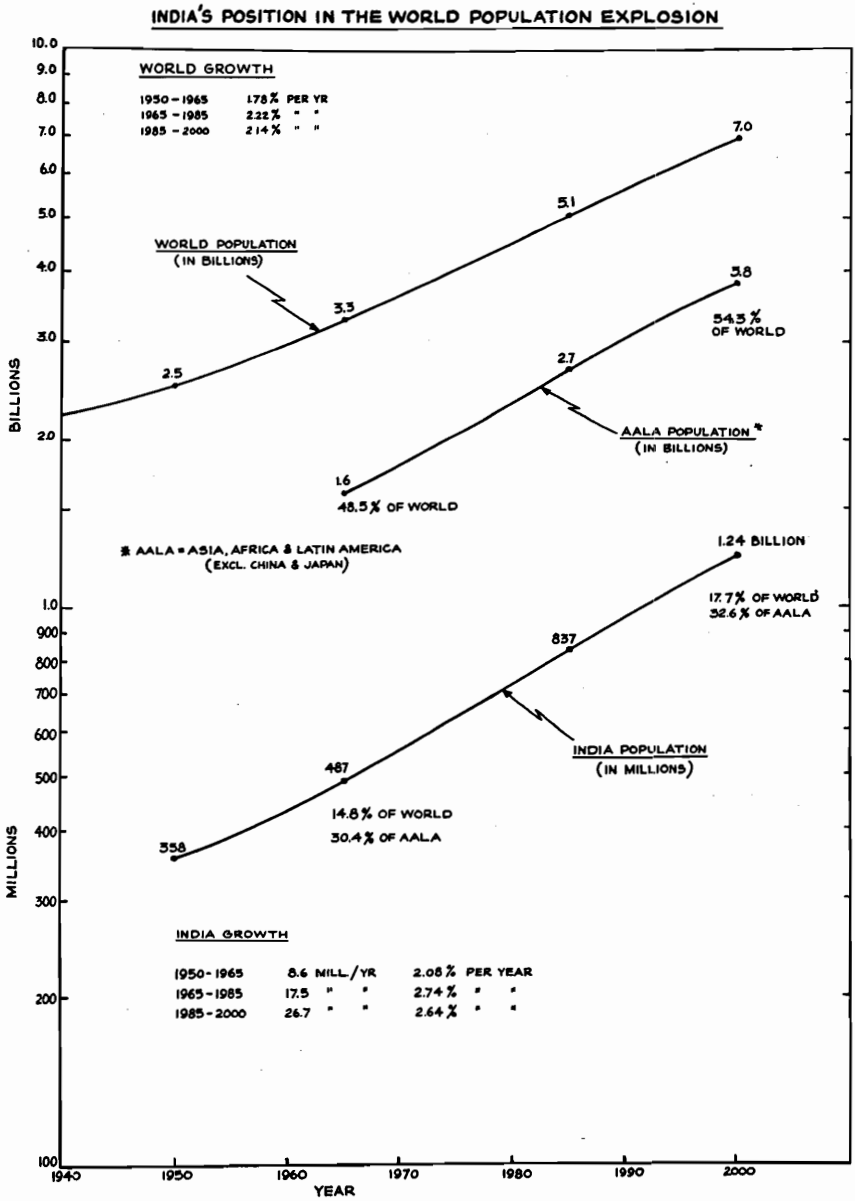



FIGURE 14–1

*14.3.1 India's Position in the World Population Explosion*

India's share of the world population in 1965 was 15 percent and is expected to increase to almost 18 percent by 1985 (Figure 14–1). It represents about one third of the population of the 96 "AALA" countries (Asia, Africa and Latin America, exclusive of mainland China and Japan). India's population of 487 million, together with those of Pakistan (115 million), Indonesia (105 million), and Brazil (81 million), comprise 50 percent of the "AALA" population in 1965, with the remaining 92 countries averaging about 9 million people each, less than 2 percent of India's population.

India's population is expected to double in 26 years from 487 million in 1965 to 975 million by 1991. The world's population is expected to double in 32 years, while in the AALA countries as a group, population is expected to double in 27 years.

India's population growth rate, which averaged 2.1 percent during the period 1950 to 1965, reached a level of 2.4 percent by 1964, and is expected to increase further to at least 2.7 percent per year before the impact of population controls causes this rate to decline; this subject is dealt with in further detail in the following section.

During the past 15 years, an average of almost 9 million more people have been added to India each year; this figure will double (18 million more each year) by 1976, and triple (27 million additional people each year) in the mid-90's. Under these circumstances, India's ability to take care of feeding its growing population cannot be taken for granted; guidelines are needed to help India select the optimum course of action to meet this urgent problem.

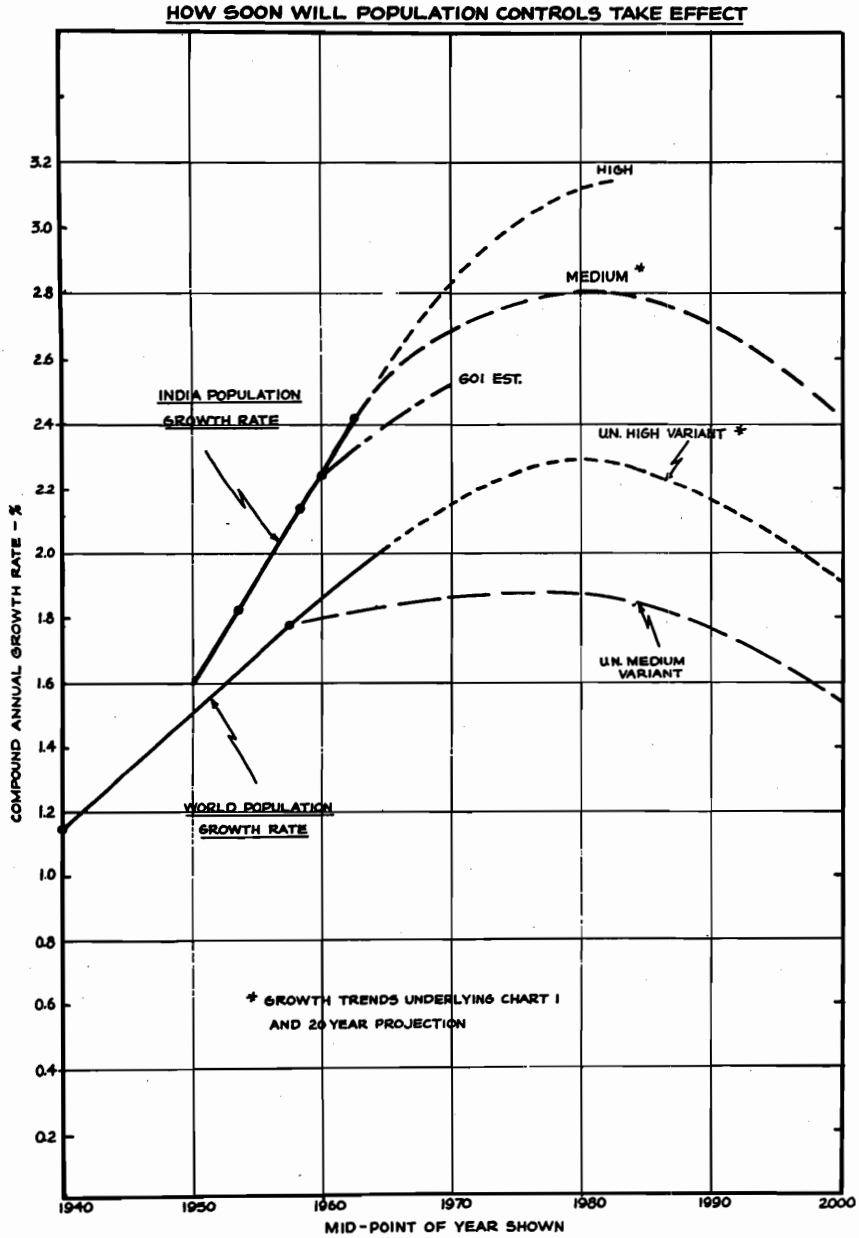

HOW SOON WILL POPULATION CONTROLS TAKE EFFECT
COMPOUND ANNUAL GROWTH RATE - %
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
HIGH
MEDIUM *
GOI EST.
INDIA POPULATION GROWTH RATE
U.N. HIGH VARIANT *
U.N. MEDIUM VARIANT
WORLD POPULATION GROWTH RATE
* GROWTH TRENDS UNDERLYING CHART I AND 20 YEAR PROJECTION
1940
1950
1960
1970
1980
1990
2000
MID-POINT OF YEAR SHOWN

FIGURE 14-2

*14.3.2 How Soon Will Population Controls Take Effect?*

In the PSAC Subpanel reports, there are "high" and "low" estimates for India's vital rates (See Chapter 1). The "high" series, based on data from the Institute of Applied Manpower Research in New Delhi, shows virtually no decline in birth rate; this results in a population growth curve corresponding to the "high" variant shown for India on Figure 14–2, in which the compound growth rate reaches 3.15 percent per year in the 1980–84 period.

The medium" variant shown for India gives greater recognition to the impact of birth controls, and is the basis underlying Figure 14–1 as well as the accompanying 20-year projection. It corresponds to the following assumed progression in vital rates per 1000 of population:

| | Birth rate | Death rate | Spread | Compound growth (percent) |
|---|---|---|---|---|
| 1960 to 1964 | 40.2 | 16.5 | 23.7 | 2.42 |
| 1965 to 1969 | 39.8 | 14.0 | 25.8 | 2.62 |
| 1970 to 1974 | 39.0 | 12.0 | 27.0 | 2.74 |
| 1975 to 1979 | 37.6 | 10.0 | 27.6 | 2.80 |
| 1980 to 1984 | 36.0 | 8.4 | 27.6 | 2.80 |
| 1985 to 1989 | 35.0 | 7.8 | 27.2 | 2.76 |

By 1985, the above progression results in a population of 837 million compared to a figure of 864 million, had the "high" variant been used. The 10 percent decline in birth rate in the "medium" variant is, of course, short of Government of India targets, but is nevertheless judged to be a sound basis for long-range projections of food demand, until a stronger downward trend in birth rate is clearly discernible.

Equally important is the question of when a turning point in population growth rate is likely to be reached. The "plateaus" shown on Figure 14–2 do not occur until the spread between birth rate and death rate begins to stabilize or decline, as the above table illustrates. This does not mean that population per se declines, since birth rates will continue to be much higher than death rates for the foreseeable future. However, with the continuing decrease in mortality rates, the only way to reach a turning point is for birth rates to decrease even faster. As the figure indicates, it is not expected that population controls will have such an impact on growth rates much before 1985, either in India or the world as a whole.

263–888 O—67——45

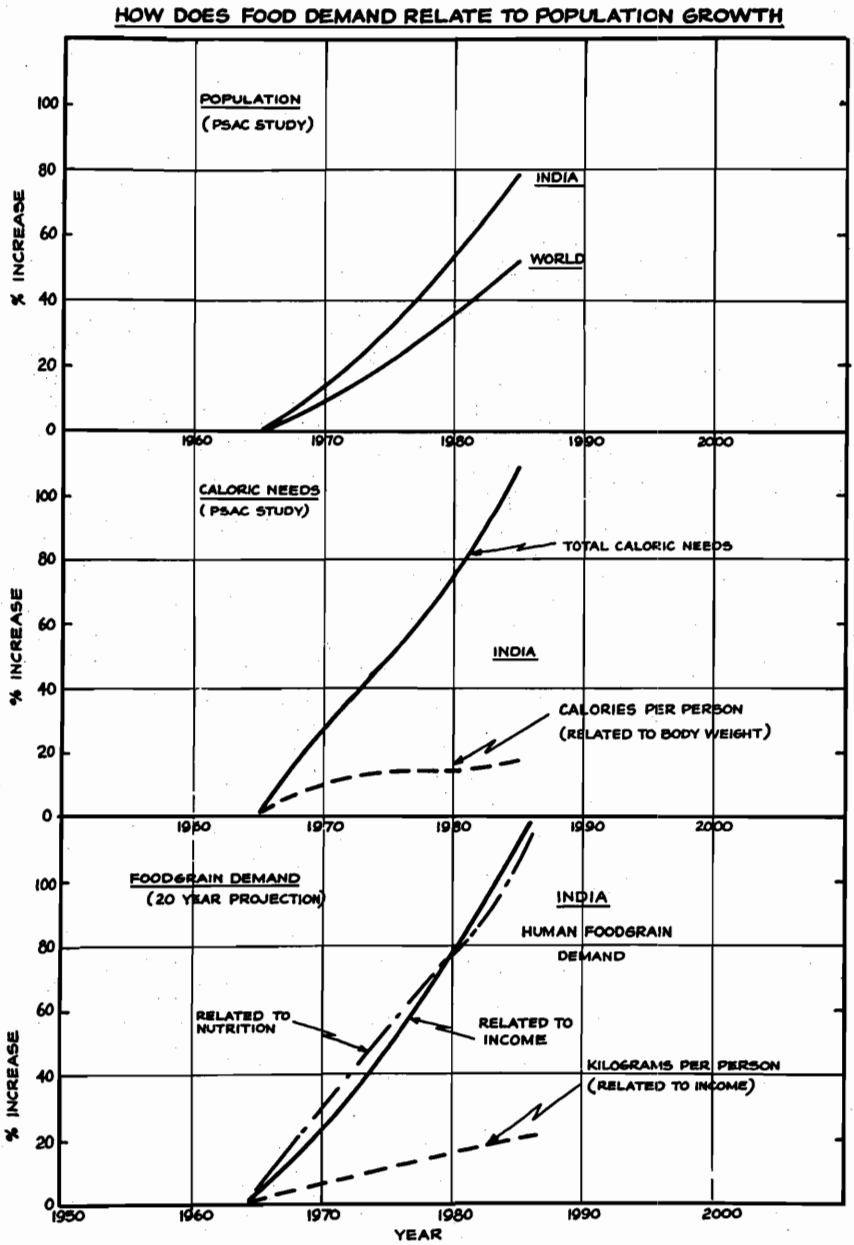

HOW DOES FOOD DEMAND RELATE TO POPULATION GROWTH
POPULATION
(PSAC STUDY)
INDIA
WORLD
% INCREASE
CALORIC NEEDS
(PSAC STUDY)
TOTAL CALORIC NEEDS
INDIA
CALORIES PER PERSON
(RELATED TO BODY WEIGHT)
FOODGRAIN DEMAND
(20 YEAR PROJECTION)
INDIA
HUMAN FOODGRAIN
DEMAND
RELATED TO
NUTRITION
RELATED TO
INCOME
KILOGRAMS PER PERSON
(RELATED TO INCOME)
YEAR

FIGURE 14–3

*14.3.3 How Does Food Demand Relate to Population Growth?*

*Other things being equal,* It is reasonable to expect that food demand will tend to increase in direct proportion to population growth. If such were the case, it would be enough to look at the top third of Figure 14–3 to note that by 1985, world food demand based on the "high" population growth rates in Figure 14–2 would be 52 percent higher, while India's food demand will have increased by 78 percent over 1965. Use of the "medium" growth variant would result in a 72 percent increase in India's food demand by 1985, showing that this change is by itself not overly critical.

In the middle third of Figure 14–3, the PSAC study shows that *other things are not equal.* As India's birth rates and death rates undergo change, population age groups and body weights change also, and with it, per capita nutritional needs. By 1985, the caloric need per person is expected to be 18 percent greater than in 1965, increasing from 1936 to 2280 calories per day; together with a 78 percent population increase, this means a 108 percent increase in food demand for 1985 over the base period 1965.

In the lower third of Figure 14–3, per capita income is introduced as a new variable. This variable can act temporarily as a constraint, if the ability to purchase food does not keep pace with per capita increase in caloric need. In the long run the two must be closely related, since any economic improvement means more food intake, which in turn means faster body growth and higher caloric need. In the accompanying 20-year projection (Table 14–1, Appendix I), human foodgrain demand was first evaluated in relation to per capita income, and this indicated that by 1985, per capita demand would be 20 percent greater than in 1964, as shown by the lower dotted line on the chart. When combined with population increase, total human foodgrain demand in 1985 is 110 percent greater than in the base year 1964. The daily caloric needs shown above were next translated to a foodgrain basis by assuming 72 percent of the Indian caloric diet to consist of foodgrains; applied to the same population base, this resulted in the "nutrition" related line on the lower third of Figure 14–3. As the two curves indicate, per capita income is the controlling factor during 1964 to 1979; thereafter, it is likely to be caloric need. If so, then by 1985 foodgrain needed for human consumption will be 105 percent greater than in 1964, compared to a population increase over this same period of only 76 percent.

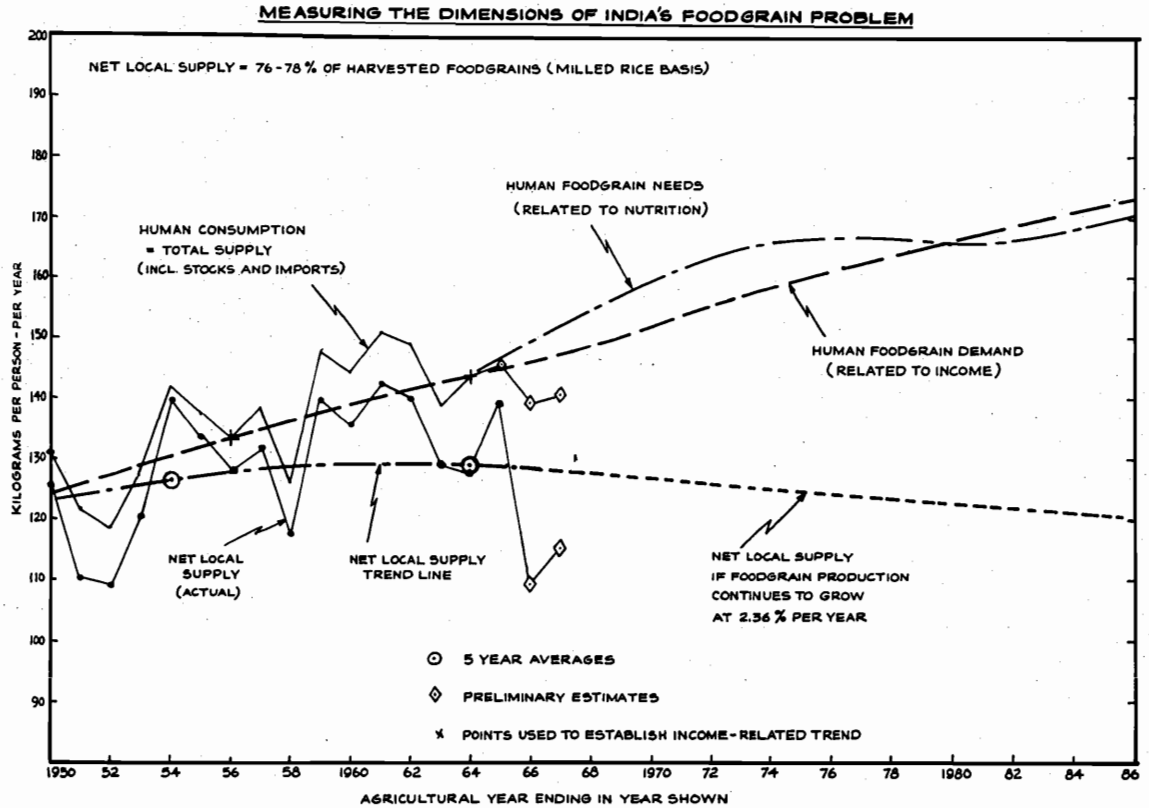

MEASURING THE DIMENSIONS OF INDIA'S FOODGRAIN PROBLEM
NET LOCAL SUPPLY = 76-78 % OF HARVESTED FOODGRAINS (MILLED RICE BASIS)
HUMAN FOODGRAIN NEEDS
(RELATED TO NUTRITION)
HUMAN CONSUMPTION
= TOTAL SUPPLY
(INCL. STOCKS AND IMPORTS)
HUMAN FOODGRAIN DEMAND
(RELATED TO INCOME)
NET LOCAL
SUPPLY
(ACTUAL)
NET LOCAL SUPPLY
TREND LINE
NET LOCAL SUPPLY
IF FOODGRAIN PRODUCTION
CONTINUES TO GROW
AT 2.36 % PER YEAR
5 YEAR AVERAGES
PRELIMINARY ESTIMATES
POINTS USED TO ESTABLISH INCOME-RELATED TREND
KILOGRAMS PER PERSON - PER YEAR
200
190
180
170
160
150
140
130
120
110
100
90
1950
52
54
56
58
1960
62
64
66
68
1970
72
74
76
78
1980
82
84
86
AGRICULTURAL YEAR ENDING IN YEAR SHOWN

Figure 14-4

*14.3.4 Measuring the Dimensions of India's Foodgrain Problem*

The India foodgrain demand figures on Figure 14–3, expressed as percentage increases over a base period, are shown on Figure 14–4 in physical terms, namely, kilograms per person per year. One curve represents human foodgrain demand related to per capita income, while another curve shows this demand in relation to caloric or nutritional needs. It is convenient to know that 1,600 calories per person per day in the form of foodgrains is equivalent to 166 kilograms per person per year, or roughly, 16 ounces per person per day.)

The measure of India's foodgrain problem is simply the difference between either of these two curves and the net local supply of foodgrains available for human consumption, on a per capita basis. Any gap between the two must be made up either by foodgrain imports or by increased local production.

Historical production data for the period 1950 to 1965 and preliminary estimates for 1966 and 1967 are shown on the chart in terms of net local supply per capita by applying appropriate disappearance factors (22 to 24 percent for seed, feed, and loss) to recorded data on harvested production.[1] By adding foodgrain imports and stocks, also on a per capita basis, the total supply and human consumption line on Figure 14–4 is obtained.

Despite the large variations in local supply per capita for individual years, the historical trend line seems to have flattened out in the 1960 to 1964 period. Drought conditions in 1966 and 1967 have caused local supplies to fall well below even this trend line, calling for greatly increased imports to satisfy foodgrain demand. In fact, on the basis of preliminary production estimates of 78 million tons for 1966–67, local supply is equivalent to only 115 kilograms per person, or 32 kilograms below income-related demand. To close this gap would require 16 million tons of foodgrain imports, but actual imports are likely to be about 13 million tons, resulting in a per capita consumption 7.4 percent or 108 calories per day below nutritional needs. Since this is an *average* figure, certain segments of the Indian population will fare a great deal worse.

If India's foodgrain production continues to grow at no more than its 14-year trend line rate of 2.36 percent per year (see Figure 14–5), per capita local supply will decline due to an even faster growth rate in population. This would result in the dotted line projection on Figure 14–4 which, if continued unchecked, would create a gap between foodgrain supply and demand of 50 kilograms per person in 1986. Foodgrain imports needed to close this increasing gap, together with their approximate import value, would be as follows:

| | Millions of tons | Billions of U.S. dollars |
|---|---|---|
| 1971 | 15.3 | 1.07 |
| 1976 | 24.0 | 1.68 |
| 1981 | 32.5 | 2.28 |
| 1986 | 42.8 | 3.00 |

Obviously, this provides a strong economic motive for increasing India's foodgrain production by more than 2.36 percent per year, and the charts which follow deal with the technological inputs and feasibility of substantially increasing food production growth rates above this trend line level.

[1] See Table 14–4, Appendix II for detail on disappearance factors.

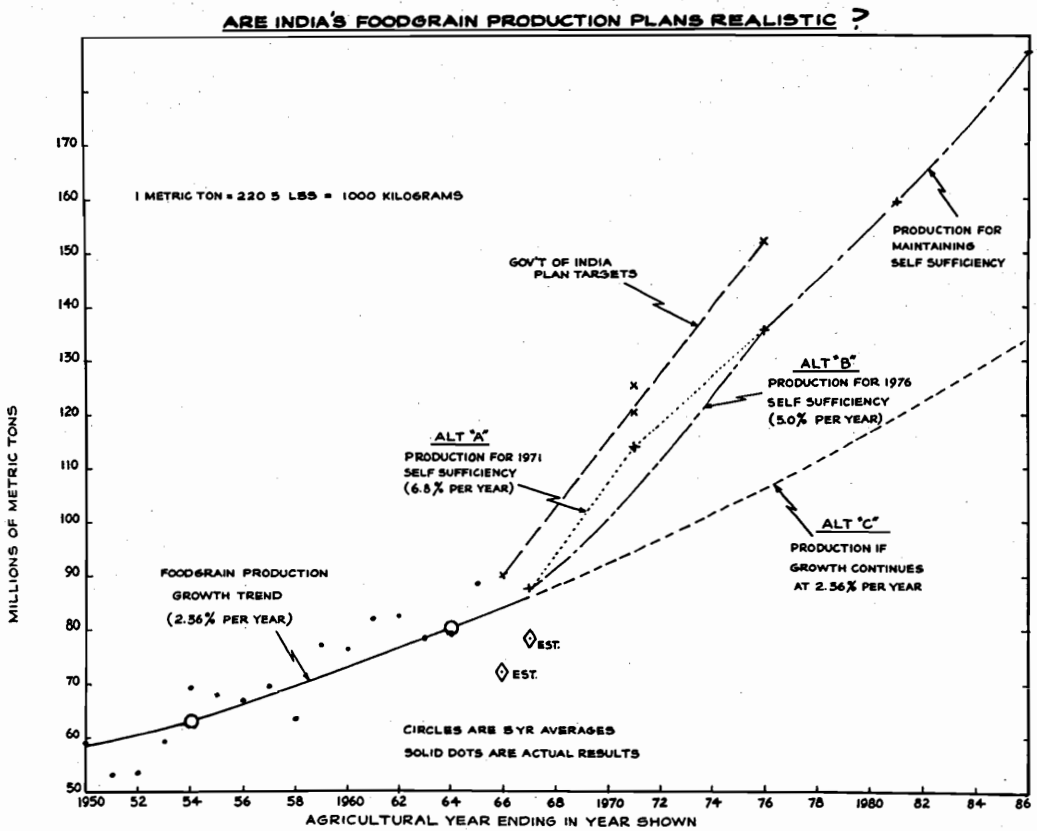

ARE INDIA'S FOODGRAIN PRODUCTION PLANS REALISTIC ?
1 METRIC TON = 220.5 LBS = 1000 KILOGRAMS
GOV'T OF INDIA PLAN TARGETS
PRODUCTION FOR MAINTAINING SELF SUFFICIENCY
ALT "B"
PRODUCTION FOR 1976 SELF SUFFICIENCY (5.0% PER YEAR)
ALT "A"
PRODUCTION FOR 1971 SELF SUFFICIENCY (6.8% PER YEAR)
ALT "C"
PRODUCTION IF GROWTH CONTINUES AT 2.56% PER YEAR
FOODGRAIN PRODUCTION GROWTH TREND (2.56% PER YEAR)
EST.
EST.
CIRCLES ARE 5 YR AVERAGES
SOLID DOTS ARE ACTUAL RESULTS
MILLIONS OF METRIC TONS
AGRICULTURAL YEAR ENDING IN YEAR SHOWN

Figure 14-5

*14.3.5 Are India's Foodgrain Production Plans Realistic?*

If foodgrain self-sufficiency is defined as satisfaction of human demand (related to either income or nutrition), together with elimination of foodgrain imports, the demand curves on Figure 14–4 and India's population numbers on Figure 14–1 can be used to determine exactly the foodgrain production needed for self-sufficiency in any desired year. Figure 14–5 indicates that self-sufficiency so defined would require a foodgrain production of 113 million tons in 1971; self-sufficiency in 1976 would require a production of 136 million tons; and in 1981 and 1986, respectively 160 and 187 million tons.

With a hypothetical production in 1967 of 87.4 million tons as a base, the chart indicates that self-sufficiency by 1971 (Alternative "A") would require a foodgrain production increase of 6.8 percent per year. Deferring self-sufficiency until 1976 (Alternative "B") would require production to grow by 5 percent per year over a 9-year period. The Government of India target for 1971 is stated to be 120 or 125 million tons, but even the lower figure would require a production increase from the same 1967 base of 8.2 per year during the period 1967–71. (Government figures, from a hypothetical base of 90 million tons in 1966, are equivalent to a growth requirement of 5.9 percent per year.)

On a cursory examination, achievement of a growth rate of 5 percent per year in foodgrain production over the next 9 years should be technologically feasible, but in practice, even this will require extremely well-coordinated resource planning and timely investment and policy decisions, to assure both the availability and effective utilization of the necessary agro-industry inputs. Growth rates higher than 5 percent per year cannot be regarded as realistic, even though they may be technologically feasible.

The charts which follow deal basically with the physical and technological inputs required to achieve a 5 percent per year growth until 1976, followed by maintenance of virtual self-sufficiency for another 10 years. They do not represent a forecast so much as a series of guidelines for measuring progress toward that goal. For this purpose, Figure 14–5 also includes an Alternative "C," representing simply a projection of foodgrain production at the trend line growth rate of 2.36 percent per year. This is equivalent to achieving a production in 1986 of 134 million tons, 53 million tons short of that needed for self-sufficiency, but 55 million tons or 70 percent higher than actually produced in 1964, the last so-called "normal" harvest year.

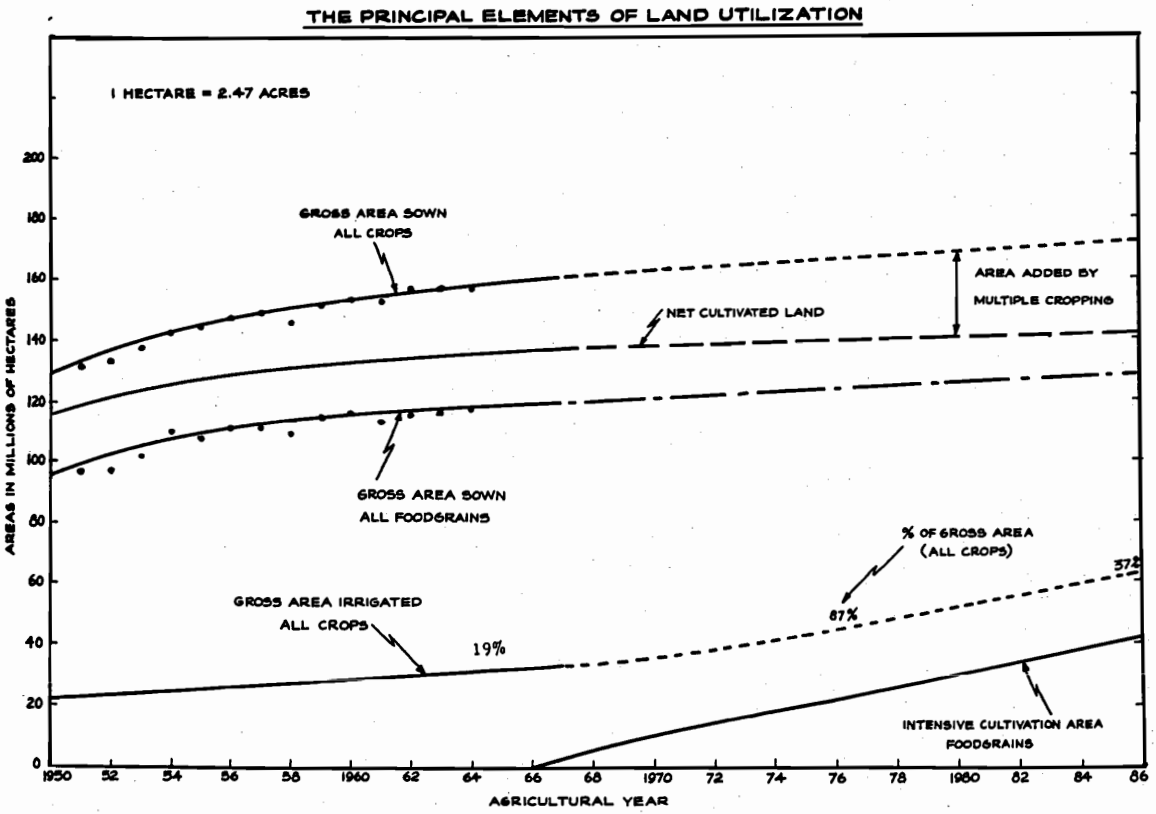

THE PRINCIPAL ELEMENTS OF LAND UTILIZATION
1 HECTARE = 2.47 ACRES
AREAS IN MILLIONS OF HECTARES
0
20
40
60
80
100
120
140
160
180
200
GROSS AREA SOWN
ALL CROPS
NET CULTIVATED LAND
AREA ADDED BY
MULTIPLE CROPPING
GROSS AREA SOWN
ALL FOODGRAINS
% OF GROSS AREA
(ALL CROPS)
37%
87%
GROSS AREA IRRIGATED
ALL CROPS
19%
INTENSIVE CULTIVATION AREA
FOODGRAINS
1950
52
54
56
58
1960
62
64
66
68
1970
72
74
76
78
1980
82
84
86
AGRICULTURAL YEAR

FIGURE 14–6

*14.3.6 The Principal Elements of Land Utilization*

India's arable land, amounting to 163 million hectares or 393 million acres, is roughly 50 percent of its total land surface. On the basis of 1965 population estimates, India's position in terms of arable land per person and precentage utilization for foodgrain is as follows:

| | Acres per person | Foodgrain cultivation (percent) |
|---|---|---|
| United States | 2.35 | 34.1 |
| Africa | 2.00 | 22.1 |
| Latin America | 1.04 | 41.4 |
| India | .83 | 71.3 |
| Asia (excluding China and Japan) | .79 | 61.6 |
| Japan | .15 | 72.8 |

India, like most countries in Asia, is not endowed with as much arable land per capita as are the developing countries of Africa and Latin America. Moreover, most of it is already under cultivation. The lowest land per capita value is in Japan. It is indicative of the effort needed in that country to feed the population and it goes far to explain the strong steps which Japan has taken to control population and to increase agricultural yields.

India's net area of cultivated land in 1964 of 136.3 million hectares was increased by multiple cropping to a gross area sown of 157.5 million hectares; of that, 116.3 million or 74 percent was used in foodgrain cultivation. In Figure 14–6, this land utilization is projected as follows:

| Additions to— | Million hectares per year | |
|---|---|---|
| | 1956–63 | 1963–86 |
| Net cultivated area | 1.00 | 0.28 |
| Multiple cropping | 0.34 | 0.38 |
| Gross area sown | 1.34 | 0.66 |
| Foodgrain areas sown | 0.79 | 0.55 |
| Percent of gross | 59 | 84 |

Irrigation and intensive cultivation (including, multiple cropping) must provide for future growth in foodgrain production. Figure 14–6 is based on extending the "package program" strategy of intensive cultivation by roughly 2 million hectares per year, to a level of 42 million hectares by 1986. Anything less would make it difficult, if not impossible, to achieve and maintain foodgrain self-sufficiency.

Since intensive cultivation requires assurance of efficient irrigation, the Figure 14–6 projection is based on the following irrigation assumptions:

| Additions to— | Million hectares per year | |
|---|---|---|
| | 1956–63 | 1963–86 |
| Gross irrigated area | 0.56 | 1.44 |
| Net irrigated area | .41 | 1.00 |

This would provide 22.6 million hectares of land under new irrigation by 1986, increased via multiple cropping to a gross figure of 32.8 million hectares. The additional 9.2 million hectares of assured irrigation needed for intensive cultivation are assumed to come from substantial improvements to about one third of currently irrigated areas.

The above projections represent neither a forecast nor a Government of India program. They simply provide a firm base from which to evaluate other technological inputs. Even though it calls for more than doubling the annual increment of newly irrigated area, it is considered a minimum goal for strategic land utilization, if foodgrain self-sufficiency is to be achieved.

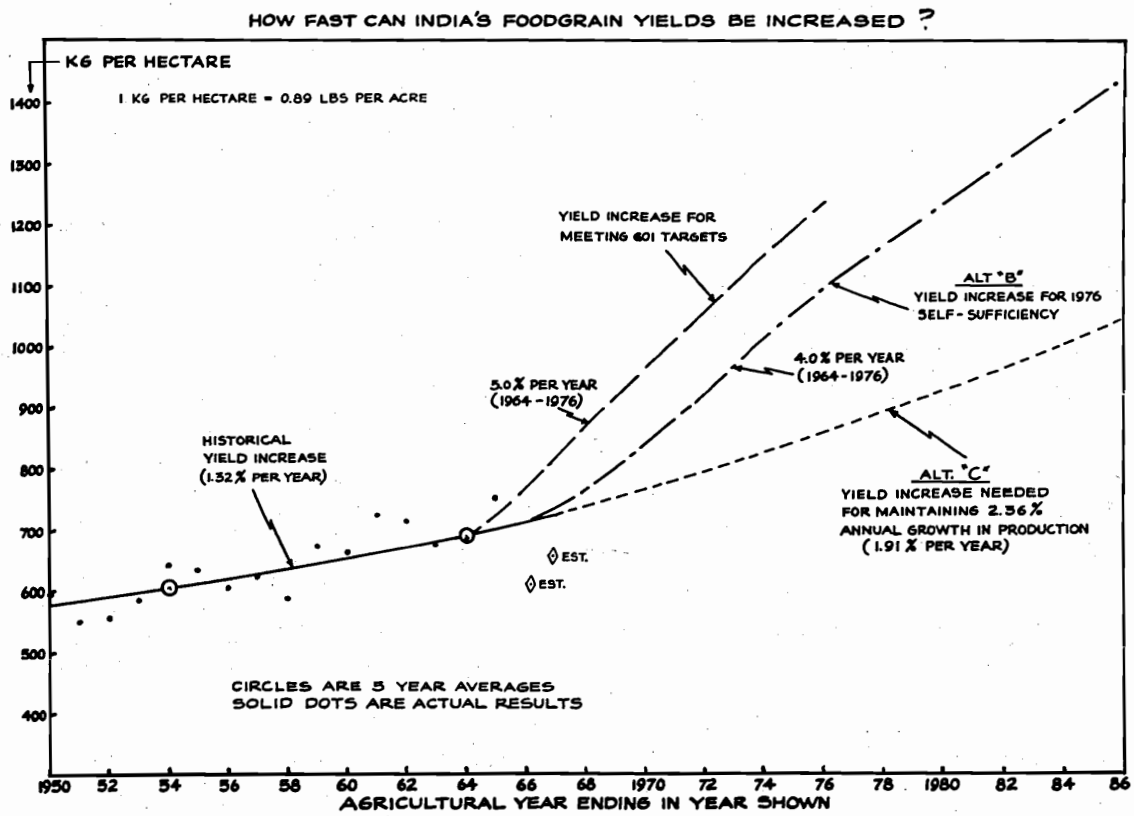

HOW FAST CAN INDIA'S FOODGRAIN YIELDS BE INCREASED ?
KG PER HECTARE
1 KG PER HECTARE = 0.89 LBS PER ACRE
1400
1300
1200
1100
1000
900
800
700
600
500
400
YIELD INCREASE FOR MEETING 601 TARGETS
ALT "B" YIELD INCREASE FOR 1976 SELF-SUFFICIENCY
4.0% PER YEAR (1964-1976)
5.0% PER YEAR (1964-1976)
HISTORICAL YIELD INCREASE (1.32% PER YEAR)
ALT. "C" YIELD INCREASE NEEDED FOR MAINTAINING 2.36% ANNUAL GROWTH IN PRODUCTION (1.91% PER YEAR)
EST.
EST.
CIRCLES ARE 5 YEAR AVERAGES
SOLID DOTS ARE ACTUAL RESULTS
1950 52 54 56 58 60 62 64 66 68 1970 72 74 76 78 1980 82 84 86
AGRICULTURAL YEAR ENDING IN YEAR SHOWN

FIGURE 14–7

### *14.3.7 How Fast Can India's Foodgrain Yields be Increased*

On the basis of 5-year averages, centered on 1954 and 1964, the data on Figure 14–7 show that India's food grain yields increased from 603 to 688 kilograms per hectare.[1] With land allocated to foodgrains over this period increasing by 1.04 percent annually, it was sufficient for yields per hectare to increase by 1.32 percent per year to achieve a 2.36 percent growth rate in total foodgrain production (as previously shown on Figure 14–5). If this growth rate were to be sustained during the period 1964 to 1986, foodgrain yields would have to increase to 1,042 kilograms per hectare by 1986; with land area increasing only 0.44 percent annually, this would require an increase in yield per hectare of 1.91 percent per year.

If foodgrain self-sufficiency is to be achieved by 1976, yields would have to increase to 1,097 kilograms per hectare, requiring a compound annual increase of 4 percent per year over the period 1964 to 1976; *this represents a tripling of the historical rate.*

After 1976, yield per acre increases for maintenance of foodgrain self-sufficiency would be about 2.8 percent per year, corresponding to anticipated population growth rates. This lower rate of increase would be possible because necessity for foodgrain imports will have been eliminated by 1976, if the 4.0 percent annual increase during the earlier period is realized fully.

Government of India plans call for 152 million tons of production by 1976. If the gross foodgrain area of 123.5 million hectares projected for that year is correct, this would call for a yield increase to 1,235 kilograms per hectare in 1976, requiring a 5 percent per year increase over the period 1964 to 1976. In the light of experience in India and elsewhere, it is questionable whether foodgrain yields can be increased that rapidly; in fact, many will even question the practical feasibility of achieving a 4 percent annual yield increase over the next nine years.

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[1] All yields are shown on a "milled rice" basis as generally reported in Indian statistics; for world-wide comparisons, a multiplying factor of 1.22 can be used to obtain all-India yields on a "paddy" or "rough rice" basis.

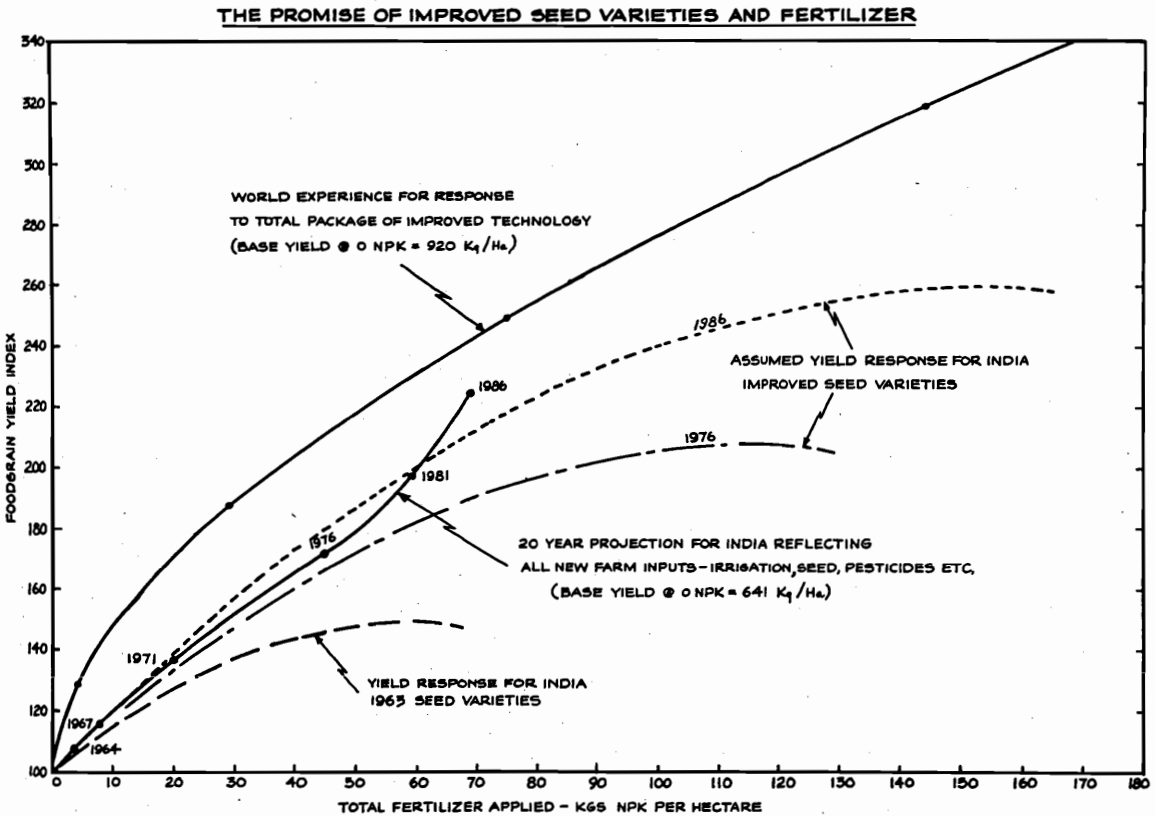
THE PROMISE OF IMPROVED SEED VARIETIES AND FERTILIZER
FOODGRAIN YIELD INDEX
TOTAL FERTILIZER APPLIED - KGS NPK PER HECTARE
WORLD EXPERIENCE FOR RESPONSE
TO TOTAL PACKAGE OF IMPROVED TECHNOLOGY
(BASE YIELD @ 0 NPK = 920 Kg/Ha)
ASSUMED YIELD RESPONSE FOR INDIA
IMPROVED SEED VARIETIES
20 YEAR PROJECTION FOR INDIA REFLECTING
ALL NEW FARM INPUTS - IRRIGATION, SEED, PESTICIDES ETC.
(BASE YIELD @ 0 NPK = 641 Kg/Ha)
YIELD RESPONSE FOR INDIA
1965 SEED VARIETIES
1964
1967
1971
1976
1981
1986
1976
1986

Figure 14-8

*14.3.8 The Promise of Improved Seed Varieties and Fertilizer*

The FAO (Food and Agriculture Organization, United Nations) has devised a yield value index plotted against fertilizer use in kilograms per hectare, to serve as an indicator of what the total package of improved technology can do towards increasing foodgrain yields. This is based on world-wide experience, and is shown on Figure 14–8 as the uppermost of several guidelines.[1]

Individual regional experiences can differ greatly from the world-wide curve. For example, the lowest line on Figure 14–8 represents the composite fertilizer-yield response for All-India foodgrain seed varieties used in 1963. As indicated, a peak yield index of 150 is reached at about 58 kilograms per hectare, after which there is actually a yield decline. Thus, in the absence of more exotic seed varieties with a better response to fertilization, a 50 percent yield increase is the overall maximum which can be expected.

The next higher curve represents the fertilizer-yield response for Sonora Wheat 63, based on recent experimental results in India. Sonora 63 can utilize higher fertilizer dosages and the response curve reaches a peak yield-index of 208 at 116 kilograms of fertilizer per hectare. In the accompanying 20-year projection, it was assumed that a 100 percent increase in yield per hectare could be achieved in 1976 by all crops used in intensive cultivation areas; the assumption was premised on the use of new seed varieties, assured irrigation, and a 90 kilogram per hectare fertilizer application. The response curves used in the projection after 1976 are speculative, but are assumed to be technologically feasible.

A combination of all new inputs, together with their appropriate or speculative yield responses, are shown in Table 14–3 Appendix I of the 20-year projection. These data are plotted on Figure 14–8 and labeled accordingly. Each point indicated by a year shows the yield index and average fertilizer application assumed to be achievable in that year. For example, in 1976 the yield index of 171 is consistent with the 1097 kilograms per hectare yield in 1976 shown on Figure 14–7 for Alternative "B." By 1986, the inputs assumed to be available are no longer sufficient to maintain foodgrain self-sufficiency and 2.1 million tons will have to be imported as shown in Table 14–1, Appendix I.

The importance of Figure 14–8 is that it places the achievement of specific and desirable time-yield objectives in a framework which also indicates the technological disparities which need to be overcome. It emphasizes that:

(*a*) fertilizer alone is by no means enough to achieve foodgrain self-sufficiency;

(*b*) adequacy of irrigation is an absolutely essential component; and

(*c*) the promise of new seed varieties in conjunction with the other two inputs is the best hope for a yield "break-through." In fact, development of new varieties with higher fertilizer responses than exist today is essential and deserves the highest priority if foodgrain self-sufficiency is to be maintained beyond 1976.

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[1] For convenience in making comparisons, the yield index at zero NPK fertilizer was made equal to 100, by dividing the original FAO curve by 0.8504.

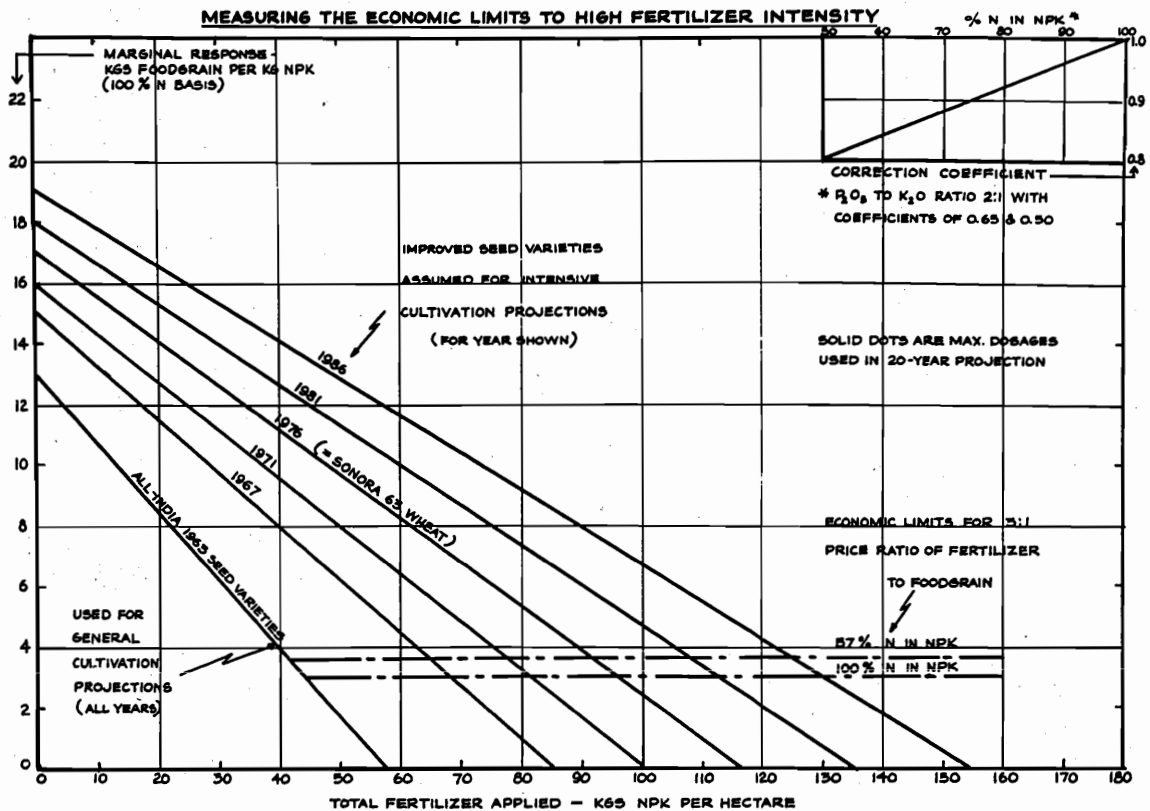
MEASURING THE ECONOMIC LIMITS TO HIGH FERTILIZER INTENSITY
MARGINAL RESPONSE - KGS FOODGRAIN PER KG NPK (100 % N BASIS)
% N IN NPK *
CORRECTION COEFFICIENT
* $P_2O_5$ TO $K_2O$ RATIO 2:1 WITH COEFFICIENTS OF 0.65 & 0.50
IMPROVED SEED VARIETIES ASSUMED FOR INTENSIVE CULTIVATION PROJECTIONS (FOR YEAR SHOWN)
SOLID DOTS ARE MAX. DOSAGES USED IN 20-YEAR PROJECTION
1986
1981
1976 (= SONORA 63 WHEAT)
1971
1967
ALL-INDIA 1963 SEED VARIETIES
ECONOMIC LIMITS FOR 5:1 PRICE RATIO OF FERTILIZER TO FOODGRAIN
57 % N IN NPK
100 % N IN NPK
USED FOR GENERAL CULTIVATION PROJECTIONS (ALL YEARS)
TOTAL FERTILIZER APPLIED — KGS NPK PER HECTARE

Figure 14-9

*14.3.9 Measuring the Economic Limits to High Fertilizer Intensity*

Even if the physical and technological inputs are available to meet a desired foodgrain production objective, the farmer must be given sufficient economic motivation to purchase the more costly inputs involved. Of these, fertilizer is the most important component of his budget at the increased intensity levels called for. Potentially it is also the most rewarding if used in conjunction with improved seed varieties and pesticides, provided the correct price relationships between fertilizer and foodgrains are established.

Figure 14–9 and Figure 14–10 which follows, should greatly simplify the problem of determining how much the farmer is likely to increase the intensity of fertilizer application. In Figure 14–9, the conventional fertilizer response curve showing total grain yield for a given seed variety has been mathematically converted to a marginal response line. Thus, for the new Sonora 63 wheat variety (corresponding to the line for 1976), the marginal response line shows that the first kilogram of NPK/hectare nutrient applied produces 17 kgs. of grain, while at 116 Kg of NPK/hectare, the last or marginal kilogram produces no additional grain. If the price of fertilizer nutrient happens to be 3 times the price of wheat, the chart shows that it does not pay the farmer to use more than 96 Kg/hectare of NPK, since the marginal kilogram applied (for 100 percent nitrogen content) produces only 3 kilograms of grain—just enough to cover the cost of the fertilizer. If appropriate correction factors for a lower than 100 percent nitrogen content are applied, the economic limit moves upward[1] and 92 Kg/hectare becomes the farmer's limiting intensity for fertilizer containing 57 percent nitrogen as shown. Any other prevailing price ratio can be similarly plotted for determining economic limits.

The marginal yield concept used in Figure 14–9, also simplifies the problem of developing a response curve reflecting the average for a large variety of crops. For All-India seed varieties used in general cultivation during 1962 to 1964, the following result is obtained:

| | Weight (percent) | Yield for first kilogram NPK [1] | Kilogram per hectare NPK at marginal yield =0 |
|---|---|---|---|
| Rice | 43.4 | 14.5 | 55 |
| Wheat | 14.8 | 10.0 | 50 |
| Jowar | 9.5 | 10.5 | 73 |
| Bajra | 4.4 | 10.5 | 67 |
| Maize | 5.3 | 14.5 | 63 |
| Ragi | 2.3 | 9.0 | 60 |
| Barley | 3.9 | 18.5 | 67 |
| Millets | 2.4 | 13.0 | [3] 58 |
| Pulses | 14.0 | 13.0 | [3] 58 |
| Total | 100.0 | [2] 13.0 | [3] 58 |

[1] Yield for 1st kilogram=(2) (Peak yield response)+(kilogram per hectare NPK at peak), with "peak" defined as the intensity beyond which total yield declines; basic response data derived from information supplied by the Indian Statistical Institute and by W. David Hopper of the Rockefeller Foundation.

[2] Average.

[3] Assumed average.

As the line on Figure 14–9 for general cultivation indicates, the All-India averages above can be plotted to show that 42 Kg/hectare is the farmer's economic limit for existing seed varieties cultivated, when fertilizer contains 57 percent nitrogen and the price ratio is 3 : 1.

Marginal response lines on Figure 14–9 for intensive cultivation represent averages for crops cultivated, and were used as a basis in the accompanying 20-year projection for the years indicated. These lines reflect a continuing and assumed improvement in seed varieties and an associated increase in fertilizer response.

[1] Determined by dividing the price ratio by the correction coefficient: 3.0/0.83=3.6 for 57 percent N.

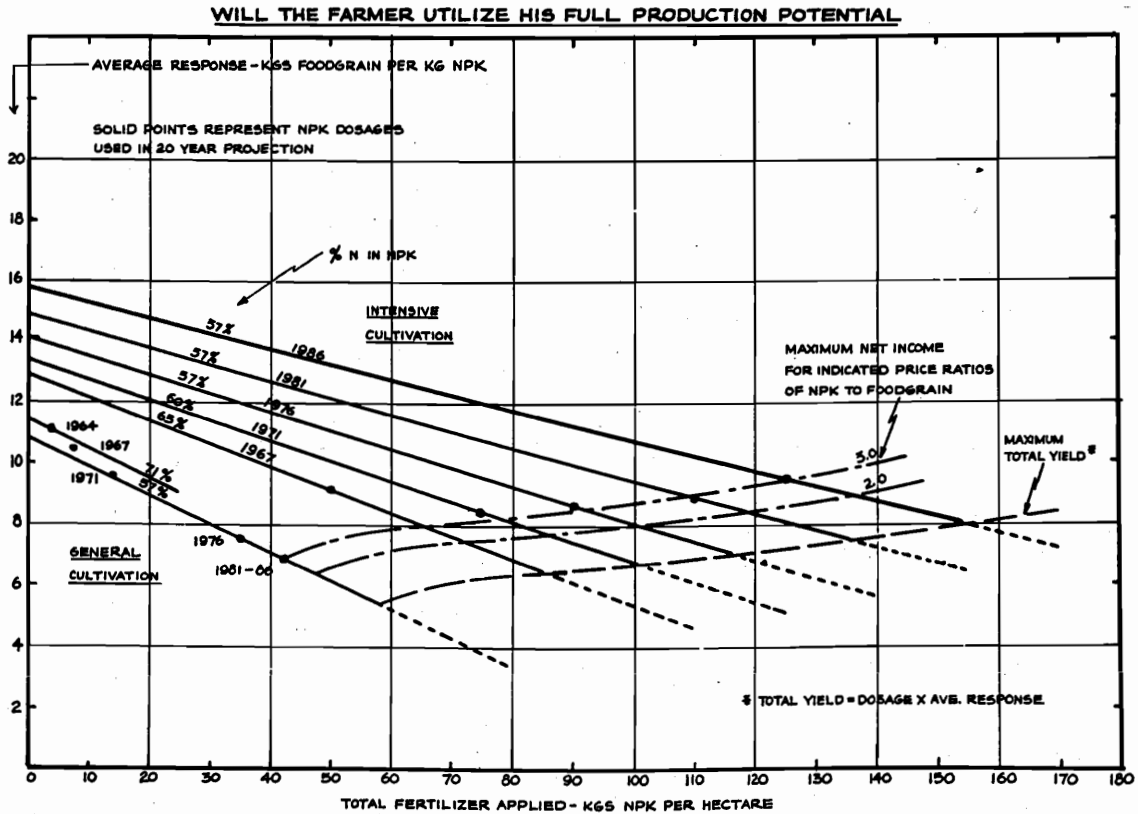
WILL THE FARMER UTILIZE HIS FULL PRODUCTION POTENTIAL
AVERAGE RESPONSE - KGS FOODGRAIN PER KG NPK
SOLID POINTS REPRESENT NPK DOSAGES USED IN 20 YEAR PROJECTION
% N IN NPK
INTENSIVE CULTIVATION
GENERAL CULTIVATION
57%
57%
57%
60%
65%
71%
57%
1986
1981
1976
1971
1967
1964
1967
1971
1976
1981-86
MAXIMUM NET INCOME FOR INDICATED PRICE RATIOS OF NPK TO FOODGRAIN
5.0
2.0
MAXIMUM TOTAL YIELD*
* TOTAL YIELD = DOSAGE X AVE. RESPONSE
TOTAL FERTILIZER APPLIED - KGS NPK PER HECTARE
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
2
4
6
8
10
12
14
16
18
20

Figure 14-10

*14.3.10 Will the Farmer Utilize His Full Production Potential?*

In Figure 14–9 the economic limits which should deter the farmer from over-application of fertilizer for a given seed or crop variety are established. Figure 14–10 attempts to broaden the question of economic motivation to determine how far the farmer can be induced to move toward either maximum production or maximum net income. It assumes that other environmental conditions are such that the farmer is fully responsive to changes in profitability.

In Figure 14–10 the marginal response lines in Figure 14–9 have been further converted to an average response line, and for convenience these have also been corrected to reflect the anticipated average nitrogen content of NPK for individual projection years. Lines for maximum total yield and maximum net income can be plotted by appropriate use of basic data from Figure 14–9.

It is obvious that maximum production potentials can be more closely approached by lowering the fertilizer to foodgrain price ratio, but the cost of doing so may be prohibitive if the level of fertilizer intensity is already high. For example, a decrease in the price ratio to a level of 2 : 1 in 1976 (=Sonora 63 wheat) would permit the intensive cultivator to increase his fertilizer dosage from 92 to 100 Kg/hectare thereby decreasing average foodgrain yields from 8.5 to 8.0 Kgs/Kg NPK, but raising his total fertilizer response from 782 to 800 kilograms per hectare. This represents an increase in yield of only 2.3 percent and hence the change in price ratio would seem entirely unwarranted. Moreover, at the 3 : 1 price ratio, the farmer's net return on his fertilizer cash outlay is 183 percent, determined as follows: $(100)(8.5-3.0) \div 3.0$, which assumes that the farmer is already sufficiently motivated to use the full 92 Kg/hectare of NPK, and has allowed for associated increases in costs such as for pesticides and specialized farm machinery.

For the general cultivator not endowed with such exotic seeds, nor indirectly subsidized by the availability of assured irrigation, a 3 : 1 price ratio should permit economic use of 42Kg of NPK/hectare as shown on the figure for achieving maximum net income. However, the average foodgrain yield obtained is only 6.9 Kg/Kg NPK resulting in a net return of only 130 percent. To realize the same 183 percent return shown above, the general cultivator might be motivated to use no more than 24 Kg of NPK/hectare. Average foodgrain yields would then increase from 6.9 Kgs/Kg NPK to 8.5 Kgs, but total fertilizer response would fall from 290 to 204 kilograms per hectare, a 30 percent decrease. Alternatively, by lowering the price ratio to the general cultivator to a level of 2.5 : 1 (by raising foodgrain prices, by subsidizing fertilizer prices, or by some combination of both), the figure indicates that the general cultivator might be induced to use 40 Kg/hectare to achieve the desired 183 percent return, and at the same time to increase overall net income from fertilizer usage by 36 percent which would help pay associated cost increases.

The returns cited above are those for an owner-operator. For a tenant farmer who does not share fertilizer costs with his landlord, the actual returns could be only a small fraction of the total. Sharing the fertilizer cost might preserve the level of return but cuts the tenant farmer's net income in half. These conditions would militate against the full potential use of fertilizer and show the need for a flexible pricing policy geared to specific local conditions.

The examples above illustrate how the format of Figures 14–9 and 14–10 can be used as guidelines for agricultural policy, planning, and pricing decisions. They provide a direct, simple, and consistent methodology to the complicated question of fertilizer response and associated economics of foodgrain cultivation, without ignoring any of the principal variable involved. It is, moreover, a conceptual approach[1] which can be used by the extension worker and fertilizer salesman to motivate the farmer to increase yields which in turn would meet the objective of utilizing India's production potential to its fullest economic extent.

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[1] Derived from data supplied by Alan S. Manne (Stanford University and U.S. Aid Mission, New Delhi).

263–888 O—67——46

TABLE 14-1.—*The capital cost of achieving foodgrain self-sufficiency* [1]

| | Physical increase 1964-86 | Capital cost: US$—millions: 22 years cumulative | Capital cost: US$—millions: Annual average | Capital cost: US$ per annual ton added | Contribution to foodgrain production, million tons per year |
|---|---|---|---|---|---|
| SPECIFIC FARM INPUTS—FOODGRAINS | | | | | |
| Increase in gross area sown | 14.7 million hectares | | | | 7.8 |
| Increase in net irrigated area | 22.6 million hectares | 9,800 | 445 | | 27.4 |
| Irrigation improvements | 9.2 million hectares | 1,400 | 64 | | |
| Increase in fertilizer use to 42 kg. per hectare: | | 11,200 | 509 | 106.7 | 35.2 |
| Nitrogen capacity | 3.37 million tons | 1,520 | 69 | | |
| $P_2O_5$ capacity | 1.75 million tons | 470 | 21 | | |
| | | 1,990 | 90 | 19.0 | 32.9 |
| Use of improved seed and 125 kg. NPK per hectare: | | | | | |
| Additional nitrogen capacity | 2.18 million tons | 980 | 45 | | |
| Additional $P_2O_5$ capacity | 1.13 million tons | 310 | 14 | | |
| Seed processing plants | 0.9 million tons | 70 | 3 | | |
| | | 1,360 | 62 | 12.9 | 36.9 |
| Subtotal for specific inputs above | 105 million tons per year additional foodgrain. | 14,550 | 661 | 138.6 | 105.0 |

| ASSOCIATED CAPITAL INVESTMENTS | | | | | |
|---|---|---|---|---|---|
| Increase in pesticide use | 130 thousand tons | 300 | 14 | 2.9 | [2] 15.6 |
| Farm machinery and equipment: | | | | | |
| Direct farm investment | 0.08 hp per hectare | 6,200 | 282 | 59.0 | |
| Manufacturing plants | | 230 | 13 | 2.7 | |
| Fertilizer mixing, storage and retail outlets | 8.44 million tons | 850 | 39 | 8.1 | |
| Working capital: | | | | | |
| Fertilizer inventory | | 500 | 22 | 4.8 | |
| Farmer credit | | 1,000 | 45 | 9.5 | |
| Road network for intensive cultivation areas | 30,000 miles (new)<br>80,000 miles (improved) | 800 | 36 | 7.6 | |
| Road transportation: Foodgrain and fertilizer | 1.5 million trucks | 4,500 | 205 | 42.8 | |
| Total capital cost: Foodgrain cultivation | 105 million tons | 28,980 | 1,317 | 276.0 | |
| Associated cost for nonfood grains: | | | | | |
| Additional nitrogen and $P_2O_5$ capacity | 1.36 + 0.71 million tons | 800 | 36 | | |
| Fertilizer marketing (including credit) | | 550 | 25 | | |
| Total capital cost | | 30,330 | 1,378 | | |

[1] Table description on page 702.
[2] Reduction in preharvest loss=15 percent of net added production.

*14.3.11 The Capital Cost of Achieving Foodgrain Self-Sufficiency*

Table 14–1 portrays the various agro-industry inputs needed for foodgrain self-sufficiency in terms of their capital costs, including working capital, where this is a large factor. These are definitely "order-of-magnitude" figures and any individual item could be off by 50 percent, or even more. In total, however, such inaccuracies tend to offset each other and the table can be used to compare overall capital costs with the potential benefits which can be gained.

Over a 22-year period from 1964 to 1986, a 105 million ton per year gain in foodgrain production and virtual self-sufficiency can be achieved at an estimated overall capital cost of $29 billion; with non-foodgrain production, the total comes to $30.3 billion. For foodgrains, this averages $1.32 billion per year, equivalent to a capital cost of $276 per annual ton of production. These figures relate only to agro-industry and farm imputs, including directly associated fertilizer and foodgrain transportation. They do not include capital costs for post-harvest food storage, food processing and marketing; nor do they include infrastructure items such as rural electrification, power plants, railroad and harbor facilities, some of which will undoubtedly contribute to achieving the projected results.

A rough guess would be that, at most, 25 percent of the capital items would originate from foreign sources, so that the foreign exchange component over 22 years is $7.25 billion. This would require $330 million per year of new foreign investment in the form of equity and loans for capital equipment.

It was shown earlier that, if India's foodgrain production were to increase at no more than the historical rate of 2.36 percent per year, the increase in production by 1986 over the base period 1964 would be only 55 million tons or slightly more than 50 percent of the 105 million ton increase projected for 1986. Under these conditions, 43 million tons of foodgrain imports would be required at a foreign exchange cost of about $3 billion for that one year. Thus, from an additional investment of $3.5 billion of foreign exchange for capital items (assuming $3.75 billion was needed to produce the 55 million ton increase), an annual import saving of $3 billion can be achieved.

With the above data as a starting point, it would seem desirable to refine the various assumptions to a point where a credible economic study can be made to determine what terms can be offered to attract the large amount of foreign capital required. Full recognition would have to be given in such a study that some foreign exchange will continue to be needed for imports of potassium ($K_2O$) rock phosphate, sulfur, and possibly ammonia to meet shortfalls in local fertilizer supply.

While it is obvious from previous charts that major farm inputs are complementary to each other, some attempt has been made in Chart 11 to attribute certain foodgrain increments to specific inputs. This would seem to indicate that benefits gained per dollar of capital cost could be ranked in this order:

1. Pesticides
2. Improved seed + fertilizer
3. Fertilizer alone
4. Irrigation
5. Farm roads & trucks
6. Farm equipment

However, pesticides are not as essential without (2) and (3), and these in turn are meaningless without (4); similarly item (5) will reduce post-harvest losses and could spell the difference, but only if sufficient foodgrain has been produced in the first place. Actually, all physical inputs are needed in the proper and timely combination, if foodgrain self-sufficiency is to be achieved.

Finally, even if the investment climate is sufficiently improved to attract the needed foreign private capital, no self-sufficiency program will succeed without the following human prerequisites:

(a) Trained agricultural scientists to develop and test ever-improving seed varieties, by local application research on an extensive scale.

(b) Extension workers, fertilizer salesmen, village distributors and credit suppliers, properly instructed to teach and motivate the farmer in utilizing the new agricultural inputs most effectively.

(c) Government leaders, economic planners and businessmen with the foresight and authority, mobilized on an emergency footing, to make the appropriate and timely planning and investment decisions in agriculture, as well as population controls.

## *14.4.0 Appendices*

# APPENDIX I

## Twenty-Year Projection of India's Foodgrain and Fertilizer Demand and Supply

## (March 31, 1967)

**Adapted and updated from Series No. 66–10 (Dec. 16, 1966), prepared for the India Committee of the Business Council for International Understanding**

Table AI–1.—*20-year projection of India foodgrain demand and supply (projection series 67–2)*

| Line Number | | Agricultural year ending in year— | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Historical | | Projection | | | | | |
| | | 1956 | 1964 | 1967 | | 1971 | | 1976 | 1981 | 1986 |
| | FOODGRAIN DEMAND (RELATED TO INCOME) | | | | | | | | | |
| 1 | Population, Mar. 1 millions | 395.1 | 471.8 | 509.0 | | 565.4 | | 647.5 | 743.4 | 853.5 |
| 2 | Compound growth percent per year | 1.82 | 2.24 | 2.52 | | 2.66 | | 2.75 | 2.80 | 2.80 |
| 3 | National income billion rupees | 104.8 | 139.1 | 155.6 | | 185.5 | | 230.1 | 284.0 | 348.8 |
| 4 | Compound growth percent per year | 3.45 | 3.60 | 3.80 | | 4.50 | | 4.40 | 4.30 | 4.20 |
| 5 | Income per capita rupees | 265 | 295 | 306 | | 328 | | 355 | 382 | 409 |
| 6 | Compound growth percent per year | 1.58 | 1.33 | 1.22 | | 1.78 | | 1.60 | 1.46 | 1.36 |
| 7 | Income elasticity of food grain demand | ------- | 0.71 | 0.65 | | 0.63 | | 0.60 | 0.55 | 0.50 |
| 8 | Growth in per capita demand percent per year | ------- | 0.95 | 0.79 | | 1.12 | | 0.96 | 0.80 | 0.68 |
| 9 | Human foodgrain demand kilograms per capita | 133.1 | 143.6 | 147.0 | | 153.6 | | 161.1 | 167.6 | 173.3 |
| 10 | Human foodgrain demand million tons | 52.6 | 67.8 | 74.8 | | 86.8 | | 104.3 | 124.6 | 147.9 |
| | FOODGRAIN SUPPLY (MILLION TONS) | | | | | | | | | |
| | | | | *Actual* | *Projected* | "A" | "B" | | | |
| 11 | Local foodgrain production (Table AI-3) | 66.9 | 79.4 | 78.0 | 87.4 | 113.5 | 106.3 | 135.5 | 158.8 | 184.4 |
| 12 | Postharvest losses (17.3 percent) | 11.6 | 13.7 | 13.5 | 15.1 | 19.6 | 18.4 | 23.4 | 27.5 | 31.9 |
| 13 | Required for seed (43 kilograms per hectare) | 4.7 | 5.0 | 5.1 | 5.1 | 5.2 | 5.2 | 5.3 | 5.4 | 5.5 |
| 14 | Required for cattle feed (assumed) | 0 | .6 | .8 | .9 | 1.7 | 1.7 | 2.7 | 3.2 | 3.7 |
| 15 | Net local supply for human consumption | 50.6 | 60.1 | 58.6 | 66.3 | 87.0 | 81.0 | 104.1 | 122.7 | 143.3 |

See notes at end of table.

TABLE AI-1.—*20-year projection of India foodgrain demand and supply (projection series 67-2)*—Continued

| Line No. | | Agricultural year ending in year— | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Historical | | Projection | | | | | | |
| | | 1956 | 1964 | 1967 | | 1971 | | 1976 | 1981 | 1986 |
| | | | | *Actual* | *Projected* | *"A"* | *"B"* | | | |
| | FOODGRAIN SUPPLY (MILLION TONS)—continued | | | | | | | | | |
| 16 | From (or to) reserve stock | 0.6 | 1.4 | | | (0.2) | | | | |
| 17 | From foodgrain imports | 1.4 | 6.3 | 13.0 | 8.5 | 0 | 5.8 | 0.2 | 0.6 | 2.1 |
| 18 | Total supply for human consumption | 52.6 | 67.8 | 71.6 | 74.8 | 86.8 | 86.8 | 104.3 | 123.3 | 145.4 |
| 19 | Percent of demand (related to income) | 100 | 100 | 95.7 | 100 | 100 | 100 | 100 | 99.0 | 98.3 |
| 20 | Percent of needs (related to nutrition) | | 99.4 | 92.6 | 96.8 | 95.2 | 95.2 | 96.9 | 100 | 100 |
| 21 | Net local supply (line 15) kilograms per capita | 128.0 | 127.4 | 115.2 | 130.2 | 153.9 | 143.3 | 160.7 | 165.1 | 167.9 |
| | FOODGRAIN NEEDS (RELATED TO NUTRITION) | | | | | | | | | |
| 22 | Total nutrition needs calories per capita per day | | 1,936 | 2,032 | | 2,160 | | 2,225 | 2,220 | 2,280 |
| 23 | Foodgrain needs at 72 percent calories per day | | 1,394 | 1,463 | | 1,555 | | 1,602 | 1,598 | 1,641 |
| 24 | Equivalent ounces per person per day | | 14.0 | 14.7 | | 15.6 | | 16.1 | 16.0 | 16.4 |
| 25 | Equivalent kilograms per per capita per year | | 144.6 | 151.8 | | 161.3 | | 166.2 | 165.8 | 170.3 |
| 26 | Foodgrain needs million tons | | 58.2 | 77.3 | | 96.2 | | 107.6 | 123.3 | 145.4 |

NOTES

Line 3: At 1948-49 constant prices.

Line 17: To meet income-related demand through 1976, and nutrition needs in 1981 and 1986.

Line 22: Based on PSAC Panel report, using average of lower estimates.

Lines 24 and 25: Using 3.518 calories per gram of food grain: 1,600 calories per day equals 166 kilograms per year and 16.04 oz. per day.

"A" and "B": See p. 675.

TABLE AI-2.—*20-year projection of India land utilization (projection series 67-2)*

[Areas in millions of hectares]

| Line No. | | Agricultural year ending in year— | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Historical | | | Projection | | | | |
| | | 1956 | 1962 | 1964 | 1967 | 1971 | 1976 | 1981 | 1986 |
| 1 | Gross area sown | 147.3 | 156.1 | 157.5 | 160.3 | 163.0 | 166.0 | 169.0 | 172.0 |
| 2 | Net area under cultivation | 128.8 | 135.4 | 136.3 | 136.8 | 137.5 | 139.0 | 140.5 | 142.0 |
| 3 | Area added by multiple cropping | 18.5 | 20.7 | 21.4 | 23.5 | 25.5 | 27.0 | 28.5 | 30.0 |
| 4 | Percent on gross area | 12.6 | 13.3 | 13.6 | 14.6 | 15.6 | 16.3 | 16.9 | 17.5 |
| 5 | Area allocated to food grains | 110.5 | 115.3 | 116.3 | 118.7 | 121.0 | 123.5 | 126.0 | 128.5 |
| 6 | Area allocated to other crops | 36.8 | 40.8 | 41.2 | 41.6 | 42.0 | 42.5 | 43.0 | 43.5 |

See notes at end of table.

TABLE AI-2.—*20-year projection of India land utilization*—Continued

[Areas in millions of hectares]

| Line No. | | Agricultural year ending in year— | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Historical | | | Projection | | | | |
| | | 1956 | 1962 | 1964 | 1967 | 1971 | 1976 | 1981 | 1986 |
| 7 | Intensive cultivation area (gross) | -------- | -------- | -------- | 2.0 | 12.0 | 22.0 | 32.0 | 42.0 |
| 8 | Balance of gross area sown | -------- | -------- | -------- | 158.3 | 141.0 | 144.0 | 137.0 | 130.0 |
| 9 | Percent irrigated | -------- | -------- | -------- | 19.4 | 17.5 | 16.0 | 16.0 | 16.0 |
| 10 | Million hectares irrigated | -------- | -------- | -------- | 30.7 | 24.5 | 23.0 | 22.0 | 21.0 |
| 11 | Gross area requiring irrigation | 25.6 | 28.4 | 30.2 | 32.7 | 36.5 | 45.0 | 54.0 | 63.0 |
| 12 | Net area irrigated | 22.8 | 24.8 | 26.4 | 28.5 | 31.5 | 37.0 | 43.0 | 49.0 |
| 13 | Multiple cropping area irrigated | 2.8 | 3.6 | 3.8 | 4.2 | 5.0 | 8.0 | 11.0 | 14.0 |
| 14 | Percent on area, line 3 | 15.1 | 17.6 | 17.9 | 17.9 | 19.6 | 29.6 | 33.6 | 46.7 |
| 15 | Gross area irrigated (percent on gross area) | 17.4 | 18.2 | 19.2 | 20.4 | 28.4 | 27.2 | 32.0 | 36.6 |
| 16 | Net area irrigated (percent on cultivated area) | 17.7 | 18.3 | 19.4 | 20.8 | 22.9 | 26.6 | 30.5 | 34.5 |
| | SUMMARY 1964 TO 1986 | | | | | | | | |
| 17 | Newly irrigated area (net) | 22.6 million hectares. | | | | | | | |
| 18 | Via major irrigation | 17.0 million hectares=42.0 million acres at $200 per acre=$8,400,000,000. | | | | | | | |
| 19 | Via tube wells, etc | 5.6 million hectares=13.8 million acres at $100 per acre=$1,380,000,000. | | | | | | | |
| 20 | Intensive cultivation area (gross) | 42.0 million hectares. | | | | | | | |
| 21 | Intensive cultivation area (net) | 31.8 million hectares. | | | | | | | |
| 22 | Newly irrigated area (net) | 22.6 million hectares. | | | | | | | |
| 23 | Additional irrigation needed | 9.2 million hectares=22.7 million acres at $60 per acre=$1,360,000,000. | | | | | | | |

NOTES

Line 11: Sum of lines 7 and 10, with 100 percent assured irrigation for intensive cultivation area.

Line 23 obtained by upgrading 35 percent of 1964 irrigated area at 30 percent of cost for major irrigation.

TABLE AI-3.—*20-year projection of food-grain yields and fertilizer application (projection series 67-2)*

| Line No. | | Agricultural year ending in year— | | | | | |
|---|---|---|---|---|---|---|---|
| | | Actual 1964 | 1967 | 1971 | 1976 | 1981 | 1986 |
| 1 | Gross area sown MM hectares | 157.5 | 160.3 | 163.0 | 166.0 | 169.0 | 172.0 |
| 2 | Allocated to foodgrains MM hectares | 116.3 | 118.7 | 121.0 | 123.5 | 126.0 | 128.5 |
| 3 | Nitrogen content of NPK percent | 71 | 65 | 60 | 57 | 57 | 57 |
| | INTENSIVE FOODGRAIN CULTIVATION | | | | | | |
| 4 | Gross area allocated MM hectares | 0 | 2.0 | 12.0 | 22.0 | 32.0 | 42.0 |
| 5 | Total NPK applied kilogams per hectare | -------- | 50 | 75 | 90 | 110 | 125 |

See notes at end of table.

TABLE AI-3.—*20-year projection of foodgrain yields and fertilizer application (projection series 67-2)*—Continued

| Line No. | | Agricultural year ending in year— | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Actual 1964 | 1967 | 1971 | | 1976 | 1981 | 1986 |
| 6 | Fertilizer response kilograms foodgrain per kilogram NPK | -------- | 9.1 | 8.4 | | 8.6 | 8.9 | 9.4 |
| 7 | Basic foodgrain yield at 0 NPK-kilograms per hectare | -------- | 761 | 761 | | 761 | 761 | 76 |
| 8 | Yield increase due to fertilizer | -------- | 455 | 630 | | 744 | 979 | 1175 |
| 9 | Yield increase due to irrigation | -------- | 500 | 525 | | 550 | 600 | 650 |
| 10 | Total foodgrain yield kilograms per hectare | -------- | 1,716 | 1,916 | | 2,085 | 2,340 | 2,586 |
| 11 | Foodgrain production MM tons | -------- | 3.4 | 23.0 | | 45.9 | 74.9 | 108.6 |
| | GENERAL FOODGRAIN CULTIVATION | | | *Alternative A* | *Alternative B* | | | |
| 12 | Gross area allocated MM hectares | 116.3 | 116.7 | 109 | 109 | 101.5 | 94.0 | 86.5 |
| 13 | Total NPK kilograms per hectare | 3.8 | 7.5 | 23 | 14 | 35 | 42 | 42 |
| 14 | Fertilizer response kilograms foodgrain per kilogram NPK | 11.1 | 10.5 | 3.7 | 9.6 | 7.6 | 6.9 | 6.9 |
| 15 | Basic foodgrain yield at 0 NPK-kilograms per hectare | 641 | 641 | 630 | 630 | 617 | 603 | 586 |
| 16 | Yield increase due to fertilizer | 42 | 79 | 200 | 134 | 266 | 290 | 290 |
| 17 | Total foodgrain yield kilograms per hectare | 683 | 720 | 830 | 764 | 883 | 893 | 876 |
| 18 | Foodgrain production MM tons | 79.4 | 84.0 | 90.5 | 83.3 | 89.6 | 83.9 | 75.8 |
| | SUMMARY (FOODGRAINS) | | | | | | | |
| 19 | Total foodgrain production MM tons | 79.4 | 87.4 | 113.5 | 106.3 | 135.5 | 158.8 | 184.4 |
| 20 | Compound growth Percent per year | -------- | 3.25 | 6.75 | 5.01 | 3.61/4.97 | 3.22 | 3.03 |
| 21 | Average foodgrain yield kilograms per hectare | 683 | 736 | 938 | 879 | 1097 | 1260 | 1435 |
| 22 | Compound growth Percent per year | -------- | 2.43 | 6.25 | 4.54 | 3.18/4.53 | 2.81 | 2.64 |
| 23 | NPK application Intensive cultivation | -------- | 0.100 | 0.900 | 0.900 | 1.980 | 3.520 | 5.250 |
| 24 | General cultivation | 0.445 | .875 | 2.507 | 1.526 | 3.553 | 3.950 | 3.635 |
| 25 | Total MM tons | 0.445 | .975 | 3.407 | 2.426 | 5.533 | 7.470 | 8.385 |
| 26 | Average NPK applied kilograms per hectare | 3.8 | 8.2 | 78.2 | 20.0 | 44.8 | 59.3 | 69.1 |

NOTES

Lines 6 and 14: Corrected for N content of NPK and obtained from Figures 14-9 and 14-10 of guidelines report.

Line 9: Based on increase from 30 percent to 100 percent irrigated; increasing effectiveness from 50 percent in 1964 to 80 percent in 1986; and a response factor of 1000 kgs per hectare at 100 percent efficiency.

Line 15: Declines as higher yielding crops are shifted to intensive cultivation area.

TABLE AI-4.—*20-year projection of fertilizer demand and supply (projection series 67-2)*

| Line no. | | Agricultural year ending in year— | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Actual 1964 | 1967 | 1971 | | 1976 | 1981 | 1986 |
| | | | | Alternative A | Alternative B | | | |
| | FERTILIZER DEMAND—MM TONS | | | | | | | |
| 1 | NPK application—Foodgrains (Table AI-3) | 0.445 | 0.175 | 3.407 | 2.426 | 5.533 | 2.470 | 8.885 |
| 2 | Area allocated to other crops—MM hectare | 41.2 | 41.6 | 42.0 | 42.0 | 42.5 | 43.0 | 43.5 |
| 3 | Total NPK applied—kilograms per hectare | 3.8 | 10 | 20 | 20 | 30 | 40 | 50 |
| 4 | NPK application—Other crops | 0.154 | 0.416 | 0.840 | 0.840 | 1.275 | 1.720 | 2.175 |
| 5 | Total NPK application—All crops | 0.599 | 1.391 | 4.247 | 3.266 | 6.808 | 9.190 | 11.060 |
| 6 | Average NPK applied—kilograms per hectare | 3.8 | 8.7 | 26.1 | 20.0 | 41.0 | 54.4 | 643 |
| 7 | Nitrogen content of NPK—Percent | 71 | 65 | 60 | 60 | 57 | 57 | 57 |
| 8 | Total N demand | 0.426 | 0.904 | 2.548 | 1.959 | 3.880 | 5.240 | 6.300 |
| 9 | Total $P_2O_5$ demand | .121 | .326 | 1.138 | .875 | 1.962 | 2.633 | 3.173 |
| 10 | Total $K_2O$ demand | .052 | .161 | .561 | .432 | .966 | 1.317 | 1.587 |
| 11 | Total NPK demand | .599 | 1.391 | 4.247 | 3.266 | 6.808 | 9.190 | 11.060 |
| 12 | Government demand targets: | | | | | | | |
| 13 | N | -------- | 1.000 | 2.400 | 2.400 | 5.000 | -------- | -------- |
| 14 | $P_2O_5$ | -------- | .370 | 1.000 | 1.000 | 3.000 | -------- | -------- |
| 15 | $K_2O$ | -------- | .200 | .700 | .700 | 1.500 | -------- | -------- |
| 16 | Total NPK | -------- | 1.570 | 4.100 | 4.100 | 9.500 | -------- | -------- |
| | NITROGEN SUPPLY—MM TONS | | | | | | *Capacity MM Tons* [1] | |
| 17 | Local plants in operation (9) | 0.219 | 0.360 | 0.440 | 0.440 | 0.470 | 0.526 | -------- |
| 18 | Plants being constructed or implemented (8) | -------- | -------- | .790 | .790 | 840 | .989 | -------- |
| 19 | Plants with preliminary approval (4) | -------- | -------- | -------- | -------- | .390 | .462 | -------- |
| 20 | Reasonably firm local supply | .219 | .360 | 1.230 | 1.230 | 1.700 | 2.037 | -------- |
| 21 | New locations under discussion (4) | -------- | -------- | -------- | -------- | .680 | .800 | -------- |
| 22 | Possible local nitrogen supply | .219 | .360 | 1.230 | 1.230 | 2.380 | 2.837 | -------- |
| 23 | Possible local $P_2O_5$ supply—MM tons | 0.108 | 0.160 | 0.280 | 0.280 | 0.380 | 0.460 | -------- |
| 24 | Imports required: | | | | | | | |
| 25 | N | 0.207 | 0.544 | 1.318 | 0.729 | 1.500 | -------- | -------- |
| 26 | $P_2O_5$ | .013 | .166 | 858 | .595 | 1.582 | -------- | -------- |
| 27 | $K_2O$ | .052 | .161 | .561 | .432 | .966 | -------- | -------- |
| 28 | Total | .272 | .871 | 2.737 | 1.756 | 4.048 | -------- | -------- |

[1] Capacities corresponding to indicated 1976 production.

# APPENDIX II

## Statistical Data Underlying Chart Presentations

Table AII-1.—*Statistical data—population (series 67-2)*

| | Midyear population (billions) | | | Population (millions) | |
|---|---|---|---|---|---|
| | U.N. [1] | PSAC [2] | | Midyear | Mar. 1 |
| World: | | | India: | | |
| 1900 | 1.650 | | 1950 [4] | 357.7 | 355.4 |
| 1930 | 2.000 | | 1951 | 363.4 | 361.1 |
| 1950 | 2.515 | | 1952 | 369.6 | 367.0 |
| 1960 | 2,977 | | 1953 | 376.1 | 373.5 |
| 1965 | 3,281 | 3.308 | 1954 | 382.9 | 380.2 |
| 1970 | 3.639 | 3.624 | 1955 | 390.2 | 387.5 |
| 1975 | 4.059 | 4.005 | 1956 | 397.8 | 395.1 |
| 1980 | 4.551 | 4.467 | 1957 | 405.8 | 403.0 |
| 1985 | 5.091 | 5.032 | 1958 | 414.3 | 411.4 |
| 2000 | 6.994 | | 1959 | 423.3 | 420.3 |
| | | | 1960 | 432.7 | 429.7 |
| | | | 1961 | 442.7 | 439.2 |
| | | | 1962 | 453.4 | 449.8 |
| | | | 1963 | 464.3 | 460.6 |
| | | | 1964 | 475.5 | 471.8 |
| AALA countries [3]: | | | | | |
| 1966 | | 1.628 | 1965 [5] | 487.5 | 483.6 |
| 1970 | | 1.792 | 1966 | 499.8 | 495.6 |
| 1975 | | 2.048 | 1967 | 513.1 | 509.0 |
| 1980 | | 2.335 | 1971 | 570.0 | 565.4 |
| 1985 | | 2.654 | 1976 | 652.7 | 647.5 |
| | | | 1981 | 749.4 | 743.4 |
| | | | 1985 | 836.9 | 830.2 |
| | | | 1986 | 860.4 | 853.5 |
| | | | 1991 | 984.9 | 977.0 |
| | | | 2000 | 1,237.6 | 1,227.7 |

[1] United Nations (U.N.) data represent "high" variant derived from January 1967 issue of "Annals", American Academy of Political and Social Science.

[2] PSAC data represent "high" series (Vol. II, Section 1.5-1.5.0).

[3] "AALA" countries comprise Asia, Africa and Latin America, excluding mainland China and Japan.

[4] Source of historical data: "India Agriculture in Brief," 7th edition, May 1965, published by Government of India Ministry of Food and Agriculture.

[5] Projections based on vital rates intermediate between "high" and "low series" in Vol. II, Chapter 1. Text accompanying fig. 14-2 of this Chapter indicates actual progression and compound growth rates used.

TABLE AII-2.—*Statistical data—Foodgrain production and consumption*

All quantities in millions of metric tons. Sources: "Indian Agriculture in Brief," 7th edition, May 1965, and "Fertilizer Statistics 1964/65," published December 1965. Series 67-2

| Agricultural year ending in June of year | Foodgrain production | | | Disappearances[1] | | | Net local supply | | From (to) stock | From imports | Total supply for human consumption | | Mar. 1 population (millions) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cereals | Pulses | Total | Seed | Feed | Losses | MM tons | Kilogram per capita | | | MM tons | Kilogram per capita | |
| Historical: | | | | | | | | | | | | | |
| 1950 | 49.21 | 9.49 | 58.70 | 4.04 | 0 | 10.16 | 44.50 | 125.3 | ---------- | 2.16 | 46.66 | 131.4 | 355.1 |
| 1951 | 44.44 | 8.69 | 53.13 | 4.15 | 0 | 9.19 | 39.79 | 110.2 | (0.59) | 4.80 | 44.00 | 121.8 | 361.1 |
| 1952 | 45.00 | 8.58 | 53.58 | 4.26 | 0 | 9.27 | 40.05 | 109.1 | (0.62) | 3.93 | 43.36 | 118.1 | 367.0 |
| 1953 | 50.27 | 9.31 | 59.62 | 4.37 | 0 | 10.31 | 44.94 | 120.3 | 0.48 | 2.04 | 47.46 | 127.0 | 373.5 |
| 1954 | 59.26 | 10.48 | 69.74 | 4.48 | 0 | 12.06 | 53.20 | 139.9 | (0.20) | 0.83 | 53.83 | 141.6 | 320.2 |
| 1955 | 57.28 | 10.94 | 68.22 | 4.59 | 0 | 11.80 | 51.83 | 133.7 | 0.75 | 0.60 | 53.18 | 137.2 | 387.5 |
| 1956 | 55.82 | 11.03 | 66.85 | 4.71 | 0 | 11.56 | 50.58 | 128.0 | 0.60 | 1.39 | 52.57 | 133.1 | 395.1 |
| 1957 | 58.32 | 11.54 | 69.86 | 4.76 | 0 | 12.08 | 53.02 | 131.6 | (0.86) | 3.63 | 55.79 | 138.4 | 403.0 |
| 1958 | 54.75 | 9.55 | 64.30 | 4.81 | 0.06 | 11.12 | 48.31 | 117.4 | 0.27 | 3.22 | 51.80 | 125.9 | 411.4 |
| 1959 | 63.99 | 13.14 | 77.13 | 4.86 | 0.15 | 13.34 | 58.78 | 139.8 | (0.49) | 3.86 | 62.15 | 147.8 | 420.3 |
| 1960 | 64.87 | 11.79 | 76.66 | 4.90 | 0.23 | 13.26 | 58.27 | 135.6 | (1.40) | 5.13 | 62.00 | 144.3 | 429.7 |
| 1961 | 69.33 | 12.70 | 82.03 | 4.94 | 0.33 | 14.19 | 62.57 | 142.5 | 0.17 | 3.49 | 66.23 | 150.8 | 439.2 |
| 1962 | 70.95 | 11.75 | 82.70 | 4.96 | 0.41 | 14.31 | 63.02 | 140.1 | 0.36 | 3.64 | 67.02 | 147.0 | 449.8 |
| 1963 | 67.01 | 11.44 | 78.45 | 4.99 | 0.47 | 13.56 | 59.43 | 129.0 | 0.01 | 4.55 | 63.99 | 138.9 | 460.6 |
| 1964 | 69.56 | 9.87 | 79.43 | 5.01 | 0.56 | 13.74 | 60.12 | 127.4 | 1.37 | 6.27 | 67.76 | 143.6 | 471.8 |
| Preliminary estimates: | | | | | | | | | | | | | |
| 1965 | 76.02 | 12.38 | 88.40 | 5.05 | 0.71 | 15.29 | 67.35 | 139.3 | (4.00) | 7.00 | 70.35 | 145.5 | 483.6 |
| 1966 | ---------- | ---------- | 72.30 | 5.08 | 0.65 | 12.50 | 54.07 | 107.1 | 4.00 | 11.00 | 68.07 | 139.4 | 495.6 |
| 1967 | ---------- | ---------- | 78.00 | 5.10 | 0.78 | 13.49 | 58.63 | 115.2 | ---------- | 13.00 | 71.63 | 140.7 | 509.0 |
| Projection "B": [1] | | | | | | | | | | | | | |
| 1967 | ---------- | ---------- | 87.4 | 5.1 | 0.9 | 15.1 | 66.3 | 130.5 | ---------- | 8.5 | 74.8 | 147.0 | 509.0 |
| 1971 | ---------- | ---------- | 106.3 | 5.2 | 1.7 | 18.4 | 82.0 | 143.3 | ---------- | 5.8 | 86.8 | 153.6 | 565.4 |
| 1976 | ---------- | ---------- | 135.5 | 5.3 | 2.7 | 23.4 | 104.1 | 160.8 | ---------- | 0.2 | 104.3 | 162.1 | 647.5 |
| 1981 | ---------- | ---------- | 158.8 | 5.4 | 3.2 | 27.5 | 122.7 | 165.0 | ---------- | 0.6 | 123.3 | 165.8 | 743.5 |
| 1986 | ---------- | ---------- | 184.4 | 5.5 | 3.7 | 31.9 | 143.3 | 167.9 | ---------- | 2.1 | 145.4 | 170.3 | 853.5 |
| Projection "C": [2] | | | | | | | | | | | | | |
| 1967 | ---------- | ---------- | 86.0 | 5.1 | 0.8 | 14.9 | 65.2 | 128.1 | ---------- | 9.6 | 74.8 | 147.0 | 509.0 |
| 1971 | ---------- | ---------- | 94.4 | 5.2 | 1.4 | 16.3 | 71.5 | 126.5 | ---------- | 15.3 | 86.8 | 153.6 | 565.4 |
| 1976 | ---------- | ---------- | 106.1 | 5.3 | 2.1 | 18.4 | 80.3 | 124.0 | ---------- | 24.0 | 104.3 | 161.1 | 647.5 |
| 1981 | ---------- | ---------- | 119.2 | 5.4 | 2.4 | 20.6 | 90.8 | 122.1 | ---------- | 32.5 | 123.3 | 165.8 | 743.5 |
| 1986 | ---------- | ---------- | 134.0 | 5.5 | 2.7 | 23.2 | 102.6 | 120.2 | ---------- | 42.9 | 145.4 | 170.3 | 853.5 |

[1] Developed in Table AII-4, Appendix II.

[2] As used in Figures 14-4 and 14-5 of this Chapter report.

TABLE AII-3.—*Statistical data—foodgrain yields and fertilizer use*

(Source: Historical data, same as table 2. Series 67-2)

| | Gross area sown (millions of hectares) | | Foodgrain production (million tons) | Foodgrain yield [1] (kilograms per hectare) | Approximate fertilizer use | | | |
|---|---|---|---|---|---|---|---|---|
| | All crops | Foodgrains | | | N | NPK | NPK (kilograms per hectare) | |
| Historical: | | | | | *Thousand tons* | *Thousand tons* | | |
| 1950 | ---------- | 98.8 | 58.70 | 594 | ---------- | ---------- | ---------- | |
| 1951 | 131.9 | 96.7 | 53.13 | 549 | ---------- | ---------- | ---------- | |
| 1952 | 133.2 | 96.8 | 53.58 | 554 | ---------- | ---------- | ---------- | |
| 1953 | 137.7 | 101.9 | 59.62 | 585 | 58 | 64 | 0.46 | |
| 1954 | 142.5 | 108.8 | 69.74 | 641 | 89 | 105 | 0.74 | |
| 1955 | 144.1 | 107.9 | 68.22 | 632 | 95 | 121 | 0.84 | |
| 1956 | 147.3 | 110.5 | 66.85 | 605 | 108 | 131 | 0.89 | |
| 1957 | 149.5 | 111.1 | 69.86 | 627 | 123 | 154 | 1.03 | |
| 1958 | 145.8 | 109.4 | 64.30 | 588 | 149 | 184 | 1.26 | |
| 1959 | 151.6 | 114.6 | 77.13 | 673 | 172 | 224 | 1.48 | |
| 1960 | 152.8 | 115.7 | 76.66 | 663 | 229 | 304 | 1.99 | |
| 1961 | 152.3 | 113.1 | 82.03 | 725 | 212 | 294 | 1.93 | |
| 1962 | 156.1 | 115.3 | 82.70 | 717 | 292 | 384 | 2.46 | |
| 1963 | 156.7 | 116.0 | 73.45 | 676 | 360 | 486 | 3.10 | |
| 1964 | 157.5 | 116.3 | 79.43 | 683 | 426 | 599 | 3.80 | |
| Preliminary estimates: | | | | | | | | |
| 1965 | 158.7 | 117.5 | 88.40 | 752 | 492 | 711 | 4.48 | |
| 1966 | 159.5 | 118.1 | 72.30 | 612 | 600 | 840 | 5.28 | |
| 1967 | 160.3 | 118.7 | 78.00 | 657 | ---------- | ---------- | ---------- | |
| | | | | | All crops | | Foodgrains | |
| | | | | | | | NPK | (kilograms per hectare) |
| Projection B: [2] | | | | | | | | |
| 1967 | 160.3 | 118.7 | 87.4 | 736 | 904 | 1,391 | 975 | 8.2 |
| 1971 | 163.0 | 121.0 | 106.3 | 879 | 1,959 | 3,266 | 2,426 | 20.0 |
| 1976 | 166.0 | 123.5 | 135.5 | 1,097 | 3,880 | 6,808 | 5,533 | 44.8 |
| 1981 | 169.0 | 126.0 | 158.8 | 1,260 | 5,240 | 9,190 | 7,470 | 59.3 |
| 1986 | 172.0 | 128.5 | 184.4 | 1,435 | 6,300 | 11,060 | 8,885 | 69.1 |
| Projection C: [3] | | | | | | | | |
| 1967 | 160.3 | 118.7 | 86.0 | 725 | [4] 780 | [4] 1,200 | ---------- | ---------- |
| 1971 | 163.0 | 121.0 | 94.4 | 780 | [4] 1,200 | [4] 2,000 | ---------- | ---------- |
| 1976 | 166.0 | 123.5 | 106.1 | 859 | [4] 1,850 | [4] 3,250 | ---------- | ---------- |
| 1981 | 169.0 | 126.0 | 119.2 | 946 | [4] 2,700 | [4] 4,750 | ---------- | ---------- |
| 1986 | 172.0 | 128.5 | 134.0 | 1,043 | [4] 3,750 | [4] 6,600 | ---------- | ---------- |

[1] On a "milled rice" basis; for approximate yields on a "paddy" basis, multiply by 1.22.

[2] As developed in Tables AI-3 and AI-4, Appendix I.

[3] As used in Figure 14-7.

[4] By interpolation of alternative "B" results plotted against foodgrain production.

TABLE AII-4.—*Disappearance factors (series 67-2)*

| *Seed requirements* | *Percent of area* | *Seed kilograms per hectare* |
|---|---|---|
| Rice | 30 | 56 |
| Other cereals | 49 | 27 |
| pulses | 21 | 62 |
| Total | 100 | 43 Average |

| *Illustrative (million tons) (Milled Rice Basis)* | *1964* | *1976* | *1986* |
|---|---|---|---|
| Foodgrain production | 79.4 | 135.5 | 184.4 |
| Foodgrain area million hectares | 116.3 | 123.5 | 128.5 |
| Seed requirement | 5.0 | 5.3 | 5.5 |
| Percent of production | 6.3 | 3.9 | 3.0 |

*Feed requirements* (assumed):

Increasing from 0.1 percent of production in 1958 by 0.1 percent each year.
Increasing to 1.0 percent of production in 1967.
Increasing to 1.5 percent of porduction in 1971.
Increasing to 2.0 percent production in 1976 and onward.

*Postharvest losses:*

| Milled rice basis: | *Weight (percent)* | *Assumed losses (percent)* *Processing and handling* | *Storage and pests* | |
|---|---|---|---|---|
| Milled rice | 43.4 | 0 | 10 | Total postharvest loss: 7.3+10.0=17.3 percent on milled rice basis. |
| Other cereals | 42.8 | 12.5 | 10 | |
| Pulses | 13.8 | 14.0 | 10 | |
| Total | 100.0 | 7.3 | 10 | |

Paddy or rough rice basis:

Paddy rice=1.5×weight of milled rice, hence production increases[1] (0.5)(43.4) or 21.7 parts by weight to 121.7 parts by weight. Adjusted weight percentages for above crop pattern are as follows

| | *Weight (percent)* | *Assumed losses (percent)* *Processing and handling* | *Storage and pests* | |
|---|---|---|---|---|
| Paddy rice (65.1/1.217) | 53.4 | 33.3 | 6.7 | Total postharvest loss, 23.8+8.2=32.0 percent[2] on paddy rice basic. |
| Other cereals (42.8/1.217) | 35.2 | 12.5 | 10.0 | |
| Pulses (13.8/1.217) | 11.4 | 14.0 | 10.0 | |
| Total | ---------- | 23.8 | 8.2 | |

Postharvest disappearance (illustrative for 1976):

Milled rice basis 3.9+2.0+17.3=23.2 percent on harvested production.
Paddy rice basis (3.9+2.0)/1.217+32.0=36.9 percent on harvested production.
Indian statistics are generally based on a 12.5 percent postharvest disappearance factor, applied to production on a milled rice basis; this is equivalent to 28.1 percent on a paddy rice basis, as follows: (12.5+21.7)/1.217=28.1 percent.

Total disappearance:

If preharvest losses due to pests, blights, etc. are assumed to be 10 percent on harvested production, total disappearance is: (36.9+10.0)/1.10=42.6 percent of potential production (in 1976). In 1986, this is assumed to increase to (36.1+18.5)/1.185=46.0 percent, if pesticide application remained at 150 g. per hectare, as in 1964.

[1] Standard 33.3 percent conversion loss, probably includes some allowance for pest and storage loss.
[2] Also obtained directly: (17.3+21.7)/1.217=32.0 percent.

# INDEX

## A


Page

Abaca, in mixed tree crop system ..... 487
Acetate, as substrate for microorganism production ..... 366
Acreage diversion, in U.S ..... 142–143, 188
Administration, in agricultural development ..... 439
Afghanistan:
  area of ..... 441
  cost of water and land development in ..... 464
  land cultivated in ..... 441
  land irrigated in ..... 441
  population of ..... 441
Aflatoxin ..... 339, 344, 552, 564–565
Africa:
  agricultural commodities production, disappearance, and trade of ..... 162, 164, 166–171
  animal disease control priorities in ..... 276–277
  animal products production ..... 256–257, 266
  area of ..... 441
  area of tropical ..... 447
  corn yields from improved varieties ..... 216
  crop yield increases from fertilizer applications ..... 228
  diet composition in ..... 317
  draft animals use in ..... 268
  education in ..... 606, 608, 631–632
  EEC preferential trade agreements in ..... 149
  endemic goiter in ..... 17
  farm machinery requirements in ..... 400–401
  fertilizer use in ..... 379
  forest management in tropical ..... 499
  game areas of ..... 478
  GNP of ..... 647
  horsepower availability for food production in ..... 396–397
  income per capita of ..... 645, 647
  iron availability in diets in ..... 66–67
  irrigation potential in tropical ..... 445–447
  land areas by climatic regions ..... 475
  land availability for grazing ..... 266, 280
  land cultivated in ..... 434, 441
  land cultivated per capita ..... 434–435
  land grazing in tropics by soil groups ..... 483
  land irrigated in ..... 441, 493
  land potentially arable in ..... 429–434, 476
  land potentially arable by soil groups ..... 483
  land tenure in ..... 515–516, 519
  livestock populations in ..... 252–253, 266




PREVIOUS PAGE BLANK

Africa—Continued Page
livestock production improvement in 266–267, 284–285
mortality rates in pre-school children 13
oil palm yields in 491
oilseed production of 339
pellagra in 18
personnel needs in agricultural programs of 612–613
pesticide use and requirements in 393
phosphate reserves of 387
population of 434, 441
population density in 21
potassium reserves of 387
price trends for agricultural commodities 151, 666, 668
projections of animal protein supplies in 262, 264, 267
projections for fish production in 355
projections of populations in 22, 30–31, 261, 263
protein food products developed for 563
protein production of cattle in 338
seed and processing plant requirements in 388–389
shifting cultivation in central 486
soil types in 413, 416
storage losses of food in 551–555
tradition and livestock production 286–287
transplant of rubber trees to 494
water runoff in 447
wheat and rice yield increases in 208
wild animal production in 269–270
xerophthalmia in 61
African eland, potential domestication of 270
African horse sickness, *see* Diseases, animal.
African swine fever, *see* Diseases, animal.
Age:
adjustment of caloric requirements for 46
adjustment of protein requirements for 50
Age-distribution, of population 20
effects on economic growth 28–30
effects on education 28–30
Age-specific fertility, defined 26
Agri-climate, elements of 651
Agricultural development:
by Belgians in Congo 496–497
by French in Madagascar 497
costs of 435–439, 460–469
elements in successful project 496, 670
Taiwan success in 497
Agricultural development and food aid 189
Agricultural development and industrialization 492–493
Agricultural machinery, *see* Farm machinery.
Agricultural practices:
improvements in Rhodesia 491
need for improved 456–460
Agricultural practices and natural systems 492–493

Page
Agricultural production:
capital investments to increase 656–660
changes in rate of growth 175
Agricultural productivity, need for increases in 182–184
Agricultural products:
prices of in international trade 666–669
world trade in 158–177
Agroclimatic regions, land types in 411–412, 427–429, 432–433
Agroclimatic regions, of world 421–422
available moisture in 421–422
production of grazing animals in 429, 434
temperature in 421–422
Ahinsa 263
Airplanes, in product transportation 585
*Albizzia falcata*, in intensively managed tropical forests 499
Alfalfa:
as livestock feed 248
boron deficiencies in 204
control of aphids 198
control of stem nematode 199
effects of fertilizer and water on 205, 456–457
Algae, *see* Microorganisms.
as source of food 370–371
Alkanes, growth of micro-organisms on 361
Allergens, in micro-organisms 367
Alto Plano, forest productivity of 499
Amazon:
arable land in basin of 409
production of peppers in valley of 411
Amino acids, *see* Protein, amino acids.
Ammonia, in fertilizer production 383–385
Anaplasmosis, *see* Diseases, animal.
Anemia, *see* Diseases.
Animal breeding:
for animal production improvement 258, 261–262, 265, 284–286, 293, 619
utilization of indigenous breeds in 284–285
Animal byproducts:
recovery of 563
utilization of, as livestock and poultry feed 248–249, 266, 280, 281–283, 292–293
Animal diseases, *see* Diseases, animal.
Animal parasites, *see* Parasites, animal.
Animal production:
effects of tradition on 263, 265, 286–287, 514
government policies in 261, 263, 265, 286, 290–291
importance of transportation in 572–575
improvement of, in developing countries 219, 230, 251–254, 278–287, 292–293
incentives in 261, 263, 286
need for research and education in 287–293, 619, 636
potential contribution to world food supply 248, 330–335
role of private sector in 290
use of inedible human foods 334
in utilization of nonarable land 248, 255, 280–281

263-888 O - 67 - 47

Page

Animal products:
- beef, amino acid composition of 315
- dairy, exports of 143, 159–160
- dairy, stocks of in U.S. 142
- demand for 159
- EEC prices on 148–149
- exportation of, by Argentina 153, 556
- import quotas on 146–147
- international trade agreements in 157
- losses in marketing channels 550–551, 555
- market quality standards for 544
- milk, efficiency of food conversion to 338
- milk, protein content of 315
- milk, protein production per acre 336
- poultry, efficiency of food conversion in 333–338
- production of by regions 338, 340
- production in regions of world 251, 258–268, 280–281
- projections of production needs, in regions of world 70, 72, 255–257, 258–259, 267
- as sources of calcium 64
- as sources of folacin 67
- as sources of iodine 66
- as sources of protein 51, 68, 341
- as sources of vitamin A 62
- as sources of vitamin $B_{12}$ 67
- transportation of 573, 586
- United States exports of 159–160
- wool, production in developing countries 268
- wool, support prices of 147

Animal protein, *see* Protein.

Animal reproduction, potential for improvement of 285–286

Animals, *see* Livestock, wild animals.

Animal science centers, need for in tropics 258, 275, 289–290, 292–293

Animal scientists, need for 288, 293

Animal wastes:
- uses in fish cultures 354
- utilization of, as livestock feed 249, 282

Antelopes, domestication of 270

Anthrax, *see* Diseases, animal.

Aquiculture, *see* Fishculture.

*Araucaria*, in tropical forest management 499

Arctic, soil types in 413

Argentina:
- area of 442
- cost of irrigation development in 466–467
- cost of land clearing 438
- cost of settlement projects in 439
- exportation of meat products 556
- export taxes on agricultural commodities 153
- financial support for research in 618
- food distribution in 75
- food prices in 152
- irrigated area of 442
- land cultivated 442

Argentina—Continued Page
population of 442
private livestock organizations in 290
protein supply in 334, 341
ratio of extension workers to farmers in 622
trade in grain 155, 175–177
Wheat Marketing Board 153
Ariboflavinosis, *see* Diseases.
Asia:
animal disease control priorities in 277–278
anticipated supplies of animal protein in 261–262, 264, 266
area of 441, 447
ariboflavinosis in 18
beriberi in 18
body weights in 49
capital costs of water development in 661
composition of diet in 317
draft animal use in 263, 265, 268
effects of malnutrition on growth of boys in 14
effects of tradition on livestock production 263, 265, 286–287, 292
endemic goiter in 17
export prices 666–668
farm machinery requirements in 400–401
fertilizer use in 228, 379
fish production in 351–352
GNP of 647
horsepower availability, for food production in 396–397
improving livestock production in 261–266, 281, 284–285, 292
income per capita in 645, 647
land areas in tropical climatic regions 475
land availability of grazing 261, 263, 280
land cultivated in 434–435, 441
land grazing in tropics by soil groups 483
land irrigated in 441, 493–494
land potentially arable in 429–434, 447
land potentially arable by soil groups 483
land tenure in 516, 519
livestock populations in 252–253, 263, 265
mortality rates in pre-school children 13
personnel needs in agricultural programs 612–613
pesticide requirements in 393
phosphate reserves of 387
population of 434, 441
population density, in 21
potassium reserves of 387
potential for wild animal production 270
processing of fish in 348
production of animal products 256–257, 259, 261, 263, 265–266
production, disappearance, and trade of agricultural commodities 162, 164, 166–171, 176–177
production of oilseeds 339
projections for fish production in 355
projections of irrigation potential in 445–447
projections of populations in 22, 30–31, 261, 263

Asia—Continued Page
protein production of livestock and poultry in 338
rice-producing areas in 476–478, 484, 488
seed and processing plant requirements in 388–389
soil types in 413–414, 416
water runoff in 447
wheat and rice yields in 208
xerophthalmia in 61
*Aspergillus* 553
Assam, shifting cultivation in 485–486
Asses, *see* Livestock.
Australia:
agricultural policies of 148
area of 441
cost of land development in 460–461, 463
exports of cereals from 20
improvement of forage crops in 280–281
land areas in tropical climatic regions 475
land cultivated in 434–435, 441
land grazing in by soil groups 483
land irrigated in 441
land potentially arable in 429–434
land potentially arable in by soil groups 483
livestock operations in 254, 284
management of tropical forests in 499
population of 434, 441
private-government ownership of sugar plantations 490
producer prices in 150
protein supply of 334
soil types in 413, 416
trade in grain 155, 175–177
transplant of Monterrey pine to 494
yields of rice in 491
yields of sugar cane in 490

## B

Babesiosis, *see* Diseases, animal, piroplasmosis.
Bacteria, *see* Micro-organisms.
Bagasse 249, 281, 282, 365
Balance of payments 145, 665, 669, 671
Bananas, *see* Fruits.
Bantu system, in Congo 496–497
Barley, *see* Cereals.
Barter, in food requirement projections 72, 153
Beans, *see* Pulses.
Belgium:
research and education programs in 626
role in agricultural development of Congo 411, 496–497
support prices for wheat 155
Beriberi, *see* Diseases.
Biochemists, need for 226
Biological availability, of amino acids 367
Biological control, of pests 198, 200, 207, 220, 233

Page

Birth control:
- artificial methods of ... 38
- factors related to success of, *see also* Family planning; Fertility ... 32–36
- folk methods of ... 34
- programs ... 37–38, 301

Birth rates, *see* Fertility rates.
Blindness, *see* Diseases, xerophthalmia.
Bluetongue, *see* Diseases, animal.
Body size:
- need for data on ... 86
- relation to genetic potential ... 40–41
- relation to nutrition ... 39–41

Bolivia:
- area of ... 442
- effect of transportation on agricultural production ... 573
- height and weight of adults in ... 39
- irrigation projects in ... 493
- land cultivated ... 442
- land irrigated in ... 442
- population of ... 442
- xerophthalmia in ... 18

Bone meal, *see* Animal byproducts.
Boron deficiencies in crops, *see* Micronutrients.
Brain drain ... 604, 609–611
Brazil:
- adult height and weight in ... 39
- age-distribution of population in ... 25
- area of ... 442, 447
- corn improvement program in ... 217, 225
- cost of irrigation development in ... 467
- cost of land clearing ... 438
- crop yield in ... 208–209
- diet composition in ... 317
- export taxes on coffee ... 153
- fertility rates, estimates of ... 27
- financial support for research in ... 618
- food distribution in ... 75
- food prices in ... 152
- food requirements for ... 69, 71–73, 75–77, 645–646, 650
- GNP of ... 646–647
- herbicide use on rice in ... 394
- import policies of ... 154
- irrigation projects in ... 493
- land cultivated in ... 442
- land irrigated in ... 442
- land potentially arable in ... 447
- oilseed production in ... 339
- per capita income of ... 645, 647
- population estimates in ... 22, 24–28
- population of ... 442
- primary education in ... 605
- projections of calcium requirements for ... 58, 64–65
- projections of caloric requirements for ... 45, 48–50
- projections of irrigation potential of ... 447

Brazil—Continued Page
projections of protein requirements for 50, 53, 56
projections of vitamin requirements for 58, 59, 60, 61, 62
protein food products developed for 563
refrigeration for meat preservation 558
storage losses of food in 555
sugar in food supply of 75
support prices for wheat 155
water runoff in 447
xerophthalmia in 18, 61
Breeding plants, *see* Plant breeding.
Britain:
mileage of access roads in 582
research and education programs in 626
Broilers, *see* Animal products, poultry.
Brucellosis, *see* Diseases, animal.
Buckwheat, *see* Cereals.
Buffalo, *see* Livestock.
Bullocks, *see* Livestock.
Burma:
adult height and weight 39
as rice producer 209
Butter, *see* Animal products.
By-products, *see* Animal/Plant, byproducts.

## C

Cacao, growth of 487, 489
Calcium:
in cereal fortification 322–324
cycles of in forest trees 477, 481
deficiency, *see* Diseases, mineral deficiencies.
deficiency in soils 481
requirements for selected countries and world 58, 64–65
Calcium cyanamide, in fertilizer production 383
Caloric content, of foods 316–317, 328
Caloric requirements:
adjustments for age 46
adjustments for fertility rate 46, 69
adjustments for temperature 46
conversion to foods and commodities 69–77
daily 329
effect of physical activity on 49–50
need for detailed surveys 49
projections for selected countries and world 49–50, 70
relation to protein requirements 50, 68, 70
Camels, *see* Livestock.
Cameroun, stored grain protection in 551
Canada:
agricultural policies of 148, 155
cost of agricultural development in 461
cost of water and land development in 463–464
fishery catch of 357–358
producer prices in 150
production of ammonia fertilizer in 384

Canada—Continued Page
production, disappearance and trade of agricultural commodities 162, 164, 166–171
protein supply of 334
as source of potassium 385
trade in grain 20, 144, 150, 160, 175–177
value of agricultural imports from U.S 159
Canadian Wheat Board 150
Capital assistance, *see* Economic assistance.
Capital-intensive:
agricultural development 436
irrigation projects 452
Capital investment:
for agricultural development 448–450
in developing marketing systems 30, 549
effect of rapid population growth on 28–30
for farm machinery 400–402
for fertilizer 382
to increase agricultural production 657–660, 671
for land settlement 439
for land and water development 460–469, 660–662
for pesticides 393, 395, 402
requirements for, in India 676, 678, 702
for transportation program for India 590
Capital investments:
direct 663–664
indirect 663–664
Carbon, production of in oceans 346
Carnivores, food conversion efficiency in oceans 346
Carotene, *see* Vitamins, vitamin A.
Carp, production of 352
Carrots, *see* Vegetables.
Carrying capacity, of animals in agroclimatic regions 429
Cassava:
as basic food crop 219
in food requirement projections 70–71
protein content of 315, 368–369
Catfish, production of 351–352
Cattle, *see* Livestock.
Cellulose 258, 365
Census data, need for 86
Central American Free Trade Area 154
Central Food Technological Research Institute 85
Cereals:
amino acids in 315, 317, 328
byproducts in poultry feed 249, 280–283
caloric content of 328
cost of fortification 320–321, 324
in diets 308–309, 316–317, 341
effect of fortification on protein quality 319
exporters of 20
fat content of 328
as fish food supplements 351
in food requirement projections, fortification of 284, 305, 308–309, 316–329

Cereals—Continued Page
in high protein food products 564
imports of 160–161
increased production to supply food requirements 19, 77
increased requirements for, in India 675–679, 686–702
in livestock feeds 163, 165, 249–250, 283
losses to pests, in marketing channels 550–552, 554–555
losses to pests in production of 198, 200, 203, 205, 210, 220
market quality standards for 545
mineral content of 323, 328
price support of 154
production, disappearance, and trade in 158–177, 655–657
production of, in response to price changes 527–528
protein production per acre 336
as protein source 51, 54, 341
selection for nutritive quality of 330
as sources of calcium 64
as sources of vitamins 58–60, 62
vitamin content of 323, 328
wastes and byproducts in animal feeds 281
yields in India 208, 223
Cereals, barley:
costs of fortification 320, 324
EEC prices on 149
hybridization of 201–202
Cereals, corn:
absorption of insecticides by 206–207
amino acids in 51, 315, 317
breeding for improved quality 199–200, 224–225
costs of fortification 320, 324
EEC prices on 148–149
effects of fertilizer on yields 197, 204, 223
effects of hybrids on yields 196–197, 204, 216–217
export prices of 145, 151
hybridization of 200, 204, 221–222
import duty on 146
improvement of, in Rhodesia 491–492
insect control on 231
Kenya's improvement program 221–222
Mexico's improvement program 221–223
niacin in 60–61
protein content of 51, 315
in shifting cultivation 485–486
yields in selected countries 196, 204, 209, 216
zinc deficiencies in 204
Cereals, maize, *see* Cereals, corn.
Cereals, millet:
as basic crop for developing countries 219
collection of varieties in India 219–225
cost of fortification of 320, 324
hybridization of 200
yields in selected countries 209
Cereals, oats:
resistance to Helminthosporium blight 202

Page
Cereals, rice:
amino acids in 51, 315
as basic crop for developing countries 219
costs of fortification 320, 324
development project in production of 493
development of varieties of 215
effects of fertilization on yields 197
exports of 143, 145, 151, 153, 159–160
in fishculture 351–354
flood farming of 488
in food aid 163
import duty on 146
international commodity agreements on 157
losses caused by poor processing 555
mycotoxins in 554
pest losses and control 213–215, 231–232
polished, protein content of 315
potential for production of 478
price in relation to fertilizer 156
producer price in Japan 150
production, disappearance and trade 163–164, 170–171, 176
production in selected countries 163, 497
projections of U.S. exports 163–164
significance in world nutrition 306
transportation of, in Bolivia 573
weed control in 392, 394
yields in selected countries 208–209, 490–491
Cereals, sorghum:
as basic crop for developing countries 219
breeding for dwarfing and quality 199, 224–225
costs of fortification of 320, 324
effects of amount of irrigation water on yield of 459–460
hybridization of 201
improvement of varieties 217
iron deficiencies in 204
Mexico's production improvement program 223
prussic acid in 199
yields in selected countries 209, 217
Cereals, wheat:
adaptation to photoperiod by plant breeding 198, 218
as basic crop for developing countries 219
breeding for quality 199, 209–213, 224–225
costs of fortification 320–321, 324
EEC prices on 148–149
exports of 143–145, 151, 153, 159–163
flour, protein content of 315
hybridization of 201–202
imports of 144, 146–147, 150
international commodity agreements on 157
Mexico's Wheat Program 210–211, 216, 223, 225, 230, 627–629
in multiple cropping system 233
Pakistan's Wheat Program 211–212, 216, 223
pest control in 198, 200, 392
price of in relation to fertilizer 156

Cereals, wheat—Continued Page
producer price in Japan 150
production, disappearance and trade of 161–163, 170–171, 175–176
as protein source 51, 68, 311
stocks of in U.S 142
support prices of 154
yields in selected countries 208–212, 229
Ceylon:
birth and death rates in 36
costs of agricultural development projects 436
desired family size in 33
mortality of infants in 33
protein supply of 334
Chagas disease, *see* Diseases, animal, trypanosomiasis.
Chayen process 369
Cheese, import quotas on 146–147
Chemosterilants, for insect control 207
Chickens, *see* Poultry.
Chickpeas, *see* Pulses.
Chicle 490
Children:
development of high protein food products for 78, 83, 89, 563–564
malnutrition in 10, 13–14, 312
preschool, mortality rates of 13, 17
protein supply from wheat diet 311
Chile:
adult height and weight in 39
area of 442
corn yields from improved varieties 317
cost of administration of development projects 439
desired family size in 33
food prices in 152
higher education in 608
import policies of 154
irrigation projects in 493
land cultivated in 442
land irrigated in 442
mortality of infants in 33
population of 442
soil types in 416
support prices for wheat 155
xerophthalmia in 18
China:
area of 441
fishery catch of 349, 357–358
imports of grain 144, 160, 163
land cultivated in 441
land irrigated in 441
marketing system in 548
population of 441
population density, in 21
soil types in 415
trade in rice 176
*Chlorella*, cost of production of 371

Page
*Chrysolina* sp. 233
Citrus, *see* Fruits.
Climate, modification and agricultural productivity 453
Climates, tropical, characteristics of 474–484
Climatic regions, forest production in 498–499
Climatic regions, of tropics 475–479
Climatic zones, *see also* Agroclimatic regions:
cold-temperate boreal 418–419, 423, 431
cool-temperate 419, 423, 431
grazing land in 423, 427–428
nonarable land in 423, 427–428
polar and subpolar 418, 423, 431
potentially arable land in 423, 427–428, 431–433
tropical climate 420–421, 423, 431
warm-temperate subtropical 419–420, 423, 431
Cloud forest, productivity of 499
Cobalamin deficiency, *see* Diseases, vitamin $B_{12}$.
Cobalt, *see* Micronutrient deficiencies.
Cocoa:
exports of 151, 179, 181
import duty on 146
in shifting cultivation 497
Coconut 339, 486
Coffee:
alternative food crops for 232
exports of 151, 153, 179, 181
growth of 487, 489, 497
imports of 146, 669
international commodity agreements on 157
trends in prices of 151, 668–669
Coffee Agreement Diversification Fund 157
Colleges, *see* Universities.
Columbia:
adult height and weight in 39
area of 442
cost of agricultural development in 439, 460
cost of settlement projects in 439
cost of water and land development in 462, 465
evaluation of nutrition programs in 81
export taxes on coffee 153
financial support for research in 618
food prices in 152
import policies of 154
land cultivated in 442
land irrigated in 442
population of 442
private livestock organizations in 290
protein food products developed for 563
support prices for wheat 155
xerophthalmia in 18
Common Market and Customs Unit, Latin America 154
Communication, need for, in marketing 544, 561, 581

Page

Communist Asia, production, disappearance, and trade of agricultural commodities 161–162, 164, 166–171, 175–176
Communist world, cotton production in 343
Community development, cost of in development projects 462–469
Comparative advantage 158, 182, 186–187, 189–190
Concessional sales, *see* Food aid.
Congo, agricultural development in 496–497
Congo River, arable land in basin of 409
Consumer, need for purchasing power of 541
Consumer demand, for protein food products 565–566
Consumer goods, influence on production incentives 523, 572, 575
Consumer protection, government responsibility for 546, 562
Contagious bovine pleuropneumonia, *see* Diseases, animal.
Copper, *see* Micronutrient deficiencies.
Copper deficiency, *see* Diseases, mineral deficiencies.
Copra, *see* Coconut.
Corn, *see* Cereals.
Costa Rica:
- area of 442
- effect of highway construction on agricultural production 573
- food prices in 152
- land cultivated in 442
- land irrigated in 442
- population of 442

Cottage industries 182
Cotton:
- development of project in Sudan for 495–496
- exports of 143, 145, 159–160, 179, 181
- imports of 146–147
- insect control in Peru 214
- interaction between water and fertilizer in production of 456–458
- production of, in response to price changes 527–528
- stocks of in United States 142
- support prices of 147
- world production of 342–343

Cottonseed, *see* Oilseeds.
Cottony cushion scale 233
Coumarin 199
Credit, influence on production incentives 507, 510, 513, 522
Crop production:
- alternative food crops to supplement monoculture 232
- concentration on adapted basic crops 219, 232
- effects of fertilizer on 198–199, 203–205, 210–211, 223, 230, 288, 380–382
- effects of soil acidity on 380
- effects of soil management on 205, 232–233
- effects of water on 198, 205, 223, 232
- importance of farm machinery in 396–400
- importance of multiple cropping 226, 233, 475–480
- improvement by plant breeding 197–204, 209–210, 212–213, 215–225
- increased requirements in India 675–676, 678–702
- losses due to pests 205, 213
- need for data on 86
- need for regional research centers 212, 220

Crop production—Continued Page
need for research in 209–210, 212, 219–225, 227–228, 232, 233, 619, 636
package approach to 197, 204–205, 210–212, 223, 229, 232, 236, 379, 392
pest control in 198, 205–206, 208, 220, 223, 226, 392–395
potential for increasing 208–225
rate of increase of in West Pakistan 662
role of transportation in 572–575
in United States 196, 204
Crop production programs, influence of food aid on 227
Crop production specialists, need for 226
Cuba:
area of 442
land cultivated in 442
land irrigated in 442
population of 442
Culebrilla, *see* Diseases, kwashiorkor.
Cyprus:
area of 441
land cultivated in 441
land irrigated in 441
population of 441
Cystine, *see* Protein, amino acids 52
Cytoplasmic male-sterility in plants 200–203

## D

Dahomey, corn yield in 216
Dehydration of foods 557–558, 560–561
Demand:
forecasts 158
for goods and services 184–185, 643, 651–652
projections of, for fish 353
Demographic characteristics and food problems 19–21
Denmark:
fish in food supply of 348
mileage of access roads in 582
protein supply of 334
support prices for wheat 155
Dental caries, flourides for prevention of 18
*Dermatobia hominis* 276
Diarrhea, *see* Diseases.
Diet:
composition of 307–310, 316–317
fish in 348
leaves as source of protein in 368–370
proteins in 341
relationship of income to 309–311
supplementation with FPC 357
Disappearance:
estimates of agricultural commodities 158–177
of grains 175–177, 655, 657
Diseases:
anemia 16–17, 19, 66–67, 86
ariboflavinosis 16, 18

Diseases—Continued Page
beriberi 16, 18
diarrhea 12, 67, 86
endemic goiter 16–18, 66
folacin deficiency 19
glossitis 67
infectious 21, 86, 301, 305
kwashiorkor 12–13, 16–17, 50, 56, 307–308, 310–311, 318
marasmus 16–17
measles, incidence of mortality compared in Chile, United States and India 13
mineral deficiencies 19, 64
pellagra 16, 18
rickets 16, 19, 66
scurvy 16, 19, 65
tuberculosis 13
vitamin deficiencies 19
vitamin $B_6$ deficiency 19
vitamin $B_{12}$ deficiency 19
xerophthalmia 16, 18, 61
Diseases, animal:
affecting humans 272–274, 276
African horse sickness 271–272
African swine fever 271–272
anaplasmosis 271, 273
anthrax 274
bluetongue 271
brucellosis 274, 276
causative agents 272–274
contagious bovine pleuropneumonia 271–272, 277
control of, for animal production improvement 254, 258, 261–263, 267, 270–278, 292–293
East Coast fever 271, 273, 277
echinococcosis 274
equine encephalitides 273
estimate of world losses to 275
foot and mouth disease 270–272, 275, 278
fowl plague 271–272
hemorrhagic septicemia 271, 273, 277
hog cholera 271–272, 277
lumpy skin disease 271
mastitis 271
Nairobi sheep disease 271
need for information on tropical 271, 275, 277, 289–290, 292–293
need for research centers in tropics 275, 277, 292–293, 289–290
Newcastle disease 271–272
Ondiri disease 271
production limitations 271–278, 332
pyroplasmosis 271, 273
rabies 273, 276
Rift Valley fever 271, 274
rinderpest 270–272, 276, 278
salmonellosis 274
sheep pox 278

Page
Diseases, animal—Continued
species affected 272–274
streptothricosis 274
trypanosomiasis 271–273, 277
tuberculosis 271
vibriosis 271, 276
wild animals as reservoirs of 270
Diseases, plant:
boll rot 456, 458
of cereals and flax 198, 200, 203, 210, 220
control by breeding 198, 200, 202–203, 210, 220
control by fungicides 206, 394–395
Helminthosporium blight on oats 202
losses due to, in United States 205
need for scientists in 226
problems in forest management 500
problems in tropics 226
rust 202, 392
Distribution:
of animal products 258, 262–263, 280, 286
problems of food 180–182
problems of income 182
Dominican Republic:
area of 442
land cultivated in 442
land irrigated in 442
population of 442
Draft animals, *see* Animals, draft.
Drainage:
in agricultural development 435–438, 451
cost of, in development projects 462–469
Drought, plant adaptation to 198
Dry farming, soils suitable for 413
Drying, of fish 348, 358
Duties 146, 186

## E

East Coast fever, *see* Diseases, animal.
*Echinochloa* spp 198
Echinococcosis, *see* Diseases, animal.
Economic assistance and economic development 179
Economic demand for food 178, 332
Economic development:
demographic theory of 644–645
and food demand 179
Economic feasibility, of increasing food production 649–652, 654, 660, 662–665, 671–672
Economic growth:
effects of rapid population growth on 28–30
relation to food production 652–655
Economic model, need for multisectorial, multiregional 654, 660, 662
Economics:
factors in agricultural development 492

Economics—Continued Page
need for research in, in developing countries 619, 636
role of in extension programs 235
Economy, components of a national 652–654
Ecuador:
adult height and weight in 39
cost of settlement projects in 439
import policies of 154
private livestock organizations in 290
xerophthalmia in 18
Education:
centers, need for 599–600, 611, 636, 639
in changing food habits 313
costs of 607–608
effects of rapid population growth on 28–30
extension, *see* Extension.
formal in human resource development 603–611
functions of 598, 604
lack of agricultural 607, 609–610, 612–613
level of, related to GNP and population 601, 604
need for in agricultural development 234, 236–239, 453, 492, 607, 610, 634–639
need for in animal production 287–289, 291–293
need for continuity in programs of 600, 624
need for in developed countries 623–629
need for in developing countries 238–239, 600–601, 611–614, 632
need for in marketing 542, 547–548
need for in nutrition programs 78–81, 83–86
need for in pest control 396
primary, status of 605–606
secondary, status of 606–607
status of in countries of world 601–603, 608–611, 623, 631–632
television in 631
university, status of 607, 631–632
Eggs, *see* Animal products.
Egypt:
higher education in 608
owner-operator land tenure in 517
seedbed preparations and irrigation in 399
support prices for wheat 155
El Salvador:
area of 442
cost of coastal embankment for flood control 468
land cultivated in 442
land irrigated in 442
population of 442
Elasticity, of demand for food 643, 647–649
Electrification and ground water development 448–449
Employment, problems of 30, 181–182
Endemic goiter, *see* Diseases.
"Enfant Rouge," *see* Kwashiorkor.
Entomologists, need for 225
Enzymes, use in fish preservation 359–360

Page

Ecuador:
- area of ... 442
- land cultivated in ... 442
- land irrigated in ... 442
- population of ... 442

Equine encephalitides, *see* Diseases, animal.

Erosion control, cost of in development projects ... 462–469

Ethiopa:
- cost of irrigation development in ... 465
- endemic goiter in ... 17
- xerophthalmia in ... 18

Eucalyptus ... 494, 499

Europe:
- area of ... 441
- broiler production in ... 163, 165
- desired family size in ... 33
- diet composition in ... 317
- fertility rates, changes in ... 31
- grain yields in ... 208
- horsepower availability for food production in ... 396–397
- land cultivated in ... 434–435, 441
- land irrigated in ... 441
- land potentially arable in ... 429–434
- livestock populations in ... 252–253
- livestock production in ... 163, 165
- mortality of infants in ... 33
- personnel in agricultural programs of ... 612–613
- pesticide use and yield improvement in ... 393
- phosphate reserves of ... 387
- population of ... 30–31, 261, 263, 434, 441
- potassium reserves of ... 387
- production of ammonia fertilizer in ... 384
- production of animal products ... 256–257, 259, 267, 338
- production, disappearance, and trade of agricultural commodities ... 162, 164, 166–171, 668
- projected needs for fish ponds ... 355
- projections of animal protein supplies in ... 262, 264, 267
- soil types in ... 414, 416
- trade in wheat ... 175–177

European corn borer ... 198, 231

European Economic Community (EEC) ... 148–149
- effect on farm export prices ... 668
- import duty on bananas ... 149
- price of feed grains ... 165
- value of agricultural imports from United States ... 159

European Free Trade Area ... 148

Evapotranspiration ... 411–412, 420, 439–440, 443, 457–459

Exportation, transportation requirements for ... 576–579

Export payments (subsidies) for agricultural commodities ... 143

Export prices, of agricultural commodities ... 145, 150–152, 666–669

Export taxes on agricultural commodities ... 153

Exports:
- of manufactured goods to meet food needs ... 179, 181–182
- of nonfood crops to meet food needs ... 179–181, 556

263-888 O - 67 - 48

Exports—Continued Page
projected growth of in developing countries 665
quality identification system for 545
of U.S. agricultural commodities 142, 158–160, 162, 164, 166–169
Extension:
influence on production incentives 507–508, 520, 522, 532–535
in Mexico Wheat Program 211
need for functional emphasis 233–234
need for personnel in 234, 287, 289–290, 293, 355
in relation to research and education 235–236, 620
status of, in developing countries 621–623, 633–634
successful programs in 633–634
Extension programs, requirements for 235–236, 622
Extension services:
functions of 532–535
influence of transportation on 574

## F

Family planning:
benefits of 24, 28–30, 68–69, 83
and food aid 189
need for research in 619, 629, 631, 636
size desired in selected countries 33
Farm machinery:
cost increases in United States 204
horsepower availability in relation to crop yields 396–398
horsepower availability in selected regions 396–397, 400
need for in crop production 390–391, 399–402
need for in developing countries 396–401, 676, 679, 701
need for in livestock production 286
projected capital investment for 400–401, 658, 660
use of in Japan 452
use of tractors 268, 399–400
Farm management, need for research in, in developing countries 619
Fats:
international commodity agreements on 157
livestock needs for 279, 281
supply of in diets 309
Feed:
byproducts as 248–249, 258, 265, 281–283, 292–293
cereal crops as 248–250
forages as 248–249, 265, 293
micro-organisms in production of 283–284, 365, 371
preservation and storage of 279–280
urea as 249, 281, 283
wastes as 248–249, 258, 265, 281–283, 292–293
Feed grains:
stocks of in United States 142
trends in export prices of 151
values of U.S. exports of 159–160
Fertility:
of animals, *see* Animal reproduction.
soil, *see* Soil fertility.

Page

Fertility rates, *see also* Age-specific fertility:
- adjustment of caloric requirements for 46, 69
- changes in 31–36
- estimates of in selected regions 24, 26–27
- relation to infant mortality 33, 36, 38
- relation to social structure 34–36

Fertilizer:
- application based on soil and plant analysis 204
- factors influencing farmers to use 508–509, 519
- farm machinery, for applying 399
- need for in livestock production 280–281, 286
- personnel required to supply 383, 613
- price of 154, 156, 204
- production of in India 658
- projected costs of capital investments for 384, 658, 660, 663–664
- quantity used, in world 379
- requirements for developing countries 380–382, 675–676, 678, 694–702
- reserves and production of 383–387
- subsidies on imports of 153
- transportation of 586
- use of, in crop production 197, 205, 228–231, 393–394, 456–459, 486

Fertilizer technology, improvements in 204

Finland:
- fish in food supply of 348
- protein supply of 334
- support prices for wheat 155

Fire, as a means of plant control 477–478, 485

Fish:
- annual catch in fresh waters 347–350
- annual catch in oceans 357–358
- effects of pesticides on 206–207, 214
- lipids in 358
- preservation of 348, 355–361
- projections of catch 345–347, 353–355
- as sources of protein 309, 315
- taste of different products 360
- toxicity in 356
- utilization of, in animal feed 284

Fishculture 350–355

Fishing, need for research on methods 347

Fish meal 328, 358

Fish pastes 358–359

Fish protein concentrate (FPC) 78, 355–361

Fish sauces 348, 358–359

Flatulence, in soybeans 340

Flax, rust on 198, 200

Flood control:
- coordination of plans for 453
- cost of in development projects 462–469

Flood farming, system of in tropics 488

Folacin deficiency, *see* Diseases.

Folacin requirements, *see* Vitamins.

Folic acid deficiency, *see* Diseases, folacin deficiency.

Food: Page
from micro-organisms 361–368, 370–371
prices of 152, 154, 668–669
world losses of due to pests 392
Food acceptability, need for information on 87
Food aid:
distribution of 82, 142–146, 158, 174, 180, 187–188
fortification of cereals in 321–322
of grain 163, 174, 176–178
to India 24, 180
influence on crop production programs 227
multilateral arrangements for 185
need for 183
to Pakistan 180
for public works 184
in relation to farmers' prices 183
Food availability, in relation to economic growth 645
Food chains:
efficiency in conversion 346, 351, 355
pesticides in 206–207, 214
Food consumption, *see also* Food demand:
alternate projections of in developing countries 457–458
per capita in developing countries 177–179
Food conversion:
efficiency of in animals 351–352, 354–355
efficiency of in oceans 346
Food demand:
in developing countries 158, 161, 163
estimates of increase in 178, 647
growth in 179, 644–652, 665, 671
mathematical expression of 648
relation to nutritional requirements 643–644
Food habits 306, 313–314, 325, 331–332
Food imports 177–181
Food needs, *see* Food requirements:
alternatives for meeting 178–181
Food for Peace 82, 189, 321
Food processing, food losses due to 310
Food production:
needed increases in 654–657, 665, 671
in nutrition programs 79–81, 84
per capita in developing countries 177–179
potential of tropical areas 490–497
relation to economic growth 643, 652–655
Food requirements, *see also* food consumption:
action programs for supplying 77
limitations in projections of 71–73
projections for Brazil 69, 71–73, 75–77
projections for India 69, 71–72, 74–77, 675–676, 687–702
projections for Pakistan 69, 71–72, 75–77
projections for World 69, 77, 165
Food reserves and food aid 183–184, 187–188

Page

Foods:
need for children of special 327
use of oilseeds in 336, 342–344
Food supply:
distribution of 44, 48–50, 55–56, 69
projections of 165, 170–177, 457–458
in relation to family planning 68–69
Food taboos, *see* Food habits.
Food technology, in nutrition programs 86–87
Foot and mouth disease, *see* Diseases, animal.
Forage crops:
advantages of fertilization of 230
as livestock feed 248–249, 265, 285, 292
supplementation with cereals in livestock feed 249–250, 283
Forages:
need for research on 219, 280–281
Ford Foundation 625, 629
Foreign exchange:
from agricultural exports 556
control of 154
in developing countries 151, 153, 158, 178–179, 670
need for in industrialization 181, 663–664
Forest fallow 476–477
Forest trees, nutrient cycles in 476–477
Forests:
area of by regions 498
elimination of, for food production 498
potential productivity of tropical 497–500
soil fertility in 481
Fortifex 78
Fortification:
with amino acids 51, 68, 77, 317–321, 324
of cereals 305, 308–309, 316–329
costs of cereal 320–321, 324
effect of on nitrogen balance 318
with fish protein concentrate 320–321
with iodine 77
planning a program of cereal 322–323
techniques of cereal 319–322
use of soybeans in 320, 342
with vitamins 62, 66–77
Fowl plague, *see* Diseases, animal.
FPC, *see* Fish protein concentrate.
France:
import duty on bananas 149
mileage of access roads in 582
production of natural gas in 384
research and education programs in 626
trade in wheat 155, 175–176
trends in retail prices of foods 668
Freedom From Hunger Campaign 79
Fruit:
iron deficiencies in 204

Fruit—Continued Page
losses in marketing channels 550–551, 555
market quality standard for 544
as source of cellulose 365
as source of vitamin A 62
as source of vitamin C 65
utilization of byproducts in poultry feed 249, 282–283
values of United States exports of 159–160
zinc deficiencies in 204
Fruit, bananas:
as basic crop for developing countries 219, 230
exports of 151
growth of 487, 489
import duty on 146, 149
international commodity agreements on 157
Fruits, citrus:
international commodity agreements on 157
overfertilization of 204
Fumigants, *see* Pest control.
Fungi, *see* Micro-organisms.
Fungicides, *see* Diseases, plant, control.
*Fusarium* 553

## G

Gametocides, for insect control 207
General Treaty of Central American Economic Integration, Latin America 154
Genetics, plant, *see* Plant breeding.
Germany:
import duty on bananas 149
trade in wheat 175–176
trends in retail prices of foods 668
Germ plasm, *see* Plant breeding.
Ghana:
cacao in mixed tree crop system 487
desired family size in 33
higher education in 608
mortality of infants in 33
soil fertility, in forests 481
Glossitis, *see* Diseases.
Goats, *see* Livestock.
Goiter, endemic, *see* Diseases.
Gossypol 199, 339, 343, 564–565
Government:
agricultural policy 142–158
participation in Mexico Wheat Program 211
policy in animal production 261, 263, 265, 286, 290–291
policy, influence on production incentives 513, 516, 518–520, 525–526
role of, in developing protein food products 565–566
role of, in developing transportation systems 583–584, 587–588, 590
role of, in marketing 542–548, 561
role of, in research and education 615–616, 637–639
role of, in seed production 390–391
Grades, in marketing 544–545, 561
Grapes, *see* Fruit.

Page

Grass:
- iron deficiencies in 204
- productivity of, in tropics 477

Greece:
- area of 441
- cost of irrigation development in 449
- fish in food supply of 348
- GNP of 647
- imports in 146, 149
- land cultivated in 441
- land irrigated in 441
- per capita income of 647
- population of 441
- support prices for wheat 155

Gross national product (GNP):
- of developing nations 646–647
- and education 601, 604
- fraction of, in capital investment 658, 660
- increases in, to meet food demand 174, 643, 649–651
- required growth of, in developing countries 665, 671

Groundnuts, *see* Oilseeds, peanuts.

Ground water:
- cost of development of 448
- extent of reserves of 446–447
- for irrigation development 446–449
- use of, in Texas 459

Guatemala:
- area of 442
- cost of agricultural development projects 436–437, 439
- cost of roads in 437
- cost of settlement projects in 435, 439
- distribution of food in 75
- land cultivated in 442
- land irrigated in 442
- population of 442
- protein food products developed for 563

Guiana, birth and death rates in 36

## H

Haiti:
- area of 442
- cost of irrigation development in 467
- land cultivated in 442
- land irrigated in 442
- population of 442

Hake, as source of FPC 360

Hardpan, in soils 414

Hawaii:
- cost of agricultural development in 460
- cost of irrigation development in 465
- cost of land development in 463
- cost of sugar cane development project in 460
- yield of sugar cane in 490

Page
Hay ..... 205, 280–281
Helminthosporium blight, resistance of oats to ..... 202
Hemagglutinin factor ..... 339
Hemorrhagic septicemia, *see* Animal diseases.
Herbicides, *see* Weed control.
Herbivores, food conversion efficiency in oceans ..... 346
Hessian fly, control by plant breeding ..... 198, 200
Heterosis, *see* Plant breeding.
Histidine, *see* Protein, amino acids.
Hog cholera, *see* Animal diseases.
Hogs, *see* Livestock, swine.
Honduras:
  area of ..... 442
  land cultivated in ..... 442
  land irrigated in ..... 442
  population of ..... 442
  yield increases in potatoes ..... 229
Horses, *see* Livestock.
Hungary, fertility rates in ..... 31
Hybridization, *see* Plant breeding.
Hybrid vigor, *see* Plant breeding.
Hydatidosis, *see* Diseases, animal, echinococcosis.
Hydrocarbons;
  cost of microorganism production on ..... 362, 364
  in fertilizer production ..... 383–384
  microorganism production from ..... 361–362
  utilization of, in animal feed ..... 283
Hydrocyanic acid, *see* Prussic acid.
Hypovitaminosis A, *see* Diseases, xerophthalmia.

## I

Iceland, fishery catch of ..... 357–358
Illiteracy ..... 28–30, 603
Import licensing, to control foreign exchange ..... 154
Import policy, agricultural of United States ..... 146–148
Imports:
  of agricultural commodities by EEC ..... 149
  of agricultural commodities by selected countries ..... 146–147, 285
  of grain ..... 160–161
Incaparina ..... 78, 81, 343, 633
Incentives:
  in agricultural production ..... 507–535
  in animal production ..... 261, 263, 286
  influence of markets on ..... 572, 575–576
  quality identification systems as ..... 545, 561
  relation of prices to farmers ..... 151
Income:
  distribution ..... 182
  effect on food consumption ..... 42–44, 69, 72, 163, 179, 309–311, 331
  effect of on food demand ..... 643, 645–649
  per capita, in developed countries ..... 20, 160, 645
  per capita in developing countries ..... 20, 161, 163, 178, 179, 645–649

India: Page
adult height and weight in 39
age-distribution of population in 25
all-India crop schemes 223, 225
area of 441, 447
calcium requirements for 58, 64–65
cost of agricultural development in 450, 460, 461
cost of water and land development in 449–450, 463, 465
crop losses due to pests 213, 232
desired family size in 33
draft animal use in 263, 265, 268
estimates of irrigation potential of 399, 443–444, 446–447
export taxes on agricultural commodities 153
farm storage of grains and pulses in 551, 557
fertility rates 26
fertilizer production in 658
financial support for research in 617–618
fishery catch of 357–358
food aid to 24, 180
food demand in 650
food prices in 152
food requirements for 69, 71–72, 74–77, 645–646, 675–711
forest management in 499
fresh-water fisheries in 349
GNP of 646–647
ground water development in 448–449
higher education in 608
improvement of cereal varieties in 199, 215–217, 219, 225, 231, 255
improvement of livestock production in 263–266, 285, 292
improvement of poultry production in 266, 285
increased food grain production in 208–209, 216, 223, 229
influence of religion on food resources 556
land arable in 28, 447
land cultivated in 441
land irrigated in 441
mixed tree crop systems in 487
mortality of infants in 33
nutrition programs in 81
owner-operator land tenure in 517
per capita income of 645, 647
personnel needs for in agricultural programs 612
pesticide use and yield improvement in 393
population of 441
potential for wild animal production 270
preservation of food by canning in 561
price of fertilizer in relation to commodity 156
primary education in 606
production of oilseeds 339, 442
projections of caloric requirements for 45–48
projections of population in 22, 24–28
projections of protein requirements for 50, 53–55, 68
protein food products developed for 563
protein supply in 310, 334, 341
pulse research center in 218

India—Continued Page
ratio of extension workers to farmers in 622
refrigeration in potato preservation 559
relation of research to extension 620
research and education programs in 619, 629, 631
role of cattle in 263–265
rural population in 541
status of agricultural research in 615
storage losses of food in 551–555
sugar in food supply of 75
support prices for wheat 155
trade in rice 176
transportation program for 589–592
variations of rainfall in 443
vitamin requirements for 58–62
water runoff in 447
xerophthalmia in 18, 61
yields of major food crops in 208–209, 229
Indian subcontinent:
area of 443
water needs in 441–445
Indicative World Plan 157, 654
Indonesia:
area of 441
desired family size in 33
fish production in 349, 351, 353
land cultivated in 441
land irrigated in 441
mortality of infants in 33
population of 441
potential for wild animal production 270
production of oilseeds 339
soybean milk in 632
yields of oil palm in 491
Industrial production, relation to food production 643
Industrialization:
in developing countries 181–182, 670
need for in modern agriculture 492–493
Infant diseases, *see* Children.
Infant food requirements, *see* Children.
Infant mortality:
developed countries 21
developing countries 21
relation to birth control 35, 38
reduction of in relation to economic growth 644–645
relation to malnutrition 38
Infectious diseases, *see* Diseases.
Insect control:
biological control 206, 233
cultural control 231
with increased irrigation 456
insecticides in livestock production 286
insecticides requirements for 394–395
insecticides, undesirable side-effects of 206–207, 214

Insect control—Continued Page
insecticides, use in United States 206, 214
need for scientists trained in 225
by plant breeding 198, 200, 207
problems in tropics 226
in storage facilities 559–561
Insecticides, *see* Insect control.
Insects:
food losses due to 310
losses caused by in marketing channels 550–554, 558
losses due to in India 213
losses due to in Pakistan 213
losses due to in United States 205
problems in forest management 500
Institute of Nutrition for Central America and Panama 85, 312, 318, 343
Inter-continent transplant, principle of 494
International Coffee Organization 157
International commodity agreements 156–158
International Rice Research Institute 176, 212, 215, 225, 226, 230, 625, 639
Intestinal parasites 13, 17, 66, 86
Iodine:
deficiency, *see* Diseases, endemic goiter.
fortification of foods with 77, 323–324
requirements 66
in soils, *see* Soils, micro-nutrients.
Iran:
area of 441
cost of sugar cane development project in 460
cost of water and land development in 449, 463
food prices in 152
land cultivated in 441
land irrigated in 441
population of 441
production of natural gas in 384
pulse research center in 217–218
use of improved seeds in 388
Iraq:
area of 441
cost of sugar cane development project in 460
cost of water and land development in 449, 464
land cultivated in 441
population of 441
Ireland, protein supply of 334
Iron:
in cereal fortification 322–324
deficiency, *see* Diseases.
deficiency in crops, *see* Micro-nutrient deficiencies.
requirements 66–67
Irradiation, in plant breeding 202, 203
Irrigation:
in agricultural development 435–438, 450–454
cost of development of 435–439, 449–450, 462–469
efficiency of use of 457–460
and evapotranspiration 420–422, 439–440, 443, 457–459

Irrigation—Continued Page
ground water for in West Pakistan 461, 661–662
historical record of 440
increased requirements for, in India 676, 691, 700–702
influence on production incentives 522–523
need for research on problems of 452
one of inputs for agriculture 454–460
land areas by continent and country under 440–443
needed on arable land 421–422, 434–435, 441–443
potential of 443–446, 493–494, 661
in relation to seed bed preparation 399
water supplies for 439–454
Isoleucine, *see* Protein, amino acids 52
Israel:
area of 441
cost of irrigation development 438
damaged grains in fishcultures 351
efficient livestock operations in 262
food prices in 152
ground water development in 448
imports of agricultural commodities 146
improved oats in 220
land cultivated in 441
land irrigated in 441
leaf protein in chicken feed 369
population of 441
trade in grain 176–177
Italy:
agricultural development in 497
fresh-water fisheries in 349
production of natural gas in 384
trade in wheat 155, 175–176
use of television in education in 631
Ivory Coast, evaluation of nutrition programs in 81

## J

Jamaica:
desired family size in 33
higher education in 608
mortality of infants in 33
multiple cropping of corn in 226
Japan:
agricultural policies of 148, 150, 155
area of 441
broiler production in 165
desired family size in 33
effects of nutrition on population height and weight 46
farm implement use in 452
fertility rates in 31
fish in food supply of 348
fishery catch of 349, 351, 357–358
land cultivated in 441
land irrigated in 441

Japan—Continued Page
livestock operations in 254
mileage of access roads in 582
mortality of infants in 33
owner-operator land tenure in 517
per capita income and food consumer 309
pest control in 213–214, 393
population of 21, 441
price of fertilizer in 156
price policies in 525–526
production of ammonia fertilizer in 384
production, disappearance, and trade of agricultural commodities 159, 162, 164, 166–171, 175–177
protein supply in 341
ratio of extension workers to farmers in 622
soil types in 416
source of dwarf wheat varieties 199, 216
use of improved seeds in 388
yield of major food crops in 208–209
Java, poultry production in 254
Jordan:
area of 441
cost of coastal embankment for flood control 469
cost of water and land development in 464
improved seeds in 388
land cultivated in 441
land irrigated in 441
population of 441
xerophthalmia in 18, 61
Jute 151, 153, 181, 527

## K

Kellogg Foundation 626
Kennedy Round 148, 157
Kenya:
corn improvement program in 221–222, 225
cost of agricultural development projects 435–436
cost of irrigation development 435, 465
foreign personnel in agricultural programs of 611–612
livestock operations in 254
Keratomalacia, *see* Diseases, vitamin A deficiency 16
Klamath Weed 233
Korea, xerophthalmia in 18
Korean lespedeza, control of root-knot nematode 199
Kuwait, production of natural gas in 384
Kwashiorkor, *see* Diseases.

## L

Labels, in marketing 544–546
Labor-intensive, agricultural development 436
Lactation, *see* Pregnancy.
Lakes, production of fish in 349, 353–354

Land: Page
arable in India 28
area of grazing by continent 483
area irrigated in tropics 493
area of in tropical climatic regions 475–476
consolidation of 488–489
cultivated by continent and area per person 434
cultivated presently 428
development, cost of 435–439, 449, 460–469
drainage, cost of 439
forests, area by regions 498
grazing in agroclimatic regions 427–428
grazing in climatic zones 423, 427–428
grazing in soil groups 423
harvested area 428–429, 434–435
irrigated areas under cultivation 440–443
nonarable 423
nonarable in agroclimatic regions 427–428
nonarable in climatic zones 423, 427–428
nonarable in soil groups 423
nonarable, utilization of, in animal production 248, 255, 258, 261, 280–281, 332–333, 423, 429, 434
ownership, *see* Land tenure.
potential of irrigated, by continent 443–446
potentially arable in agroclimatic regions 427–428, 432–433
potentially arable in climatic zones 423, 427–428, 431, 482
potentially arable, by continent 428–434, 483
potentially arable, in soil groups 423, 430
protein production per unit area 336
settlement, cost of 439
Land tenure:
in animal production 286
influence on production incentives 514–521, 508, 509–512
systems of 515–519, 521
Laterites, in soils 415, 476, 480
Latin America:
composition of diet in 317
corn as source of niacin 61
cost of roads in 438
distribution of food in 74–75
draft animal use in 268
endemic goiter in 17
farm machinery requirements in 400–401
GNP of 647
high protein vegetable products in 633
horsepower availability in 396–397
improvement of livestock production in 261, 284–285
improvement of sorghum varieties in 217, 225
iron availability in diets in 67
land grazing in tropics, by soil groups 483
land potentially arable, by soil groups 483
livestock populations in 252–253, 258
malnutrition in children of 14
mortality rates in preschool children 13

Latin America—Continued Page
oilseed production in 339
per capita income of 645, 647
personnel in agricultural programs of 612–613
pesticides 393
population density, in 21
potential for wild animal production 270
prices internal for agricultural commodities 151
primary education in 606
production of animal products 256–259, 338
production, disappearance, and trade of agricultural commodities 162, 164, 166–171, 176–177
projected needs for fish ponds 355
projections of animal protein supplies in 258, 262, 264
projections of population in 22, 30–31, 261, 263
seed and processing plant requirements in 388–389
trend of farm export prices from 667–668
universities offering agricultural education in 632
use of fertilizer in 228, 379
xerophthalmia in 61
Latin American Common Market 154
Latin American Free Trade Area 154, 156
Leaching, of soils in tropics 474–475
Leaf protein, as food source 368–370
Lebanon:
area of 441
land cultivated in 441
land irrigated in 441
population of 441
Legumes, as source of protein 309
Lentils, *see* Pulses.
Leucine, *see* Protein, amino acids.
Leveling, cost of in development project 462–469
Libya:
production of natural gas in 384
protein supply of 334
Lignin, as livestock feed 258
Lime, to reduce soil acidity 380
Limited good, doctrine of 513–514, 520
Lipid, content of leaves 369
Lipids, extraction of in FPC preparation 358–359
Lipoprotein, of peanuts 344
Livestock:
buffalo, potential for improvement of 265, 268
bullocks 263, 265, 268, 397
cattle, areas suitable for production 331
cattle, EEC prices on 148, 149
cattle, productivity of in regions of world 251, 267
cattle, role of in India 263–265
diseases, *see* Diseases, animal.
efficiency of food conversion in 249–251, 333, 337, 352
import duty on 146–147
importation of, into developing countries 285
need for water 284

Livestock—Continued Page
nutrition requirements of 14, 279–281
population of species by regions 251–253, 261, 265–266
production, need for data on 86
production of, in selected countries 165, 254, 262
production, use of grains in 163, 165
production of protein per acre 336
sheep, areas suitable for production of 331
swine, increased gains from improved corn genotypes 224
urea and forages as protein feed source 249
prussic acid poisoning 199
as source of power 268
Lumpy skin disease, *see* Diseases, animal.
Lysine, *see* Protein, amino acids.

## M

Machinery, farm, *see* Farm machinery.
Madagascar, rice production in 497
Magnesium:
cycles of in forest trees 477, 481
deficiency, *see* Diseases, mineral deficiencies.
deficiency in soils 481
requirements 67
Maize, *see* Cereals, corn.
Malawi, corn yield from improved varieties 216
Malaya:
forest management in 499
height and weight of adults in 39
mileage of access roads in 582
soybean milk in 632
Malaysia:
improved rice varieties in 215
private-government ownership of rubber plantations 490
xerophthalmia in 18
Mal de caderas, *see* Diseases, animal, trypanosomiasis.
Male-female ratio, in human population 39–42
Male sterility:
for insect control 207
in plants 200–202, 203
Malnutrition:
in animals 14, 279
in children 10, 12–14, 312
diseases caused by, *see* Diseases.
effects on health, work efficiency, and social attitudes 12, 303–304
extent of 10, 17, 82, 316
prevention of 78–79, 564
protein in pregnant women and nursing mothers 312–313
relation to income level 42–44
relation to infant mortality 38, 310
relation to infection 312
relationship to protein quality 302
in urban areas 303
Malvalic acid, in cottonseed 339

Page

Management:
in crop production 198, 204–205, 210–213, 223, 229, 232, 236, 379, 392
of fresh-water fisheries 349–355
in livestock production 251, 254–255, 256, 258, 261, 262–263, 267, 280–281, 293
of tropical forest 497–500
Manganese deficiencies in crops, *see* Micronutrients, deficiencies.
Mangoes, *see* Fruits.
Manpower, *see* Personnel.
Manure, *see* Animal wastes.
Marine, *see* Oceans.
Marketing:
and agricultural production 507, 521
of animal products 258, 262–263, 286, 333, 549–550, 555
consumer's role in 541
food losses in 549–555
of high protein food products 566
influence on production incentives 510, 520, 522, 531, 532, 572, 576
information system in 542, 546–547
quality identification system in 542, 543–546, 561
refrigeration in 585, 586
research and education in 542, 547–548, 619, 636
role of government in 542–548, 561
role of private enterprise in 548–549, 561, 562
of seed 390
storages in 542, 547, 554–557, 559–563, 575
in a subsistence economy 541
system in United States 540
transportation in 543, 555, 558, 562–563, 572–574, 575
Marketing boards 153
Marketing centers, need for transportation to 575, 580, 586–587
Mastitis, *see* Diseases, animal.
Mauritius:
birth and death rates in 36
protein supply of 334
Measles, *see* Diseases.
Meat, *see* Animal products.
Meat scraps, *see* Animal byproducts.
Mehlnahrschaden, *see* Diseases, kwashiorkor.
Mekong River, irrigation project of 493
Methionine, *see* Protein, amino acids.
Mexico:
area of 441
corn improvement program in 221–223, 225
diet composition in 317
financial support of research in 618
food demand in 650
food prices in 152
higher education in 606
improved seeds in 388
land cultivated in 441
land irrigated area in 441
multiple cropping of corn in 226

263-888 O - 67 - 49

Mexico—Continued Page
population of 441
potato improvement program in 223
poultry operations in 254
primary education in 606
private livestock organizations in 290
production, disappearance, and trade of agricultural commodities 162, 164, 166–171
production of natural gas in 384
production of oilseeds 339
sorghum improvement program in 223
status of agricultural research in 614–615, 617, 620
swine operations in 254
transportation system in 543
universities offering agricultural education in 632
wheat production in 199, 210–211, 213, 216, 230
wheat storage in 557
Mexico Wheat Program 210–211, 216, 223, 225, 230, 627–629
Micronutrient deficiencies 204, 230–231, 281, 481
Micro-organisms:
control of, in storage facilities 559–560
cost of production for food 362–364, 367, 371
in fish preservation 359–360
food losses due to 310, 550, 552–554, 557, 558
production of for feed 283–284
production of for food 328, 361–368, 370–371
toxic metabolities of 365
Milk, *see* Animal products.
Milkfish 352
Millet, *see* Cereals.
Mill wastes, *see* Plant wastes.
Minerals:
content of in cereals 323
fortification of foods with 564
requirements of 67, 329
requirements supplied by soybeans 218
Mohair, *see* Animal products.
Moisture, in agroclimatic regions, *see* Agroclimatic regions.
Molasses, *see* Plant byproducts.
Molybdenum, *see* Micronutrient deficiencies.
Monsoons, need for studies of 453–454
Morocco:
cost of agricultural development projects 436
cost of water and land development in 464
support prices for wheat 155
Mortality:
infant, relationship to birth control 35, 38
relation to malnutrition in children 38, 310
Mortality rates 24
estimates of 24
of preschool children, in selected countries 13, 17, 21, 33, 312
Mules, *see* Livestock.
Mullet 352
Mutagens, in plant breeding 202, 203

Page
Multiple cropping 434, 440
Multiple purpose food 78
Mungbeans, *see* Pulses.
Mushrooms, as food source 365
Mycotoxins 552–554

## N

Nagana, *see* Diseases, animal, trypanosomiasis.
Nairobi sheep disease, *see* Diseases, animal.
Natural gas, production of in selected countries 384
Nematodes, control by plant breeding 198–199
Nepal:
area of 441
land cultivated in 441
land irrigated in 441
population of 441
Netherlands:
improved seeds in 388
research and education programs in 626
support prices for wheat 155
Newcastle disease, *see* Diseases, animal.
New Guinea, sweet potatoes in food supply 368
New Zealand:
agricultural policies of 148
exports of cereals from 20
forest management in 499
land areas in tropical climatic regions 475
land cultivated in 434–435
land grazing in tropics by soil groups 483
population of 434
potentially arable land in 429, 434
potentially arable land in by soil groups 483
protein supply of 334
soil types in 416
Niacin, requirements, *see* Vitamins.
Niacin-tryptophan deficiency, *see* Diseases.
Nicaragua:
area of 442
land cultivated in 442
land irrigated in 442
population of 442
Nicotinic acid, in cereal fortification 322–324
Nigeria:
corn yield from improved varieties 216
cost of agricultural development projects in 436
export prices on peanuts and oil palm 153
food prices in 152
forest management in 499
higher education in 608
poultry production in 254
primary education in 605
production of natural gas in 384

Nigeria—Continued Page
production of oilseeds in 339
protein food products developed for 563
sorghum yield from improved varieties in 217, 225
xerophthalmia in 18
Nitrogen, *see* Fertilizer.
cycles in forest trees 477, 481
and irrigation 456–458
retention of fortified foods 317–318
Nomadic gathering, systems of in tropics 490
North America:
area of 441
composition of diet in 317
export prices 668
fertilizer reserves of 387
land areas in tropical climatic regions 475
land cultivated in 434–435, 441
land irrigated in 441
land potentially arable in 429–434
livestock populations in 252–253, 266
population of 434, 441
production of animal products 256–257, 259, 267
production of oilseeds 339
projected needs for fish ponds 355
projected supplies of animal protein in 262, 264, 267
projections of populations in 30–31, 261, 263
protein production of cattle in 338
soil types in 413–414
wheat and rice yield increases in 208
Norway:
fishery catch of 357–358
fish in food supply of 348
Nuclear energy, for agricultural development 449
Nutrients:
cycles in forest trees 476–477, 481
plant, *see* Fertilizer.
Nutrition:
animal, improvement of 261, 279–281, 293
need for research on 86–87, 619
plant, *see* Plant nutrition.
protein in 302–307, 314, 330, 335–345, 366, 368, 370
relation to income level 42–44
relation to mental development 86
Nutrition programs:
in developing countries 79–83
evaluation of 80, 88
planning of 78, 88–89, 325–329
relation to societal conditions 305, 313
role of United States in 87–89
training centers for 85
Nutrition surveys 16, 79–80, 82, 88
Nutritional requirements:
factors affecting 38–42
need for data on 87, 325–326

## O

Page

Oatmeal, protein production per acre ..... 336
Oats, *see* Cereals.
Oceania:
  fish processing in ..... 348
  land areas in tropical climatic regions ..... 475
  livestock populations in ..... 252–253, 266
  need for personnel in agricultural programs of ..... 612–613
  pesticide use in ..... 393
  production of animal products ..... 256–257, 267–338
  production, disappearance, and trade of agricultural commodities ..... 162, 164, 166–171
  projected populations in ..... 30–31, 261, 263
  projected supplies of animal protein in ..... 262, 264, 267
  wheat and rice yield increases in ..... 208
Oceans, fishery potential of ..... 345–347, 356–357
Oil palm:
  export prices in Nigeria ..... 153
  in mixed tree crop system ..... 487
  in shifting cultivation ..... 497
  yield of ..... 411, 491
Oils, edible, in food requirement projections ..... 70
Oilseeds:
  absorption of insecticides by ..... 207
  export of ..... 143, 159–160
  as fish food supplement ..... 351–352, 354
  in high protein food products ..... 68, 218, 564, 632
  import duty on ..... 146–147
  international commodity agreements on ..... 157
  as livestock feed supplement ..... 165, 250, 265, 283
  losses to pests in marketing channels ..... 205, 550–552, 554
  mycotoxins in ..... 553–554
  need for production of ..... 77, 342
  oil content of ..... 339
  as poultry feed supplement ..... 249, 282–283
  processing as food ..... 339, 342–344
  protein content of ..... 218, 309, 315, 336–345
  protein production per acre ..... 336
  world production of ..... 339–341
Oilseeds, cottonseed, gossypol in ..... 199, 343
Oilseeds, peanuts:
  amino acids in ..... 315, 344
  as basic crop for developing countries ..... 219
  "groundnut" project, British ..... 479, 495
  stocks of in U.S ..... 142
  yields in selected countries ..... 209
Oilseeds, sesame meal, amino acid composition of ..... 315
Oilseeds, soybean meal, amino acid composition of ..... 315
Oilseeds, soybeans:
  adaptation to photoperiod by plant breeding ..... 198, 218
  as basic crop for developing countries ..... 219
  control of nematodes ..... 199
  effects of fertilizer on yields ..... 197
  in multiple cropping system ..... 233

Oilseeds, soybeans—Continued Page
nutrient composition of 328
production, disappearance and trade of 151, 165, 168–169, 341
yields of different varieties 218–219
yields in selected countries 196–197, 209, 217–218
Oilseeds, soy products, types of 340–341
Olive oil:
import duty on 146
international commodity agreements on 157
Ondiri disease, *see* Diseases, animal.
Osteomalacia, *see* Diseases, mineral deficiencies.

## P

Packaging, for product shipping and marketing 579, 581, 586–587
Pakistan:
adult height and weight 39
area of 441, 447
cost of agricultural development in 448, 461
cost of coastal embankment for flood control 469
cost of fertilizer in 156
cost or irrigation development in 448, 450
crop production in 208–209, 211–212, 394, 662
desired family size in 33
draft animals in 268
extension programs in 633
fertility rates in 26
fisheries in 349
food aid to 180
food demand in 650
food prices in 152
food requirements for 69, 71–72, 75–77, 645–646
GNP of 646–647
development of ground water in 447–449, 661–662
improved seeds in 388
improved wheat and rice varieties in 199, 211–212, 215–216
infant mortality in 33
irrigation potential of 444, 446–447, 452
land cultivated in 441
land irrigated in 441
per capita income of 645, 647
population of 25, 441
population estimates, in 22, 24–28
potentially arable land in 447
poultry production in 254
projections of calcium requirements for 58, 65
projection of caloric requirements for 45, 48–49
projection of protein requirements for 50, 53, 55–56
protein supply of 334
rice losses due to pests 213, 231
support prices for wheat 155
vitamin requirements for 58–62
water runoff in 447
xerophthalmia in 18–61

Page
Pakistan, West, Third Plan of 662
Pakistan Wheat Program 211–212, 216, 223
Palm nut, *see* Oilseeds.
Pan-American Foot and Mouth Disease Center 276
Panama:
area of 442
cost of coastal embankment for flood control 468
land cultivated in 442
land irrigated in 442
population of 442
Pantothenic acid deficiency, *see* Diseases, vitamin deficiencies.
Pantothenic acid requirements, *see* Vitamins.
Papain, in fish preservation 360
Papaya, *see* Fruit.
Paper, waste as source of cellulose 365
Paraguay:
area of 442
land cultivated in 442
land irrigated in 442
population of 442
Parasites, animal 258, 270, 276, 332
Pea aphid, control by plant breeding 198
Peanuts, *see* Oilseeds.
Pellagra, *see* Diseases.
*Penicillium* 553
Personnel, need for in:
agricultural programs 611–614, 616–617
animal production 287–289, 291, 293
developing high-protein food products 565
extension 621–622
fertilizer production 383
fisheries 355
food processing and distribution 563
irrigation development 450–455
pest control 395
research 616–617
seed production 391
teaching 605–607
Peru:
area of 442
cost of agricultural development in 461
cost of settlement projects in 439
cost of water and land development in 463, 464, 468
cotton insect control in 214
extension programs in 633
financial support of research in 618
fishery catch of 357–358
high-protein food products in 563, 567
high-protein food products developed for 563
irrigation projects in 493
land cultivated in 442
land irrigated in 442
malnutrition in children of 14

Peru—Continued Page
population of 442
poultry production in 254
private livestock organizations in 290
protein supply of 334, 341
research and education programs in 629
xerophthalmia in 18
Pest Control, *see also* Insect control; Diseases, plant control; Weed control:
in improving crop production 392–395
need for in future 214–215, 220, 232
need for personnel in 225–226, 395, 613
need for research in 395–396, 619, 636
problems in tropics 226
in storage facilities 559–560
Pest control, pesticides:
equipment for application of 399
manufacturing of 396
need for 208, 214–215, 220, 231, 392
in preventing storage losses 555, 557–560
projected costs of 393, 395, 402, 658, 660
requirements for, in Asia, Africa, Latin America, and India 393–395, 676, 678, 701–702
return from use of 206, 214, 392–395
undesirable side-effects of 206–207, 214
Pesticides, *see also* Insect control; Weed control; Disease plant control.
Pest Management 207, 215
Pests:
biological control of 198, 200, 207, 220, 233, 392
cultural control of 231
losses in marketing channels 550–555, 557–558
losses to, in India 213
losses to, in Pakistan 213
losses to, in United States 205
losses to, in world 392
plant breeding for control of 198–200, 207, 219–220, 392
Phenylalanine, *see* Protein, amino acids 52
Philippines:
area of 441
beriberi in 18
cost of irrigation development in 467
desired family size in 33
food prices in 152
fresh-water fisheries in 349
fish in food supply of 348
fish production in 351
graduate training in 239
land cultivated in 441
land irrigated in 441
land tenure and fertilizer use 519
mileage of access roads in 582
mortality of infants in 33
nutrition programs in 81
population of 441
price of fertilizer 156

Philippines—Continued Page
production of cereals in 215–216, 223, 226, 394
protein supply of 334
ratio of extension workers to farmers in 622
trade in rice 176
Phosphorus:
availability in soils 481, 486, 491
cycles in forest trees 477, 481
Phosphorus deficiency, *see* Diseases, mineral deficiencies.
Phosphorus fertilizer, *see* Fertilizer.
Photoperiods, adaptation to, by plant breeding 198, 210, 218–219
Pigeonpeas, *see* Pulses.
Pigs, *see* Livestock, swine.
Pineapple, *see* Fruit.
Pine, Monterrey, transplant of from California 494
*Pinus*, management of in tropical forests 499
Pirosplasmosis, *see* Diseases, animal.
PL 480, *see* Food aid.
Plantains, protein content of 315
Plant analysis, as aid in crop fertilization 204
Plantation cropping, systems of in tropics 489–490
Plant breeding:
of barley, for malting quality 199
of corn for improved protein content 224, 309, 329–330
for crop production improvement 197–204, 209–210, 215–225, 232, 456
for disease control 198, 200, 202–203, 210, 216, 219–220
for dwarf plant production 199, 210, 231, 233
emphasis on, in developing countries 619
of forage crops 219
germ plasm alteration 202–203
germ plasm, availability of desirable 198–200, 202–213, 215–225
hybridization, in improving plant varieties 198–204
for insect control 198, 200, 207, 216, 219
in Kenya's corn improvement program 221–222
for lowered coumarin in sweet clover 199
for lowered gossypol in cotton 199
for lowered prussic acid 199
in Mexico's corn improvement program 221–222
need for scientists trained in 220, 223, 225
for nematode control 198–199
polyploidy in 203
of pulses 217
requirements for national programs in 220
of sorghum 217
variety trials, need for 230
Plant byproducts:
as livestock and poultry feed 248–249, 258, 265–266, 281–283, 292–293
molasses, for micro-organism production 362
Plant diseases, *see* Diseases, plant.
Plant genetics, *see* Plant breeding.
Plant nutrients, *see* Fertilizer.
importance of research on 204, 223
Plant pathologists, need for 226
Plant protection, *see* Pest control.

Plant protein, *see* Protein.
Plant wastes: Page
in fish culture 350–351
as livestock and poultry feed 248–249, 258, 265–266, 280–283, 292–293
Poland:
area of 441
fertility rates in 31
land cultivated in 441
land irrigated in 441
land tenure in 518
population of 441
Polycarencil infantile, *see* Diseases, kwashiorkor.
Polyploidy, in plant breeding 203
Ponds:
fresh-water culture of fish in 348
production of fish in 348, 350–351
projections for new fish 354–355
Population:
changes in geographic distribution 30
by continents 434
density in selected countries 21
projections of 21–31, 261, 263
related to education and GNP 601, 604
Population and animal protein supplies 255, 258, 261–264
Population control, need for research in 619
Population growth:
effects of rapid 28–30, 647–649
in India 676–677, 680–685
in selected countries 20, 22, 24, 27, 656
Port facilities, need for adequate 578
Portugal, fish in food supply of 348
Potash fertilizer, *see* Fertilizer.
Potassium, cycles in forest trees 481
Potassium fertilizer, *see* Fertilizer.
Potatoes:
as basic crop for less developed countries 219
in food requirement projections 70–72
losses due to pests in India 205
Mexico's production improvement program 223
protein content of 315
shifting cultivation of 485–486
yields in selected countries 209, 229
Poultry:
feed, use of leaf protein for 369
food conversion efficiency of 249–251, 333–337, 352
importation of, into developing countries 285
potential for improvement of production in developing countries 266, 279, 285
production of 254, 338, 340
protein production per acre 336
Poultry products, *see* Animal products.
Power supply, cost of in development projects 462–469
Pregnancy:
in animals, *see* Animal reproduction.

Pregnancy—Continued Page
calcium requirements during 64
caloric requirements during 42, 46
niacin requirements during 60
protein requirements during 42, 51, 312
riboflavin requirements during 59
Vitamin A requirements during 62
Preservation of animal products 258, 262–263, 280, 286, 332, 559–560
Preservation of fish 348, 355–361
Preservation of food:
by dehydration in 557, 560–561
by heat sterilization 559
in marketing system 541–542, 547, 549–563
by radiation in 559–560
by refrigeration 558–560, 562
Price, systems for sugar 147–148
Price supports 143, 147, 154
Prices:
of agricultural commodities by EEC 148–149
effect of food aid on 183–184
influence of, on marketed surplus 529–532, 654
influence of quality identification systems on 545, 561
international of farm products 143
as production incentives to farmers 212, 508, 510, 523–532
Private enterprise:
in developing protein food products 566
in developing transportation system 587–588
inclusion in agricultural development 496–497
Processing, *see also* Preservation.
of oilseeds for food 344–345
Processing plants:
advantages of large scale 555, 562–563
for fish 355–358
for high-protein food products 565
foor seed 388–389
Production:
estimates of grain 158–177, 655, 657
potential of fresh-waters 353–355
potential of grazing animals in agroclimatic regions 429, 434
potential of oceans 345–347, 356–357
potential of tropical forests 497–500
potential of tropics 492–493
relationship of agricultural output to overall 643
of vegetation in tropics 477, 481
Production function, need for empirical estimate of in national economy 653
Production inputs, economic considerations of 661
Pro-nutro 78
Protein:
animal, projected supplies of, by regions 255, 258, 261–264, 266–267
content of cassava 368
content of fish 356
content of foodstuffs 315, 328
content of leaves 368–369
content of soilseeds 339–340

Protein—Continued Page
content of pulses 217
content of sweet potatoes 368
FAO reference 50, 54–57
local production of 327
microorganism production of 283–284, 361–368, 370–371
net protein utilization (NPU), definition of 50
in nutrition programs 302–307
nutritive quality of 50, 68, 314–315, 317–318
production of by animals 249–251, 338, 340
production per unit area of land 336
production of in world 338, 340
quality, of animal products 331
quality, effect on nitrogen retention 317–318
quality, improvement by genetic means 309, 329–330
quality of related to amino acid composition 200, 216, 224–225, 302, 314–315
supplements in livestock feeds 163, 249, 281, 283
supply of in diets 308–311, 316–317, 338–341
supply of selected countries of world 55–57, 334, 341
USDA, reference standard 57
Protein, amino acids:
composition of foodstuffs 315, 328
composition of leaves 368
composition of in microorganism 366–368, 371
content of 50, 302
fortification of foods with 51, 68, 77, 317–322
requirements 51–52, 302, 314–315, 329
Protein, amino acids, cystine in pulses 217
Protein, amino acids, lysine:
content in pulses 217
in corn 200, 224, 329
deficiency in plant products 314, 344
fortification with 317–318, 323–324
in protein nutrition of children 311
in rumen bacteria 366
Protein, amino acids, methionine:
deficiency in plant products 217, 314, 342, 344
in protein of leaves 368
Protein, amino acids, threonine:
fortification with 317
in peanuts 344
in plant products 313, 317–318
Protein, amino acids, tryptophan:
conversion to niacin 59–61
in corn 200, 224
and opaque-2 in corn 329
in plant products 314
Protein-calorie malnutrition, prevention of 78–79
Protein deficiency, prevalence of 50
Protein efficiency ratio (PER) 317, 319
Protein intake, relation to income level 42–44
Protein malnutrition, *see* Diseases, kwashiorkor.

Protein requirements: Page
adjustment for age 50
adjustment for body weight 50
conversion to foods and commodities 69–77
projections for Brazil 50, 56
projections for India 50, 53–55, 68
projections for Pakistan 50, 55–56
projections for World 50, 56–57
Protein requirements and caloric requirements 50 68, 70
Protein-rich foods 78–81, 89, 304, 563–567, 632
Protein sources:
animal products as 51, 68, 71
cereals as 51, 54, 70
fish as 68, 347
oilseeds as 68–70, 335–345
pulses as 54, 70
vegetables as 51, 70–71
Puerto Rico:
desired family size in 33
forest management in 499
GNP of 647
per capita income of 647
mortality of infants in 33
Pulses:
amino acid composition of 315
as basic crop for less developed countries 219
improvement of yields 217, 218
increased production to supply food requirements 77
losses to pests in marketing channels 551, 552
production of, in response to price changes 528
protein content of 217
protein in diets supplied from 54, 341
protein production per acre 336
yields in selected countries 209, 217
Pyridoxine deficiency, *see* Diseases, vitamin $B_6$ deficiency.

## Q

Quinoa, *see* Cereals.

## R

Rabies, *see* Diseases, animal.
Radiation, in food preservation 559
Radio, for information dissemination in nutrition programs 88
Railroads, in marketing 543, 585
Rats, *see* Rodents.
Reclamation projects, in agricultural development 437
Refrigeration, need in food preservation 550, 555, 558–559, 560, 562, 586–587
Regulatory programs:
animal production 287, 290, 292–293
pest control 396
Religion:
effects on livestock production 263, 265, 286–287
influence on food resources 556

Rental, of land, *see* Land tenure.
Research: Page
in developed countries 623–629
financial support for 617–618, 637
need for, in agricultural programs of developing countries 228, 600–601, 614–621, 634–639
need for, in animal production 287, 289–290, 292–293
need for continuity in programs of 600, 614, 624, 635–637
need for facilities to perform 617
need for, in fisheries 347, 353, 355
need for, in food preservation and distribution 360, 563
need for, on forage and range management 280–281
need for, in irrigation 452
need for, in marketing 542, 547–548
need for, on micro-organisms 364, 367–368
need for, in nutrition 78, 86–87, 89
need for, in pest control 395–396
Research:
need for, in price policy 526
need for, in seed production 391
need for, on soybeans 342
need for, on tropical forests 498–499
in relation to extension and formal education 236, 620
relationship of public- to private-supported 620–621
Research centers, need for 227, 599–600, 629, 636
Research and education, returns from undeveloped countries 598–599
Research programs, organization and administration of 616, 618–620, 363–639
Reservoirs, production of fish in 349–350, 353–354
Resource surveys:
in agricultural development 436–437, 443, 446, 451
in irrigation development 451
Restorer genes 201
Retinol, *see* Vitamins, vitamin A, sources of 62
Rhodesia:
corn yields in 216, 491
development of modern agriculture in 491–492
livestock operations in 254
wild and domestic animal production compared 269
Riboflavin deficiency, *see* Diseases, ariboflavinosis.
Riboflavin requirements, *see* Vitamins.
Rice, *see* Cereals.
Rickets, *see* Diseases.
Rift Valley fever, *see* Diseases, animal 271, 274
Rinderpest, *see* Diseases, animal.
River basins, water runoff from major 447
Rivers, production of fish in 349, 353–354
Roads:
access, construction of 582–583, 590–591
access, planning for 581–582, 590
in agricultural development 437, 439
cost of in development projects 462–469
financing and operation of 583–584, 590
in industrial development 579–580

Roads: Page
need for, in marketing 543, 575, 581
Rockefeller Foundation 210–212, 222, 227, 239, 615, 625, 627, 628
Rodents:
control of, in storage facilities 559
food conversion efficiency of rats 352
food losses due to 310, 551–552
Root-knot nematode, control by plant breeding 199
Rubber:
growth of on plantations 487, 489, 497
harvest by nomadic gathering 490
in mix tree crop system 487
need for alternative food crops 232
in shifting cultivation 497
transplant of trees from Brazil 494
Rumania:
fertility rates in 31
natural gas production in 384
Rumen bacteria, amino acids of 366
Ruminants, *see* Livestock.
Runoff, annual from major river basins 447
Rust diseases 198, 200, 202–203, 210–220
Rwanda-Urundi, corn yields from improved varieties 216

## S

Safflower, *see* Oilseeds.
Sahara, soil types in 413, 417
Salaries, of agricultural scientists 237
Salinity:
adaptation of crops to 198, 232
in agricultural development 437–438, 451
in irrigation development 451
Salmonellosis, *see* Diseases, animal.
Salt, as iodine source 18, 66
Saudi Arabia, natural gas in 384
Savanna:
anthropic 475, 478
forest productivity of 499
productivity of, in tropics 477
Schools, *see* Education.
School lunch programs 78, 81, 83, 89
Screw worm 207, 392
Scurvy, *see* Diseases.
Seed:
farm machinery for planting 399
government production and marketing of 223, 390–391
need for improvement of 387–388
private production and marketing 223, 391
production and harvesting problems of 390–391
production, research needs for 391
projected costs of capital investment for 658, 660
requirements for developing world 223, 388–389
requirements for India 675–676, 694–702
requirements for processing plants 388–389

Selenium deficiency, *see* Diseases, mineral deficiencies. Page
Self-help, policies and food aid 144, 189
Self-sterility in plants 200–203
Senegal, peanut project in 495
Sesame, *see* Oilseeds.
Settlement, in agricultural development 437, 443
Sewage:
use of algae in reclaiming 371
use in fishculture 353
Sex attractants for insect control 207
Sheep, *see* Livestock.
Sheep pox, *see* Diseases, animal.
Shifting cultivation 425, 476, 478, 485–488, 496–497, 500
Shipping, *see* Transportation.
Sierra Leone, graduate training in 239
Silage, as feed 280, 283
Singapore, soybean milk in 632
Single cell protein, *see* Micro-organisms.
Social attitudes:
in agricultural development 492
effects of malnutrition on 12
in nutrition programs 313, 327
Social conditions, relation to nutrition programs 303, 305
Sodium nitrate, in fertilizer production 383
Soils:
acidity in 380, 414, 416
alkalinity in 413, 415, 418
analysis, in crop fertilization 204, 230
area of 423
fertility in forest 481
fertility related to plant nutrition 203–205, 223
fertility in tropics 476–480
maize producing 413
micronutrient deficiency in 413–415, 418, 481
need for research in 204, 223, 409, 619
nitrogen deficiency in 413–416, 418, 481
nonarable 423
organic matter in 413
phosphorus deficiency in 413–416, 418, 481
potassium deficiency in 413–415, 418, 481
potential grazing 483
potentially arable 430, 480, 483
salinity, excessive 413, 418
surveys, costs of 437
tilth, maintenance of 414–416, 418
tropical, characteristics of 474–484
in tropical climatic regions 476
weathered and leached in tropics 415, 476–477, 479
wheat producing 413
of the world 412–418
Soils, soil groups:
ando 416, 423, 430, 476, 480
alluvial 412, 417, 423, 430, 476, 483, 484
black cotton 482

Soils, soil groups—Continued Page
brown 413, 424
brown forest 416, 424, 430, 476, 480
brown podzolic 414, 424
brun acides 414, 426
brunizem 413, 423–424, 430
calcisol 413, 424
chernozem 413, 423–424, 430, 476, 480
chestnut 413, 424
dark colored, base rich 476, 480, 482–484
desert 413, 423–424, 430
dry sands 476, 480, 483
gray-brown podzolic 414, 424
gray wooded 414, 424
ground water laterite 415, 424, 481, 487
ground water podzol 412–414, 424
grumusol 416, 423–424, 430, 476, 480
half bog 413–414, 425
highly weathered and leached 476, 480, 481–482, 483
humic gley 413, 425
latosol 415, 423, 425, 430, 476, 480
light colored, base rich 476, 480, 482, 484
lithosols 412, 417, 423, 425, 430
low-humic gley 413–414, 425
moderately weathered and leached 476, 480, 482–483
noncalcic brown 414, 423, 425, 430, 476, 480
podzol 414, 423, 425, 430
red desert 413, 425
reddish-brown 413, 415
reddish-brown lateritic 415, 425
reddish chestnut 413, 425
reddish prairie 413, 426
red-yellow podzolic 415, 423, 426, 430, 476, 480
regosols 417, 423, 426, 430
regur 482
rendzina 416, 423, 426, 430, 476, 480
sandy 484
shallow 476, 480, 483–484
sierozem 413, 426
solonetz 413, 426
soloth 413, 426
subarctic brown forest 413, 426
terra rossa 416, 423, 426, 430
tundra 412, 423, 427, 441, 430
volcanic, *see* ando.
yellowish-brown lateritic 415, 427
Soil specialists, need for 226
Solar radiation 474, 490
South Africa:
livestock operations in 254
support prices for wheat 155
South America:
animal disease control priorities in 275–276
area of 442, 447

263-888 O - 67 - 50

South America—Continued Page
body weights in 49
costs of administration of development projects 439
endemic goiter in 17
irrigation potential of tropical 445–447
land arable 429–434, 447
land areas in tropical climatic regions 475
land cultivated in 434–435, 442
land for grazing in 258, 280
land irrigated in 442, 493
land tenure in 516, 519
land unexploited in 476
multiple cropping of corn in 226
phosphate reserves of 387
population of 434, 442
potassium reserves of 387
soil types in 413–414
water runoff in 447
wheat and rice yields in 208
South Korea:
desired family size in 33
mortality of infants in 33
Soybeans, *see* Oilseeds.
Spain:
area of 441
commercial imports of agricultural commodities by 146
fish catch of 357–358
fish in food supply of 348
GNP of 647
land cultivated in 441
land irrigated in 441
per capita income of 647
population of 441
price of fertilizer in 156
support prices for wheat 155
Specifications, in marketing 544, 546, 561
Spelt, *see* Cereals.
Spinach, *see* Vegetables.
Spotted alfalfa aphid, control by plant breeding 198
Standards, in marketing 544–546, 554, 562
Starches, in diets in different areas 316–317, 341
Stem nematode, control by plant breeding 199
Storage, *see* Preservation.
Streptothricosis, *see* Diseases, animal.
Sucrose, for microorganism production 362
Sudan:
area of 441
cost of agricultural development projects 435–436
cost of irrigation development 435
food prices in 152
land cultivated in 441
land irrigated in 441
population of 441
successful agricultural project in 495–496

Page
Sudangrass 199, 201, 248
Sugar:
control of sugar cane borers 231
international trade in 146–149, 151, 157, 186
need for alternative food crops 232
supply of in diets 75, 308–309, 316–317
transportation of 586
"Sugar baby," *see* Diseases, kwashiorkor.
Sugar beets:
cost of land development for production of 449
over-fertilization of 204
protection of production of 186
Sugar byproducts, as livestock feed 249, 280, 282
Sugar cane:
borers, control of 231
cost of development projects 460
losses caused by poor processing 555
production of 388, 489–490, 527
Sulfur deficiencies in crops, *see* Micronutrient deficiencies.
Sulfur, in fertilizer production 385–386
Surra, *see* Diseases, animal, trypanosomiasis.
Surveys:
nutrition 88, 311–312
as a prerequisite to increased crop production 232
of protein supplies in India 310
Swamps, production of fish in 349, 353–354
Sweden:
fish in food supply of 348
protein supply of 334
support prices for wheat 155
Sweet clover, coumarin in 199
Sweet potatoes 70, 71, 219, 368, 369
Swine, *see* Livestock.
Syria:
area of 441
land cultivated in 441
land irrigated in 441
population of 441
Switzerland:
protein supply of 334
support prices for wheat 155

## T

Taiwan:
area of 441
brackishwater fish production in 351
cost of irrigation development in 465
desired family size in 33
exportation of crops 556
fish in food supply of 348
food demand in 152, 650
imports of agricultural commodities 146
land cultivated in 441

Taiwan—Continued Page
land irrigated in 441
land tenure in 517
mileage of access roads in 582
mortality of infants in 33
population of 441
protein supply of 334
rice production in 490, 497
seedbed preparations and irrigation in 399
source of dwarf rice varieties 215, 230
state trading agency 153
success of agricultural development in 497
sugar cane varieties in 388
Tanganyika, groundnut project in 495
Tankage, *see* Animal byproducts.
Tanzania, foreign personnel in agricultural programs of 611–612
Taste:
effect of fortification on 320–321, 329, 342
of fish products 360
in food acceptance 342, 366, 369, 371
Taungya 500
Taxes:
influence on production incentives 508, 510, 525
as market barriers 186
Tea:
exports of 181
international commodity agreements on 157
Teaching, *see* Education.
Teff, *see* Cereals.
Television, in education 631, 634
Temperature, in agroclimatic regions, *see* Agroclimatic regions.
Tenure, *see* Land tenure.
Textbooks, *see* Education.
Textile imports, relationship to cotton prices 147
Thailand:
adult height and weight in 39
area of 441
cost of irrigation development in 467
desired family size in 33
effect of highway construction on agricultural production 573
fish in food supply of 348–349
food prices in 152
improved corn and rice varieties 215–216, 223
increase in yields from irrigation 455
land cultivated in 441
land irrigated in 441
mortality of infants in 33
population of 441
price of fertilizer 156
ratio of extension workers to farmers in 622
soybean milk in 632
xerophthalmia in 18
Theileriasis, *see* Diseases, animal, East Coast fever.
Thiamin deficiency, *see* Diseases.

Thiamin requirements, *see* Vitamin requirements.
Threonine, *see* Protein, amino acids. Page
*Tilapia* 351–352
Tobacco:
exports of 143, 159–160, 668
stocks of in U.S 142
Tomatoes, import duty on 146
Trace element deficiencies in crops, *see* Micronutrient deficiencies.
Tractors, *see* Farm machinery.
Tradition:
influence on production incentives 508–510, 512–514, 519–520
in livestock production 263, 265, 286–287, 292
Training, *see* Personnel.
Transportation:
developing country expenditures on 573
as essential for agricultural production 232, 507, 520, 521, 522, 572–579
of fertilizer 586
influence on production incentives 522, 532
importance of, in animal production 280, 286, 333
international, requirements for 576–579
of perishable goods 586
requirements for, in India 676, 701–702
roads, cost of in agricultural development 437, 439
Transportation system:
characteristics of 574–579
construction and operation of roads 582–585, 590–591
need for, in marketing 542–543, 555, 558, 562–563, 586–587
need for vehicles in 585, 590
planning of 579–582, 588–592
Trinidad, forest management in 499
Tropical agriculture, lack of information on 227
Tropical agriculture research centers, need for 227
Tropical climates, characteristics of 474–484
Tropical soils, characteristics of 474–484
Trout, production of 351–352
Trypanosomiasis, *see* Diseases, animal.
Tryptophan, *see* Protein, amino acids.
Tsetse fly 269–277
Tuberculosis, *see* Diseases.
Tuberculosis, *see also* Diseases, animal.
Tunisia:
area of 441
land irrigated in 441
population of 441
support prices for wheat 155
Turkey:
area of 441
cost of roads in 438
desired family size in 33
food prices in 152
GNP of 647
land cultivated in 441
land irrigated in 441
mortality of infants in 33

Turkey—Continued Page
per capita income of 647
population of 441
preference on imports by EEC 149
protein supply of 334
support prices for wheat 155
trade in grain 176–177
Tyrosine, *see* Protein, amino acids.

## U

Uganda, foreign personnel in agricultural programs 611–612
Undernutrition, *see* Malnutrition.
United Arab Republic:
area of 441
food prices in 152
land cultivated in 441
land irrigated in 441
population of 441
price of fertilizer in 156
protein supply of 334
United Kingdom:
fish catch of 357–358
fish in food supply of 348
price policies in 148, 525–526
support prices for wheat 155
trends in retail prices of foods 668
United Nations Conference on Trade and Development 670–671
United States:
agricultural policies of 142, 146–148
area of 441
cost of agricultural development projects 436
cost of irrigation development in 447, 465–467
crop losses due to pests 205
crop production in 196, 204, 208–209, 224–225, 343
desired family size in 33
exports of agricultural commodities 158–160, 162, 164, 166–169
fish catch of 301, 349, 357–358
fishery potential of coastal waters 357
forest management in 499
horsepower availability for food production in 396–397
land cultivated in 441
land irrigated in 441
livestock production in 252–253, 267–268
marketing system in 540
mileage of access roads in 582
mortality of infants in 13, 17, 33
pesticide use in 393
population of 441
price of fertilizer in 156
producer prices in 150
production of ammonia fertilizer in 384
production of animal products in 256–257, 259, 267–268
production, disappearance, and trade of agricultural commodities 162, 164, 166–171

United States—Continued Page
protein supply of 334, 341
ratio of extension workers to farmers in 622
relationship of research to extension 620
research and education programs in 623–629, 636–637
soil types in 413–416
support prices for wheat 155
trade in grains 20, 144, 175–176
training in animal production for foreign service 291
transportation system in 574
trends in retail prices of foods 668
United States government, role in nutrition programs 82, 301, 307
Universities:
in agricultural programs of developing countries 636–639
contribution to agricultural advancement 600, 607–611, 616, 633–637
role of, in agriculture 237–239
role of, in improving world food supply 237–239, 623–626, 629, 631–632, 637–639
Urea, utilization of, in ruminant feeds 249, 281, 283
Urdbeans, *see* Pulses.
Uruguay:
adult height and weight in 39
area of 442
cost of irrigation development in 465
distribution of protein food in 75
land cultivated in 442
land irrigated in 442
population of 442
U.S.S.R.:
area of 442
cultivated land in 434–435, 442
fish catch of 357–358
fresh-water fisheries in 349
land irrigated in 442
land potentially arable in 429–434
marketing system in 548
population of 434, 442
price policies in 525–526
production of ammonia fertilizer in 384
production, disappearance, and trade of agricultural commodities 162, 164, 166–171
projections of population in 30–31
wheat imports of 144, 160, 163, 175–176

## V

Valine, *see* Protein, amino acids.
Varieties, *see* Plant breeding.
Vectors of animal diseases 272–274, 276–277
Vedalia beetle 233
Vegetables:
losses in marketing channels 550–551, 555
market quality standard for 544
seed production of 390
as sources of calcium 64

Vegetables—Continued Page
as sources of protein 51
as sources of vitamin A 62
as sources of vitamin C 65
value of United States exports of 159–160
Venezuela:
adult height and weight of 39
area of 442
cost of land clearing 438
cost of settlement projects in 439
financial support for research in 618
food prices in 152
increase in food demand in 650
land cultivated in 442
land irrigated in 442
population of 442
poultry production in 254
production of natural gas in 384
trade in grain 176–177
xerophthalmia in 18
Veterinarians, need for in animal production 288, 293
Veterinary services, effect on animal disease losses 275, 278, 286
Vibriosis, *see* Diseases, animal.
Vietnam:
adult height and weight in 39
trade in rice 176
xerophthalmia in 18
Vitamin deficiencies, *see* Diseases.
Vitamins:
in cereal fortification 319, 322–324
content of in foods 323, 328
livestock, needs for 279, 281
niacin from tryptophan conversion 59–61
requirements for 323, 329
requirements for selected countries and world 58–62
requirements supplied by soybeans 218
sources of riboflavin 59
sources of thiamin 58
sources of vitamin A 61–62
supplementation of high-protein food products with 564
Vitamins, requirements for:
folacin 67
niacin 59–61
pantothenic acid 67
riboflavin 58–59
thiamin 58
vitamin A 61–62
vitamin $B_6$ 67
vitamin $B_{12}$ 67
vitamin C 65
vitamin D 66
vitamin E 67
vitamin K 67
Vita-soy 632

## W

Wastes, *see* Animal wastes; plant wastes.
Water: Page
development, costs of 460–469, 661
efficiency of use in irrigation 457–460
need for, in livestock production 284
quality, effect on fish culture 352
supply of for irrigation 439–460
Water for Peace, studies by national committee on 450
Watershed management, coordination of plans for 453
Waterways, need for, in marketing 543
Weather, modification and agricultural productivity 453
Weathering, of soils in tropics 474–475
Weed control:
biological control 233
effects of on crops 197, 204
herbicide use in United States 206
herbicides in crop production 197–198, 204, 392, 394–395
herbicides, effects of, on plankton and fish 207
use of fire for 477–478, 485
Weeds, losses due to, in United States 205
Western Europe, population density, in 21
West Germany:
fresh-water fisheries in 349
support prices for wheat 155
Wheat, *see* Cereals.
Whey, use of in yeast industry 367
Wild animals:
as disease reservoirs 270
domestication of 270, 494–495
for effective land utilization 268–270
need for conservation of 271
potential contribution to food supply 267–271
Wildlife, effects of pesticides on 206, 214
Wool, *see* Animal products.
Work efficiency, effects of malnutrition on 12
World:
age distribution of population in 25
agroclimatic regions of 421–422
caloric requirements for 49–50
climatic zones of 418–422
fertility rates, estimates of 26–27
fertilizer use in 379
food requirements for 69, 77, 645–646
livestock populations in 251–253
production of animal products 256–257, 259, 267
production of cotton 343
production of oilseeds 339
projected supplies of animal protein in 255, 262, 264
projections of population in 21–22, 24–28, 261–263
protein requirements for 50, 56–57
soils of the 412–418

World—Continued Page
trade in agricultural products 158–177
vitamin requirements for 58–62
World Food Fund 176
World Food Program 79

## X

Xanthophylls, in leaves 370
Xerophthalmia, *see* Diseases.

## Y

Yams:
as basic crop for less developed countries 219
in food requirement projections 70–71, 77
Yeast, *see* Micro-organisms.
Yugoslavia:
area of 441
land cultivated in 441
land irrigated in 441
land tenure in 518
population of 441
support prices for wheat 155

## Z

Zinc deficiencies in crops, *see* Micro-nutrient deficiencies.
Zinc, deficiency in soils 481

U. S. GOVERNMENT PRINTING OFFICE : 1967 O - 263-888

# NOTES

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