THE WORLD FOOD PROBLEM

A Report of the

President's Science Advisory Committee

VOLUME III

Report of the Panel on the World Food Supply

THE WHITE HOUSE
SEPTEMBER 1967

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RESOURCE PAPERS

Preface

This is the third and final volume of the report of the Panel on the World Food Supply of the President's Science Advisory Committee.

Volume I contains a description of the overall problem, the specific recommendations of the Panel, and a summary of the organizational and economic requirements for alleviating the food shortage during the next two decades.

Volume II contains the detailed reports of the several subpanels assigned to study the major factors needing attention in considering nutritional demands and food production in the developing nations where populations are expanding rapidly.

Volume III consists of selected resource papers prepared by Panel members and consultants. These have been chosen because they contain detailed information that should be helpful to those having concern or responsibility for certain phases of the problems of food supply and nutrition with which this study has dealt.

The Panel approved each paper included in this volume but made no attempt to require any uniformity in style of presentation. They are published as individual contributions by the authors who assume responsibility for content.

The collection may be especially beneficial to those who have found Volumes I and II of the report useful and who wish to have more technical details on certain subjects.

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THE WORLD FOOD PROGRAM

VOLUME III

Table of Contents

CHAPTER 1

VARIATIONS IN BODY WEIGHTS AMONG DIFFERENT POPULATIONS

By Rose Frisch and Roger Revelle, Center for Population Studies, Harvard University

Introduction

Cross-sectional data on growth as measured by increases in body weight with age in seven Latin American countries (Bolivia, Chile, Colombia, Ecuador, northeastern Brazil, Uruguay and Venezuela) and seven Asian countries (Burma, India, Japan, Malaya, Pakistan, Thailand and Vietnam) were collated from the literature as part of a study of nutritional requirements. Analysis of these data provides information on the variation in body weights of the populations among each group of countries and between the two groups of countries, and how these variations are related to estimated supplies of calories.

The Data

A description of the height and weight data available for each country (number of subjects, areas of country covered, proportion of rural subjects, and standard errors of weights and heights when available) is presented in Table 1.[1]

In order to obtain for comparable age series, the data were plotted and the weights at the required ages read off the graphs (Figures 1 and 2). A study of these figures suggests that the uncertainty in the weight estimates is probably about 2 percent. This accords well with the few estimates of standard errors at different ages given in the original sources (Table 1).

Mature weights for males and females were taken to be at 25–29 years of age. Growth curves for people in the developing countries show that mature weights are attained by this age (Figures 1 and 2). (Full growth in stature and related body dimensions is currently generally achieved in the United States and England by the late teens or early twenties for men and a few years earlier for women, as shown in reports by Stoudt et al. (20) and Tanner (21).)

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[1] **All tables and figures follow the text for this paper and are on pages 20 to 41.**

The per capita calorie supplies estimated for each country by the United States Department of Agriculture are based on food balance sheets and are for supplies at the retail level; the sources of error in these estimates include inaccuracies of population size and food production statistics, and uncertainties of the losses due to processing and wastage. A comparison by Frisch (4) of estimates of per capita calorie supplies from food balance sheets made by the USDA and the Food and Agriculture Organization of the United Nations (FAO) for the same countries at comparable times shows differences up to 10 percent, which may be taken as an indication of the order of magnitude of error involved. It must be noted that these estimated supplies are averages: the distribution within the population in developing countries is very unequal; Brazil has an average estimated calorie supply of 2700 calories per day, but the poor people in northeastern Brazil consume about 1600 calories per day in their diets [Frisch (4)].

The calorie supply estimates at the physiological level made from the surveys performed by the Interdepartmental Committee for Nutrition and National Defense are averages of the three methods used in these surveys: the questionnaire method, food composite analysis, and the food recipe method. Since the numbers of people surveyed by each of these methods varied a great deal from country to country, and the results from different methods often varied by 10 to 20 percent, these data were used only as supplementary information; the USDA calorie estimates were used as the basis for conclusions on the correlations between calorie supplies and weight.

The mean weights for India in Tables 6 and 7 were computed as follows: first, a weighted average of data from rural, semi-urban and urban surveys was made, weighting the rural data eight times since India is about 80 percent rural. [U.N (22)] The source of these data was the Indian Council of Medical Research, Report of the 42nd meeting of the Nutrition Advisory Committee held in Hyderabad, December 1960. Since these ICMR data did not include any surveys for the states of West Bengal, Bihar, and Assam, representing 20 percent of the total Indian population, and also included only a very small amount of data for rural areas in the Punjab, Rajasthan, and Kashmir, which contain about 10 percent of the population of India, the final figures for the Indian population given in Tables 6 and 7 were computed by making a weighted average of: (1) the average for rural, semi-urban, and urban data in Tables 9 and 10 multiplied by 7; (2) the data for East Pakistan multiplied by 2; and (3) the data for West Pakistan (Tables 6 and 7).

Findings

Body Weights

There are marked variations in average mature body weights among the different peoples of Latin America and Southeast Asia. The ranking by average body weight of males and females of ages 25–29 years in seven Latin American countries for which data are available is shown in Table 2 and Figure 1. The difference between the average Uruguayan man and the average Ecuadoran man is about 18 percent.

Of the seven Asian countries for which average body weights are available, the Japanese males are the heaviest, followed by males from Malaya, Thailand, Pakistan, Burma, Vietnam, and India (Table 3 and Figure 2). The difference between the average Indian and the average Japanese is 15 percent; the total range between Indians and Vietnamese at one extreme and Uruguayans and Chileans at the other is about 30 percent.

Average body weights among Southeast Asian females maintain the same ranking as the males of the same age except that Burmese women seem to be slightly heavier than Pakistani women (Table 4).

A statistical comparison of the mean weights at maturity (25–29 years) of the Latin American and Asian peoples shows that Latin American males and females are significantly heavier than Asian males and females: Latin American males average 61.8 kg., S.E., 1.6, Asian males 52.5 kg., S.E., 1.2 [2] ($t=4.26$, $P<0.01$ [3]); Latin American females average 53.3 kg., S.E., 1.5, Asian females 45.4 kg., S.E., 0.91 ($t=4.51$, $P<0.01$). This is true even if Uruguayan males and females, who are the heaviest of all the Latin American peoples studied, are omitted from the averages. (Coon (2) shows that the Uruguayan population is 90 percent of European stock compared to an average of 27 percent for the other six Latin American countries.) The mean weight of Latin American males is then 60.5 kg., S.E., 0.94, of the Latin American females 52.2 kg., S.E., 0.90. If Uruguay is omitted from the Latin American countries, and Japan, as a developed country, from the Asian countries, the difference between male weights is even more significant than if both countries were included: Latin American mean weights=60.5 kg., S.E., 0.94, Asian mean weights 51.6 kg., S.E., 1.5 ($t=5.29$, $P<0.01$).

A significant difference in body weights of both males and females of the Latin American countries and the Asian countries is found

[2] Does not include India for which there are no data above 20–21 years of age.

[3] Probability that the difference between the means is due to chance. S.E.=standard error of the mean.

at early ages (Table 13).[4] At 5.5 years the difference between the mean weight of boys and girls is highly significant ($P<0.01$). At 2.5 years of age the probability of the significance between the means is between 0.02 and 0.01 for boys, but the difference in mean weights of girls is still highly significant at $P<0.01$. At 1.5 years of age the difference between the mean weights of boys is no longer significant ($P\sim0.10$), but the difference between the mean weight of the girls is still significant at the 0.05–0.02 probability level (Table 13).

For the people of any Latin American or Asian country studied, the correlation between mature weight and weight at 5.5 years of age is high: for males of the Latin American countries the correlation coefficient, r, is 0.88 (S.E. 0.41), for females r is 0.94 (S.E., 0.41); for the males of the Asian countries r is 0.87 (S.E., 0.45), for females it is 0.73 (S.E., 0.45). If the peoples of the different countries are ranked by body weight at ages 5.5, 10.5, 15.5, 19.5, 20–24, and 25–29 (Tables 14 and 15), it can be seen that, in both Latin America and Southeast Asia, in general the slow growing children remain slow growing relative to the others throughout the whole period of growth, and the faster growing children maintain their faster pace of growth relative to the others throughout their whole period of growth. The one exception to this statement is Thailand in which the children are slow growing and cross over at the time of the adolescent spurt into the fast growing group (Figures 1 and 2). Since the data are cross-sectional, this would imply that the pre-teen children in Thailand are growing more slowly than those in the teen-age group.

Height and Body Weights

There is no significant difference in the heights of either males or females at 25–29 years of age between the peoples of the Latin American countries and the peoples of the Asian countries: the mean height of Latin American males is 162.1 cms., S.E., 0.12; the mean height of Asian males, 161.4 cms., S.E., 0.82; the mean height of Latin American females is 151.3 cms., S.E., 0.96, of Asian females, 150.4 cms., S.E., 0.60.

Among the Latin American countries height and weight are highly correlated for males, r is 0.93, S.E., 0.41, and less so but possibly still significantly for females, r is 0.73, S.E., 0.41.

Among the peoples of the Asian countries, males show little correlation of height and weight ($r=0.41$, S.E., 0.45), females a higher correlation, $r=0.69$, S.E., 0.45.

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[4] All these means were calculated excluding Uruguay and Japan as developed countries. Comparisons of the means including these countries, or excluding Uruguay but including Japan, are given in Table 12.

Calorie Supplies and Body Weights

There is no significant difference between the means of the estimated calorie supplies of the Latin American and Asian countries; this is true for both USDA food balance estimates and ICNND survey results. The mean of the USDA calorie supply estimates for the Latin American countries is 2,393 calories, S.E., 153.0; the mean of the USDA estimates for the Asian countries is 2,205 calories, S.E., 57.0. The mean of the calories consumed in Latin American countries based on ICNND data is 2,004, S.E., 162.0; the mean for the Asian countries is 2,183 calories, S.E., 185.0.

There is a very high correlation between the average body weight of a people and their estimated average calorie supply (USDA) in both the Latin American countries and the Asian countries. For Latin American males the correlation coefficient for weight and USDA calorie supplies is 0.93, S.E., 0.45, for females $r=0.85$, S.E., 0.45; in the Asian countries the correlation coefficient of male weights and USDA calorie supplies is 0.85, S.E., 0.45, for females $r=0.72$, S.E., 0.45.

The correlation of weight with ICNND calorie estimates is fairly high for Latin American males, $r=0.61$, S.E., 0.41, and very high for Latin American females $r=0.92$, S.E., 0.41, but it is very low for Asian males, $r=0.28$, S.E., 0.58, and for Asian females, $r=0.57$, S.E., 0.58.

When body weights are plotted against calorie supplies (USDA) (Figure 3), the data fall into two groups and are best fitted by two lines, as has already been indicated by the fact that the mean of the weight of the Latin American peoples differs significantly from that of the mean of the weight of the Asian people, while calorie supplies do not differ significantly between the two groups. (The two line fit was confirmed by an $F_{2/8}=24.5$ ($P<0.005$)[5] when the hypothesis of one line was tested as a special case of two lines [i.e., two lines with the same slope and intercept].)

The regression equation for the Latin American countries is:

$$w=0.0107C+36.7$$

when w is average weight in kilograms and C is average daily calorie supply. For the Asian countries the equation is:

$$w=0.0174C+14.4$$

Height and Calorie Supplies

Height at maturity (25–29 years) shows a fairly strong correlation with calorie supplies (USDA) for Latin American males, $r=0.87$, S.E., 0.45 and a low correlation for Latin American females $r=0.54$, S.E., 0.45. The heights of mature Asian males show no cor-

[5] Probability that the data can be fitted by one line is less than 1 in 200.

relation with calorie supplies (USDA) r=0.47, S.E., 0.50; Asian females also show no correlation r=0.45, S.E., 0.50.

Time of Maximum Increment of Growth, Percentage of Weight Attained, and Calorie Supplies

Following Tanner's (21) observation that the occurrence of the adolescent spurt possibly is a sensitive indicator of nutritional deficiency before the time of adolescence, a test was made of the significance of difference in the means of the time of maximum increment of growth for countries with estimated calorie supplies of 2,300 calories or over (Uruguay, Chile, Venezuela, Malaya, and Japan), and those with supplies estimated at under 2,300 calories (Colombia, Ecuador, Northeast Brazil, Bolivia, Burma, India, Vietnam, and Thailand). The mean age of maximum increment in weight for adolescent boys of the high calorie countries was 13.0 years, S.E., 0.10; that of boys of the low calorie countries was 15.1 years, S.E., 0.30. The difference is significant at $P<0.01$. For females, the mean age of maximum growth in weight for the high calorie countries was 12.2 years, S.E., 0.38 and 13.5 years, S.E., 0.42, in the low calorie countries (Table 17). This difference is significant between P 0.05 and 0.02. If Thailand, where the number of subjects measured at the time of adolescence is very small, is excluded from the group, the mean for the girls of the low calorie countries is then 13.9 years, S.E., 0.26, and the difference of the means is significant at $P<0.01$ (Table 17).

The negative correlation between age at time of maximum increment of weight and calorie supplies (USDA) is high for adolescent boys (combined data Latin American and Asia) r=−0.85, S.E., 0.32; it is low for adolescent girls, −0.30, S.E., 0.32. (If Thailand is omitted from the data the correlation coefficient is −0.48, S.E., 0.33).

The mean age at which the maximum increment in weight takes place in Latin America and Asia does not differ significantly in either boys or girls: the mean age for all Latin American boys is 14.1 years, S.E., 0.59, for all Asian boys 14.5 years, S.E., 0.29. The mean age for boys of the *low-calorie* Latin American countries is 15.3 years, S.E., 0.48; of the *low-calorie* Asian countries 15.0 years, S.E., 41. The mean age of girls of the *low-calorie* Latin American countries is 14.0 years, S.E., 0.41; the mean age of girls of the low-calorie Asian countries is 13.6 years, S.E., 0.36, if Thailand is omitted. The mean percentage of mature weight attained by boys at the age of maximum increment [6] in weight in the low-calorie countries, (65.5 percent, S.E., 2.0) differs significantly (P 0.02–0.01) from the mean percentage of mature

[6] The weight used to figure the percentage is that of the earlier of the two ages which give the maximum increment in weight.

weight attained at the time of the spurt in the *high-calorie* countries, (57.7 percent, S.E., 2.3), (Table 18), but this percentage does not differ for boys of the *low-calorie* Latin American countries (65.3 percent, S.E., 3.9) and boys of the *low-calorie* Asian countries (65.9 percent, S.E., 3.1).

The mean percentage of mature weight attained by girls in the low-calorie countries at the time of the maximum increment of weight (69.7 percent, S.E., 2.0), while higher than that attained in the high-calorie countries (64.8 percent, S.E., 2.7), does not differ significantly (P 0.20–0.10) from the latter percentage.

Differences in Urban and Rural Population in India

Indian urban males of 20–21 years of age are heavier than rural males by 5.2 kg.; urban females are heavier than rural females by 3.8 kg. These differences in body weight are accompanied by differences in stature. The urban males are taller than the rural by 5.60 cms; the urban girls are taller than the rural by 4.85 cms.[7] The height and weight of semi-urban males and females are intermediate between the urban and rural (Tables 9, 10, Figure 4).

Though the results are only an approximation since no tests of significance could be made,[8] urban boys had their height and weight spurt a full year earlier than rural boys (urban boys, 15 years, rural boys, 16 years); urban and rural girls showed no difference in time of onset of the adolescent spurt in weight, but urban girls were a year earlier in the time of onset of the height spurt (urban girls 11 years, rural girls 12 years) (Table 19).

Discussion

Men and women in the Asian countries do not differ significantly in mean height from the Latin American, but they weigh significantly less, even though both groups of people apparently consume about the same mean quantity of calories. This might be explained if there were a considerable difference in age and sex distribution of the populations on the two continents. For example, if the Asians had much smaller proportions of children and females, the average weight of the populations in the Asian countries might be the same as that of the Latin Americans, even though the Asian adults were smaller. Although some differences in these proportions exist among the different countries, the differences are too small to have much effect on the ratios between

[7] No tests of the significance of the difference between these averages could be made because the Indian growth rate data gave no figures for variability.

[8] However the number of subjects in this study was large, about 57,000. The mean weights at each age probably are representative of the population, and the difference between the times of the spurt is most probably a real one.

average body weight of the populations as a whole and the average weight of adult males or females.[9] The simplest explanation would be that the estimates of calorie supplies are wrong, and the Asian people actually consume less calories than the Latin Americans. The probability of this explanation is not large because no significant difference was found between the calorie supplies of Latin American and Asian countries using both USDA estimates and ICNND estimates, the latter based on three methods of survey. The ICNND estimates are at the physiological level which also makes improbable the explanation of possible differences in wastage of food between "retail" level and actual consumption in the Latin American and Asian countries.

Assuming then that the calorie estimates are not inaccurate, other environmental differences can be considered. There is the possibility that the Asian people have a greater load of intestinal parasites and more gastro-intestinal disturbances, making the absorption of food less efficient. Since the difference in body weight is already present at 1.5–2.5 years of age, this explanation would imply that Asian children at an early age are already more disadvantaged than Latin American children. The few direct data that exist on this point, based on field studies in rural India and Guatemala [Scrimshaw and Gordon (18)], do not support such a supposition: in both communities there was a common pattern of highly frequent diarrhea in the early years of life related to the weaning process. Extensive indirect evidence also makes improbable the supposition that Asian children are more affected by parasites and disease: the death rates of 1–4 year old children in developing countries in Asia are of the same order of magnitude as those of developing countries in Latin America [Frisch (4)]—both are high compared to developed countries because of the synergism of malnutrition and disease [Scrimshaw (7)].

The presence of a significant difference in weight at an early age between Latin American and Asian children probably also rules out the explanation that the Asian peoples work harder and are more active than Latin American peoples.[10] It does not seem very probable that Asian children of 2 years of age are significantly more active than Latin American children of that age.

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[9] Data on these proportions are available in the U.N. Demographic Year Books of 1963 and 1964 and in Volume II Chapter 1, "The World Food Problem," PSAC Report of the Panel on the World Food Supply, May 1967, for six of the seven Latin American countries and for six of the Asian countries. The percentage of children under fifteen in Asia is 3.5 percent higher than in Latin America, while the ratio of males to females is 3.8 percent greater in Asia.

[10] In a different context, Mayer, Jean, Physical activity and anthropometric measurements of obese adolescents, *Fed. Proc. 25,* 1, P. 11, 1966.

Since corn is the staple of the diet of most of the Latin American peoples and rice the staple of most of the Asian peoples,[11] [12] there is the possibility of some basic difference in the efficiency of these cereals in the diet. However, though whole corn has more protein than rice (corn 9.2 percent, milled rice 7.6 percent), the quality of rice protein (B.V. 70)[13] is superior to that of corn (B.V. 62) and the protein efficiency ratio [14] of rice, 2.1, is more than twice as large as that of corn. 0.9 [14] [FAO (3)].

Possible differences in other aspects of the diet, such as protein intake from other sources than cereals, would not seem to be an important factor because of the significant difference in weight of Latin American and Asian children as young as 1.5–2.5 years of age. In both groups of countries children of that age are weaned onto diets consisting mainly of gruels of the basic cereals, and protein is unfortunately a very small part of the diet.

Since the mean heights of Latin Americans and Asians are about the same, the effect of difference in body shape on loss of heat cannot account for the observed differences in body weights. (When two people are the same weight but differ in height, the taller person has more surface area and therefore, other things being equal, requires more energy to maintain body temperature.)

Nor can differences in climate be invoked, because average seasonal temperatures in these Asiatic and Latin American countries are about the same.[15]

The body size of Latin American peoples may be genetically different from that of Asian peoples, a difference to be expected since they are of different races and the races of man are known to differ in body size, body proportions, and bone structure [Stoudt et al. (20), Garn (5), and Coon (2)]. Differences of body build exist even within one race, for example, ectomorphic and mesomorphic types among Caucasians; the mesomorphs were significantly heavier than the ectomorphs by two years of age [Tanner (21)]. In the case of three dif-

[11] Interdepartmental Committee of Nutrition and National Defense Nutrition Surveys.

[12] An exception to the rice-eating Asian peoples are the Punjabis of India and West Pakistan, who eat mainly wheat (and also drink milk, about 130 gms/day). (White House-Department of the Interior Panel, *Report on Land and Water Development in the Indus Plain,* 1964.) Their average weight is much higher than that of the rice-eating East Pakistanis (who consume only about 17 gms. of milk/day). (U.S. Department of Health, Education, and Welfare, Office of International Research, *Nutrition Survey of East Pakistan,* 1964, Washington, D.C. 1966.) (Figure 5)

[13] B.V. is the proportion of absorbed nitrogen retained in the body.

[14] P.E.R.—ratio of gain in body weight to amount of protein consumed over a specific period and at a level of intake just sufficient to support adequate protein nutrition.

[15] Volume II, Chapter 7 "The World Food Problem," PSAC Report of the Panel on the World Food Supply, May, 1967.

ferent American Indian tribes, the differences in body build were foreshadowed in the children by six years of age [Kraus (10)].

Within each group of countries practically all the data [16] indicate a consistent direct relationship between calorie supply and rates of growth as measured by body weight: the males and females who grow at the fastest rates and have the heaviest mature body weights among the Latin American and Asian countries respectively, by and large also have the highest estimated daily calorie supply.

If calories are the most important factor determining weight *within* each group of countries, the facts that weights at maturity are highly correlated with weights at 5.5 years of age among Asian and Latin American countries respectively, that rankings of weight at 5, 10, 15 and 20 years of age remain fairly consistent within each group, and that the data are cross-sectional, indicate that calorie supplies of the Latin American and Asian countries studied have maintained the same relative rankings during the last twenty years. (The exception is Thailand whose pre-teen children are inexplicably growing more slowly relative to the other Asian countries than teen-age children.)

Within each group of countries the body weight-growth curves show a gradual decline in body weight after middle age (Figures 1 and 2). Since the data are cross-sectional, this apparent weight loss may be due to the fact that the older people had a less adequate diet and a poorer health environment when they were young. A similar decline in body weight after middle age is also observed in a well-fed country like the United States, hence this effect according to Stoudt et al. (20) may also reflect preferential survival of smaller persons or may result from changes in mature individuals with advancing age.

What is the significance of the body weight data in relation to the absolute nutritional status of these Latin American and Asian peoples? That body weight is highly correlated with calorie supply within each group of countries does not of itself tell us whether inadequate nutrition is a limiting factor for people who have slow rates of growth and low body weights at maturity. By using as a standard of comparison the body weight-growth data of a population known to be well-fed, like that of the United States, it is usually concluded that poor nutrition is a cause of the relatively slow growth rates and small body sizes in the developing countries. But using the United States as a standard for an Asian or Latin American country is meaningless because of the basic differences in body size and bone structure among the different races of man. For a meaningful comparison, what is needed are data

[16] The exception is the low correlation between Asian male mature weights and ICNND calorie supply estimates, for which there is no explanation other than that the number of countries is small—four, and variability may be especially large.

on growth of children of the economically favored groups in each country compared with the growth of poor children, assuming insignificant racial segregation at different economic levels. Unfortunately, although it has been noted in general that within a given nation children from economically favored areas are taller and heavier than children from economically underpriviliged areas, very few quantitative data of this type can be found. There is a comparison of the weight of children from northeast Brazil and São Paulo from 1.5 to 5.5 years of age (the São Paulo children are most probably of a higher economic status) : the São Paulo males are heavier than the Northeast males by an average of 2.7 kg.; the São Paulo females are heavier by an average of 1.8 kg. [ICNND (7)]. There are also a small amount of data comparing Ecuadorian children of the general population and Ecuadorian children attending an American school: the latter males of ages 6.5 to 12.5 average 7.5 kg. heavier than the males from the general population; the females average 6.2 kg. heavier [ICNND (8)]. In this case racial differences may be as important as economic status in accounting for the differences in body weight.

In the absence of the ideal comparative growth rate data, one must consider more indirect methods of estimating undernutrition and malnutrition; the time of onset of the adolescent spurt (measured by the time of the maximum increment in height or weight in the adolescent years) has been shown to be delayed if there is malnutrition preceding adolescence: in man this is known as one of the effects of famine associated with war; it is known in animals from direct experiments.[17] So far as can be ascertained from existing data, nutrition has a greater influence on the time of the adolescent spurt than either climate or race, at least where the differences in nutritional status are wide. The time of occurrence of the spurt may be a more sensitive indicator of nutritional deficiency than growth rate at earlier periods. For example, the relatively slight malnutrition associated with the economic depression of 1929–1933 in the United States was insufficient to cause any alteration in the weights of children aged 6–11 in Hagerstown, Maryland, but it seemed to retard the onset of adolescence in both boys and girls [Tanner (21)].

Since malnutrition preceding adolescence is thus known to delay the appearance of the adolescent spurt, our finding of a significant difference of 1.8 years in the time of the adolescent spurt between boys of countries with estimated calorie supplies of over 2,300 calories and those with calorie supplies lower than 2,300 calories may be considered indicative of undernutrition or malnutrition preceding adolescence in the low calorie countries and suggests that those people at the low

[17] Many references, cited as Tanner (21), page 121.

275-253 O—67——3

end of the scale in each group of countries studied in this paper would be taller and heavier if they had a better diet.

It is of special interest that the difference in time of onset of the adolescent spurt in girls of the high and low calorie countries, while still significant, is a little smaller than that of the boys, 1.3 years as compared to 1.8 years. There is much evidence that the growth of girls is less affected by adverse circumstances than that of boys [Tanner (21), (12)]. This better power of homeorhesis [18] displayed by girls in their growth—thought to be related to the fact that they have two X chromosomes [Tanner (21)]—could also be the explanation for the fact that at ages 1.5, 2.5 and 5.5 there is a more highly significant difference between the mean weights of the Latin American and Asian females than the males: if a true genetic difference in body weights does exist between the two groups, this difference would be less obscured by environmental effects in the case of body growth data for the girls than for the boys.

Palmer and Reed (16) and Palmer et al. (15) have shown from longitudinal data that in the United States the time of the adolescent spurt is more closely related to the height or weight attained within a growth cycle than to an absolute chronological age. An additional indicator of nutritional status may therefore be our finding that the percentage of mature weight attained in boys at the time of onset of the adolescent spurt is significantly greater in the low-calorie countries than in the high-calorie countries [19] (Table 18), while the means of this percentage for boys of low-calorie Latin American countries and boys of the low-calorie Asian countries do not differ significantly.

A possible inference from this difference in percentage of mature weight attained at the time of the maximum increment in weight is that a certain absolute body weight is necessary before the onset of adolescence. Table 18 shows that the mean weight at the age of the maximum increment of weight in boys or girls does not differ significantly between high and low calorie countries: the mean weight at that time for boys of high-calorie countries is 35.4 kg., S.E., 0.95; of low-calorie countries 35.8 kg., S.E., 1.6; for girls of the high-calorie countries the mean weight is 34.1 kg., S.E., 2.0, for girls of the low-calorie countries the mean weight is 33.4 kg., S.E., 1.6. No definite conclusion can as yet be drawn from these results, however: for when countries in Latin America and Asia of the same nutritional level (below 2,300 calories) are compared, the mean weight of the Asian

[18] Waddington's (23) word, best translated as: "the end result is less easily altered."

[19] That no significant difference in this percentage was found between girls of high and low-calorie countries may be due to homeorhesis in girls.

girls at the time of the spurt (29.9 kg., S.E., 0.62) differs significantly ($P<0.01$) from the mean weight of the Latin American girls (36.4 kg., S.E., 1.2) while the percentage of mature weight attained does not differ significantly. The data for the boys of the low-calorie countries are apparently not adequate (variability is very large) to distinguish between whatever differences in percentage of mature weight attained or in absolute weight exist at the time of the adolescent spurt: both differences are not significant at the 0.01 probability level, a result incompatible with the fact that the mature weights of the two groups differ significantly. However, the probability that the difference between the means of the percentage weight attained by boys in the low-calorie countries of Latin America and Asia was due to chance was >0.50, while the probability that the difference in absolute weight was due to chance was between the 0.10–0.05 level, which accords with results found in girls.

That nutrition can be a determining factor in fulfilling genetic potential is strongly suggested by the changes of body size of the Japanese, accompanying the marked improvement in the quality of the food in Japan from 1948 to 1963. During this period calorie intake [20] increased only slightly from 2,010 to 2,080 (3.5 percent), but protein consumed increased from 63 to 70.6 gms. per day (12 percent), and animal protein increased from 13 to 27.7 gms. (113 percent). In the same interval, nineteen year old males increased 3.1 cms. in height, and 2.16 kg. in weight; nineteen year old females increased 1.2 cms. in height, but lost 1.12 kg. in weight (the latter loss most probably the result of a conscious effort among women to limit their weight). The greatest increment was made by the fourteen year old boys: height 11.4 cms., weight 7.5 kg [Mitchell (13), (12)].

A further indication that the time of the adolescent spurt is a sensitive index to nutrition is the fact that the adolescent spurt in height and weight for Japanese boys and girls was considerably earlier in 1963 than in 1948.[21] Also, the size of the increment at the time of the maximum increment in height and weight is greater in 1963 than in 1948 for both boys and girls (Table 20), which fits well with the established fact that the earlier the spurt occurs the more intense it appears to be [Tanner (21)].

That particular nutrients may be of great importance in promoting increased growth in height and weight is also suggested by experi-

[20] Note that Japanese calorie supplies given in Table 3 from USDA data are 13.5 percent greater than calorie intake as reported by the Japanese.

[21] No test of significance could be made since the original Japanese data did not give standard errors of the means.

ments in which one group of children in a Scottish city received extra milk, and two control groups received either no supplement or a supplement of biscuits of the same caloric content as the milk. The children receiving the milk showed greater height and weight gains at ages 5–6, 8–9, and 13–14 than the two control groups of children [Tanner (21)].

Evidence for the role of generally improved nutrition in achieving genetic potential is provided by two studies of the children of Japanese migrants: the first, a comparison of the growth of American-born Japanese children in California (1956–57) and children of the same sex and age in Japan (1953) by Greulich, using cross-sectional data. California-born Japanese children were significantly taller, heavier, and more advanced in skeletal development than comparable children in Japan, and the magnitude of the difference was very large: at every age (6–19 years), American-born Japanese boys exceeded Japanese boys in average stature by an amount greater than the increase which has taken place in average stature of the boys of Japan since the beginning of the present century. At 18 years of age, the California-born Japanese boys were 6.4 cms. taller and 4.6 kgs. heavier than 18 year old Japanese boys. California-born Japanese girls were 6.3 cms. taller and 2.3 kgs. heavier than 18 year old Japanese girls. Though the Japanese children in California grew so much more rapidly than those in Japan, the ratio of sitting height to stature in older children did not differ significantly between the two groups. The ratio is apparently a valid racial characteristic of adult Japanese [Greulich (6)].

The time of the adolescent spurt in height and weight was computed by us for the American-Japanese children and the Japanese children from Greulich's data cited above: the time of the height spurt in American-Japanese boys was four years earlier than that of the Japanese boys; the time of the weight spurt, three years earlier; the American-Japanese girls had their height spurt two years earlier than the Japanese girls; the time of their weight spurt did not differ. In all cases, the size of the maximum increment of growth is larger for the American-Japanese boys and girls. When the time of onset of the spurt in height and weight of the American-Japanese children in 1956–7 is compared with the Japanese children in 1963, the Nisei still have the earlier time of onset of the spurt in both boys and girls,[22] and the

[22] These differences are significant at the 1 percent probability level. The girls show the lesser effect, as expected, because of homeorhesis.

increment of growth at the time of the spurt is larger for the Nisei children (Table 20). Presumably these differences reflect the superior nutrition of the Nisei children.

Shapiro's (19) study of Japanese migrants to Hawaii is of special interest because the migrants were shown to be a distinct subgroup of the original Japanese population: the males, for example, had shorter trunks, longer legs, wider shoulders, and different facial proportions, and the females were 2.5 cms. taller, with differing facial proportion. That the migrant group inexplicably diverged from the original population was irrelevant, however, to the environmental effect on their offspring: the Hawaiian-born children of the immigrants as adults were significantly taller than the immigrants, the males by 4.1 cms. and the females by 1.7 cms. They did not differ significantly in weight, but this is readily explained by the 14 year age difference between the immigrant and the Hawaiian-born groups when measured, and the fact that the immigrants were significantly heavier than their relatives in Japan, an increase undoubtedly due to their better nutrition in Hawaii. As in the Nisei, although there was an increase of stature among the Hawaiian born, the ratio of sitting height to stature remained unchanged from that of the immigrants.

Another example, as shown by Bayne (1), of a greater attainment of genetic potential most probably due to improvements in nutrition is that of the steady increase in Great Britain of the heights and weights of 5, 8, and 12 year old children from 1911 to 1953, except when the two World Wars had a retarding effect on growth. The weight of 5 year old urban boys increased from 17.9 kgs. to 20.1 kgs., that of 8 year olds from 23.0 kgs. to 27.3 kgs., and that of 12 year olds from 32.7 kgs. to 39.1 kgs.

The trend in this century in the United States to increased height and weight at maturity is most 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 kgs. heavier than the inductees of World War I. Inductees measured during 1957–58 were 1.27 cms. taller and over 3.2 kgs. 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 kgs. Civilian studies in the United States show the same trend: in two successive generations of Harvard students from the same families, the sons were 3.3 cms. taller and the 4.5 kgs. heavier than their fathers at the same age [Stoudt (20)].

The secular trend in height and weight in all the developed countries has been accompanied by a trend to an earlier time of adolescence as typified by menarche or the growth spurt. For example, in Western Europe from 1830–1960, the age at menarche has become earlier by some four months per decade [Tanner (21)].

The data on urban and rural Indians show that urban males and females are taller and heavier at maturity than the rural. Though better nutrition of the urban people seems the most reasonable hypothesis for their larger size, there is also the possibility that larger people migrate to the cities. However, when the time of the adolescent spurt in height and weight is considered (the time for maximum increment in height and weight for urban boys is a year earlier than for rural boys), nutrition seems much more likely to be the determining factor in the differences between the urban and rural people.

Based on the examples in this paper, we conclude that the age of maximum increment of growth in height or weight of adolescent boys may be a very useful indicator of nutritional status up to the time of adolescence. It is very easily calculated (though, of course, it is necessary that all the data being compared be based on the same time intervals—e.g., from mid-year to mid-year, as in this paper), and it is only necessary to take growth measurements of boys from about ages 9 to 17, rather than the full period of growth of both sexes. Also, it may be possible to use the time of onset of the adolescent spurt in height or weight of any well-nourished country as a standard for nutritional status, provided the age of onset of the adolescent spurt in height or weight is not influenced by race. No significant difference in the age of onset of the spurt was found in boys or girls of Latin American and Asian countries of the same nutrition level (or of all Latin American and Asian countries) in our data. The considerable other evidence in the literature that race may not affect the time of adolescence is tabulated by Tanner (21).

If further data support its usefulness, the developing countries might be particularly interested in collecting longitudinal and cross-sectional data of height and weight of boys. (More refined significance tests can be made with longitudinal growth data.) [23] Comparisons

[23] When only cross-sectional data are available, the significance of the difference between two different times of the spurt can be tested by comparing the standard error of the difference of the two means ($\sqrt{(S.E._1)^2 + (S.E._2)^2}$) at the time of the greatest increment of growth, with the difference between the two means at that time. If the latter is three times the standard error, the means are a good measure of the population and the calculated time of onset of the spurt can be considered reliable.

could then be made of the age of onset of the adolescent spurt in different groups within the population, between countries of a region, and between developing and developed countries.

Summary

1. Cross-sectional data on growth as measured by increases in body weight with age in seven Latin American countries and seven Asian countries were analyzed for variation among each group of countries, between the two groups of countries, and for variation related to estimated calorie supplies.

2. There are marked variations in average mature body weights among the different peoples of Latin America and Southeast Asia. The differences among the peoples within each continent are in the range of 15–18 percent. The difference between the extremes of the two groups is about 30 percent.

3. There is no significant difference in height between the Latin American peoples and the Asian, but the Latin American adults weigh about 9 kilograms more than the Asian adults, though the estimates of calorie supplies available to the two groups of peoples (based on two different sources) do not differ significantly. This difference in mean weights between Latin Americans and Asians may be of genetic origin.

4. The difference in weight between the Latin American peoples and Asian is significant at 1.5, 2.5, and 5.5 years of age.

5. The correlation between mature weight and estimated calorie supplies within a group of countries is very high ($r=0.93$ for Latin American males, $r=0.85$ for Asian males).

6. The mean age of occurrence of the adolescent spurt in weight (the age of occurrence of the maximum increment in weight) does not differ significantly for either boys or girls of Latin America and Asia.

7. The mean age of the occurrence of the adolescent spurt in weight was significantly earlier (13.0 years, S.E., 0.10, for boys) for countries

which had daily per capita calorie supplies over 2,300 than for those which had calorie supplies under 2,300 (15.1 years, S.E., 0.30) ($P<0.01$). The difference for girls, while still significant, was slightly smaller: girls of the high-calorie countries, 12.2 years, S.E., 0.38, and girls of the low-calorie countries 13.5 years, S.E., 0.42, which fits well with other observations in the literature that the growth of girls is less affected by adverse environmental circumstances than the growth of boys.

8. The data on the adolescent spurt suggest that the people of the countries in each continent at the low end of the calorie scale are not realizing their genetic potential because of poor nutrition.

9. The percentage of mature weight attained at the time of the adolescent spurt in weight in boys is significantly greater in the low-calorie countries than in the high-calorie countries. Boys and girls in low-calorie Latin American and Asian countries show no significant difference in this percentage.

10. The actual weight of boys and girls at the age of the maximum increment in weight does not differ significantly in the high- and low-calorie countries, but in low-calorie countries the mean weight of the Asian girls at the time of the spurt differs significantly from the mean weight of Latin American girls.

11. Based on examples given in this paper, it is suggested that the age of maximum increment of growth in height and weight of adolescent boys may be a very useful index of nutritional status. Its advantages are that only boys need be measured, and for a limited period of their growth; the computations are simple; and it may be possible to use the growth spurt data of any country as a basis of comparison.

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TABLE 1.—*Number of subjects and other details of the height and weight data of Latin American and Asian countries* [a]

Country	Total Number of Subjects	Males	Females	Per-cent Rural	Number of Subjects at Specific Ages: Age (Years)	Males	Females [b]	Survey Sites	Mean Age Years (Males)	Mean Ht. cms. (Males)	S.E. cms. (Males)	Mean Wt. kg. (Males)	S.E. kg. (Males)
Latin America:													
Bolivia	5,787	3,480	2,307	63.9	0–4	178	163	La Paz and sites in 8 departments	------	------	------	------	------
					5–9	772	627		------	------	------	------	------
					10–14	706	507		------	------	------	------	------
					15–44	1,305	592		------	------	------	------	------
					45+	519	256						
Chile	5,351	1,951	3,400	22.6	0–4	158	153	15 areas representing varying altitude, terrain, & climate	------	------	------	------	------
					5–9	505	522		------	------	------	------	------
					10–14	450	526		------	------	------	------	------
					15–19	143	309		------	------	------	------	------
					20–24	398	1,251		------	------	------	------	------
					45–64	216	516		------	------	------	------	------
					65+	81	123		------	------	------	------	------
Colombia	4,818	2,259	2,559	57.3	0–4	326	358	14 sites in 4 main regions of country	------	------	------	------	------
					5–14	1,664	1,578		------	------	------	------	------
					15+	269	623		------	------	------	------	------
Ecuador	4,523	----------	----------	------	0–4	236	250	12 sites in 5 main regions	20+	157.7	0.3	57.5	0.4
					5–14	1,066	1,267		------	------	------	------	------
					14–20	594			------	------	------	------	------
					20+	549	561		------	------	------	------	------
Northeast Brazil	5,538	2,009	3,300	≈63.0	<5	457	506	16 sites in 6 states	------	------	------	------	------
					5–9	478	547		------	------	------	------	------
					10–14	393	617		------	------	------	------	------
					15–44	535	1,307		------	------	------	------	------
					45+	146	323		------	------	------	------	------

Uruguay	5,377	2,180	3,197	62.0	<1–4	300	321	5 areas in 3 main zones of interior—62%, Monte-video—38%.	2	87.4	0.7	13.2	[d] 0.2
					5–9	369	416		4	103.1	0.7	17.3	0.3
					10–16	363	441		6	115.0	0.7	21.1	0.4
					15+	1,148	1,936		8	126.6	0.8	25.8	0.6
									10	134.9	0.7	30.9	0.6
									12	146.3	1.1	39.0	1.0
									14	158.4	1.6	49.4	1.6
									16	166.4	1.4	56.2	1.3
Venezuela	6,515	2,487	4,028	42.3	0–4.4	680	684	35 communities in 6 areas	2.3	84.8	0.6	11.9	[e] 0.2
					4–9	878	942		4	99.8	0.8	15.6	0.2
					10–14	470	584		6	110.2	0.5	18.8	0.2
					15–24	152	555		8	120.6	0.6	22.8	0.3
					25–34	80	491		10	130.8	0.7	27.8	0.4
					35–44	86	373		12	139.6	0.8	34.0	0.8
					45–64	110	342		14	150.4	1.3	40.8	1.2
					65+	31	51		------	------	------	------	------
Asia:													
Burma	2,003	1,104	899	------	<15	346	241	9 villages in S. & Central Burma.	------	------	------	------	------
					15–24	166	92						
					25–44	341	146						
					45+	251	214						
India	57,214	30,710	26,504	23 (semi-urban 27.5)	0–5	5,748	5,035	12 states and Delhi	------	------	------	------	------
					5–9	8,560	7,840						
					10–14	8,742	7,602						
					15–18	5,748	4,632						
					19–21	1,912	1,395						
Japan:													
1948, 1963	No numbers given; an annual national survey and numbers presumably are large.							random sample. Non-agricultural & agricultural households.	6	107.0	.02	17.5	[e] .01
1953	2,291,182	1,220,205	1,070,977	------	6.5–10.5	378,590	367,161	------	8	117.4	.02	21.6	.01
					10.5–14.5	393,512	381,380	------	10	126.5	.02	26.0	.01
					15.5–17.5	410,492	308,779	------	12	135.5	.02	31.0	.01
					18.5–19.5	37,611	13,657	------	14	146.5	.02	39.0	.02
									16	159.3	.02	49.9	.02
									19	162.6	.06	54.9	.06

See footnotes at end of table.

TABLE 1.—*Number of subjects and other details of the height and weight data of Latin American and Asian countries*[a]—Continued

Country	Total Number of Subjects	Males	Females	Per-cent Rural	Number of Subjects at Specific Ages: Age (Years)	Males	Females[b]	Survey Sites	Age Years	Mean Ht. cms.	S.E. cms.	Mean Wt. kg.	S.E. kg.
									Males				
Malaya	[e] 6,179	3,231	2,948	79.2	<5	488	455	Sites in all 9 states	15	155.9	1.1	44.7	[c] 1.0
					5–9	820	751		17	160.9	1.0	51.2	1.0
					10–14	974	689		19	162.2	1.0	52.4	1.0
					15–44	631	713		25	161.8	0.9	55.1	0.9
					45+	318	340		30	160.0	0.8	54.0	1.0
									35	160.3	1.0	53.3	1.0
									40	160.7	0.8	54.7	1.2
									50	159.4	0.8	52.7	1.3
									60	158.8	0.9	50.6	1.1
Pakistan:													
West	2,388	1,141	1,247	------	0–1	214	292	random sample urban and rural areas, Lahore region.	------	------	------	------	------
					1.5	81	67						
					3.5	59	49						
					7.0	158	159						
					11.6	124	129						
					18.0	114	133						
					28.5	192	222						
					41.5	96	107						
					65+	103	89						

East	16,238	9,579	6,659	[f] 76	0–4	578	511	All 17 districts 17 rural sites, 5 urban.	4	34.1	0.4	10.62	0.2
					5–14	3,777	2,628						
					15+	5,224	2,114						
Thailand	2,389	1,067	1,310	93	<1–4	200	198	6 areas in 6 of the 9 regions	25–29	------	------	53.2	0.9
					5–9	175	169		------	------	------	------	------
					10–14	184	201		------	------	------	------	------
					15–19	37	101		------	------	------	------	------
					20–24	44	33		------	------	------	------	------
					25–29	57	32		------	------	------	------	------
					30–39	159	59		------	------	------	------	------
					40–49	80	75		------	------	------	------	------
					50–59	80	77		------	------	------	------	------
					60–69	51	72		------	------	------	------	------
Vietnam	4,511	2,353	2,158	------	0–4	335		6 major sites, 2 in each of 3 principal areas.	------	------	------	------	------
					5–9	1,214			------	------	------	------	------
					10–14	915			------	------	------	------	------
					(0–14	1,334	1,137)		------	------	------	------	------
					15–44	1,314			------	------	------	------	------
					45–64	576			------	------	------	------	------
					65+	155			------	------	------	------	------
					(15+	1,024	1,021)		------	------	------	------	------

[a] See Tables 4 and 6 for sources.
[b] Non-pregnant, non-lactating females.
[c] Standard errors of the means for females are the same order of magnitude.
[d] Standard errors of the means are slightly smaller for females.
[e] Malayans 53%, Chinese 40%, Indians 6%.
[f] Of males ages 17–65.

TABLE 2.—*Average height and weight of males and females (25–29 years), and estimated daily calorie supplies for seven Latin American countries*

Country	Males		Females		(5) Daily Calorie Supply	
	(1) Height cms	(2) Weight kg	(3) Height cms	(4) Weight kg	(a) USDA	(b) ICNND
Uruguay	[a] 168.1	70.0	[a] 155.5	60.0	3030	2670
Chile	162.8	64.3	151.9	56.4	2610	2380
Venezuela	164.2	62.4	152.5	53.0	2330	2180
Bolivia	161.3	61.0	151.0	54.0	2010	1810
Colombia	[a] 160.1	59.6	[a] 151.2	49.4	2280	1450
N.E. Brazil	[a] 160.6	58.0	[a] 150.4	48.8	n.a.	1650
Ecuador	[b] 157.7	57.5	[b] 146.3	51.3	2100	1890

[a] Average of 15+ years.
[b] Average of 20+ years.

Sources: Columns (1)–(4) Interdepartmental Committee for Nutrition and National Defense Surveys for each country; (5)(a) Estimates (1959–1961), U.S. Department of Agriculture, *World Food Budget 1970*, 1964, (b) ICNND Surveys for each country, average of three survey methods.

TABLE 3.—*Average height and weight of males and females (25–29 years), and estimated daily calorie supplies for seven Asian countries*

Country	Males		Females		(5) Daily Calorie Supply	
	(1) Height, cms	(2) Weight, kg	(3) Height, cms	(4) Weight, kg	(a) USDA	(b) ICNND
Japan	163.2	56.8	151.9	49.1	2360	n.a.
Malaya	161.8	55.1	149.8	47.8	2400	2560
Thailand	161.0	53.2	151.0	45.8	2120	1800
Pakistan	n.a.	50.6	n.a.	43.8	2120	n.a.
Burma	[a] 161.5	49.9	[a] 150.7	45.2	2170	2430
Vietnam	157.6	49.1	147.6	43.5	n.a.	1940
India [b]	163.0	48.2	150.7	42.5	2060	n.a.

[a] Ages 15+.
[b] Ages 20–21.

Sources: Columns: (1)–(4) Interdepartmental Committee for Nutrition and National Defense Surveys for each country except India, *Indian Council of Medical Research, 1960*, and Japan, Ministry of Health and Welfare, *Nutrition in Japan, 1964*, Tokyo, 1965; (5)(a) Estimates (1959–1961), U.S. Department of Agriculture, *World Food Budget 1970*, 1964, (5)(b) ICNND Surveys for each country. Average of three survey methods.

TABLE 4.—*Average weight of males by age in seven Latin American countries*

Age Years	(1) Ecuador	(2) Venezuela	(3) Uruguay	(4) Bolivia	(5) Chile	(6) Colombia	(7) N.E. Brazil
	kg	*kg*	*kg*	*kg*	*kg*	*kg*	*kg*
0.5	----------	7.0	7.5	7.7	----------	6.5	6.4
1.5	8.3	10.2	12.3	9.5	12.3	8.8	8.9
2.5	11.3	12.0	14.0	11.1	13.5	10.6	11.4
3.5	13.5	14.4	16.0	13.3	15.8	12.5	13.0
4.5	14.3	15.5	18.0	15.2	17.7	13.3	14.5
5.5	16.8	17.3	20.0	16.4	19.3	15.9	15.9
6.5	17.5	18.6	22.5	20.5	21.0	17.3	17.7
7.5	18.1	21.1	24.5	22.3	22.7	19.1	19.9
8.5	20.5	22.7	27.0	24.5	25.0	20.9	22.1
9.5	22.3	25.9	29.5	26.4	27.0	22.7	24.3
10.5	23.4	28.1	32.0	28.2	28.9	25.0	26.5
11.5	25.9	30.5	36.8	31.8	31.3	28.2	28.2
12.5	28.6	34.1	42.5	33.2	36.5	28.6	30.4
13.5	31.4	38.2	48.0	36.8	43.5	32.7	33.2
14.5	35.9	41.4	51.5	41.4	49.5	37.3	38.4
15.5	39.5	45.2	55.0	44.3	54.0	43.2	41.8
16.5	44.1	49.2	56.0	49.5	55.4	47.3	47.8
17.5	51.8	53.0	59.8	54.5	57.7	52.0	49.0
18.5	53.5	56.6	64.0	56.5	59.5	54.0	50.5
19.5	55.3	59.5	65.0	57.4	60.0	56.0	52.0
20–24	57.5	61.9	65.5	59.0	61.2	61.0	55.0
25–29	57.5	62.4	70.0	61.0	64.3	59.6	58.0
30–34	57.5	66.3	71.1	62.0	67.0	59.0	55.0
35–39	57.5	68.1	75.6	62.0	67.1	59.0	57.0
40–44	57.5	66.0	75.6	63.0	69.7	59.0	57.6
45–49	57.5	66.0	76.0	62.0	71.0	59.0	58.0
50–54	57.5	66.8	76.0	63.0	69.0	55.2	57.2
55–59	57.5	68.2	72.9	64.0	72.9	55.2	55.8
60–64	57.5	64.0	72.0	57.0	71.6	53.4	53.5
>65	57.5	59.7	72.0	56.0	67.2	53.4	52.0

Sources: ICNND (Interdepartmental Committee for Nutrition and National Defense). Nutrition Surveys: Ecuador 1960, Venezuela 1964, Uruguay 1962, Bolivia 1964, Chile 1961, Colombia 1961, N.E. Brazil 1965.

TABLE 5.—*Average weight of females by age in seven Latin American countries*

Age Years	(1) Ecuador	(2) Venezuela	(3) Uruguay	(4) Bolivia	(5) Chile	(6) Colombia	(7) N.E. Brazil
	kg	*kg*	*kg*	*kg*	*kg*	*kg*	*kg*
0.5	------------	6.8	7.0	6.4	----------	6.0	6.1
1.5	9.0	9.1	11.5	8.8	11.5	8.6	8.4
2.5	10.5	11.6	13.5	10.7	13.2	10.4	11.1
3.5	12.5	13.5	15.5	12.7	15.5	12.1	12.5
4.5	14.3	15.5	17.4	14.8	17.0	13.4	14.5
5.5	15.9	16.8	19.1	16.5	19.0	15.9	16.4
6.5	16.8	18.6	21.5	18.6	21.7	16.8	17.7
7.5	18.6	20.5	24.1	19.5	23.5	19.3	19.5
8.5	19.6	22.6	27.0	22.3	25.5	20.1	21.7
9.5	22.0	25.5	31.0	24.5	28.0	22.3	24.2
10.5	23.6	28.6	34.5	27.3	31.0	25.0	27.4
11.5	26.8	32.3	38.3	30.5	34.3	28.2	29.3
12.5	29.5	36.8	43.5	33.9	39.5	30.9	33.2
13.5	33.9	41.1	48.2	37.5	46.5	35.5	38.3
14.5	39.0	44.5	51.6	44.3	49.6	40.1	41.6
15.5	42.0	47.6	54.0	48.6	50.6	46.5	44.0
16.5	44.5	49.5	54.5	52.3	51.0	49.5	46.0
17.5	48.6	50.3	55.0	54.3	53.4	51	47.0
18.5	49.5	50.4	55.8	54.5	53.8	51.5	47.3
19.5	50.0	50.5	56.2	54.8	54.0	50.8	47.5
20–24	50.8	50.7	57.7	54.4	54.4	49.2	47.9
25–29	51.3	53.0	60.0	54.0	56.4	49.4	48.8
30–34	51.6	54.9	62.6	56.0	58.4	50.9	50.6
35–39	51.3	56.4	65.7	55.5	61.5	53.9	50.9
40–44	51.3	58.2	68.2	55.5	62.3	53.2	51.1
45–49	51.3	58.7	69.2	56.0	62.7	51.8	51.5
50–54	51.3	58.6	69.1	55.5	64.6	51.2	51.0
55–59	51.3	54.8	69.1	57.0	63.1	50.3	50.6
60–64	51.3	50.2	68.0	49.5	61.6	49.4	49.3
65+	51.3	51.3	65.0	49.0	60.8	48.5	47.0

Sources: ICNND Nutrition Surveys: Ecuador 1960, Venezuela 1964, Uruguay 1962, Bolivia 1964, Chile 1961, Colombia 1961, N.E. Brazil 1965.

TABLE 6.—*Average weight of males by age in seven Asian countries*

Age Years	(1) West Pakistan	(2) East Pakistan	(3) Pakistan Average (1)+(2)	(4) Thailand	(5) Vietnam	(6) Malaya	(7) Burma	(8) India	(9) Japan
	kg	*kg*	*kg*	*kg*	*kg*	*kg*	*kg*	*kg*	*kg*
0.5	6.3	5.8	6.1	6.2	6.0	7.0	6	--------	-------
1.5	9.4	7.8	8.6	8.0	7.7	9.2	9.5	8.3	11.5
2.5	11.0	9.3	10.2	9.8	8.8	10.7	11.0	10.1	13.0
3.5	12.8	11.0	11.9	11.2	10.9	12.2	12.0	11.5	15.0
4.5	14.5	12.0	13.3	12.4	13.0	13.8	13.0	13.0	16.5
5.5	16.2	13.0	14.6	14.2	14.5	15.3	14.0	14.4	18.4
6.5	18.1	14.7	16.4	15.9	17.4	17.2	16.3	15.8	20.0
7.5	20.0	16.3	18.7	17.1	18.6	18.6	18.1	17.6	22.5
8.5	23.1	18.7	20.9	18.8	20.0	20.1	20.0	18.9	24.5
9.5	24.4	21.2	22.8	19.9	22.2	21.7	23.0	21.2	26.7
10.5	26.8	23.0	24.9	22.8	23.5	24.2	24.0	23.7	29.4
11.5	29.0	25.0	27.0	26.0	24.5	26.6	25.4	25.6	32.5
12.5	32.0	27.5	29.8	28.4	27.0	29.0	26.0	28.2	37.4
13.5	35.6	32.0	33.8	32.6	28.9	32.4	29.7	31.5	43.0
14.5	39.0	35.0	37.0	33.7	33.7	39.6	35.0	34.6	48.5
15.5	42.2	39.0	40.6	40.5	39.7	44.7	39.5	37.9	52.5
16.5	45.3	42.0	43.7	41.1	40.8	50.6	42.5	41.8	54.8
17.5	49.0	44.0	46.0	47.5	45.0	51.2	45.9	43.9	55.5
18.5	50.0	45.2	47.6	46.6	46.1	54.3	46.1	45.9	56.3
19.5	51.0	45.5	48.3	51.2	46.4	52.4	47.0	47.0	56.5
20–24	52.6	45.6	49.1	53.0	49.0	52.2	47.6	[1] 48.2	56.7
25–29	55.0	46.1	50.6	53.2	49.1	55.1	49.9	--------	56.8
30–34	56.2	45.8	51.0	50.5	49.1	54.0	50	--------	56.9
35–39	57.0	46.0	51.5	52.0	48.0	53.3	49.5	--------	56.9
40–44	56.6	45.6	51.1	51.7	47.8	54.7	48.5	--------	56.8
45–49	56.6	45.8	51.2	50.1	47.5	52.9	--------	--------	56.5
50–54	56.2	45.0	51.1	51.8	47.4	52.7	--------	--------	56.0
55–59	55.0	45.1	50.1	50.6	47.5	50.6	--------	--------	55.5
60–64	----------	44.6	----------	49.4	47.5	50.6	--------	--------	54.5
65+	----------	43.8	----------	48.1	46	49.0	--------	--------	53.1

[1] 20–21 years.

Sources: Interdepartmental Committee for Nutrition and National Defense, Nutrition Survey: Burma 1963, Thailand 1962, Vietnam 1959, Malaya 1962 (ages 18.5–65+ personal communication from E. B. Bridgforth, University of Texas, Galveston). East Pakistan, Office of International Research, National Institute of Health, U.S. Department of Health, Education and Welfare, *Nutrition Survey, East Pakistan*, 1966. West Pakistan (1964), Personal communication, Dr. Barbara Underwood, Institute of Nutrition Sciences, Columbia University. (See Table 11.) India, Indian Council of Medical Research, *Report of the 42nd Meeting of the Nutrition Advisory Committee. Hyderabad*, December 1960. (See text, p. 4, for method of computation.) Japan, Ministry of Health and Welfare, *Nutrition in Japan 1964*, Tokyo, 1965.

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TABLE 7.—*Average weight of females by age in seven Asian countries*

Age Years	(1) West Pakistan	(2) East Pakistan	(3) Pakistan Average (1)+(2)	(4) Thailand	(5) Vietnam	(6) Malaya	(7) Burma	(8) India	(9) Japan
	kg	*kg*	*kg*	*kg*	*kg*	*kg*	*kg*	*kg*	*kg*
0.5	6.3	5.8	6.1	6.4	4.5	6.8	4.5	--------	--------
1.5	9.2	7.7	8.5	7.5	6.9	8.7	8.0	7.9	10.6
2.5	10.8	9.0	9.9	9.2	8.3	10.1	10.0	9.5	12.9
3.5	12.1	11.1	11.6	10.6	10.4	11.8	11.0	11.2	14.5
4.5	14.0	11.5	12.8	12.5	12.1	13.9	12.4	12.5	16.0
5.5	15.6	12.5	14.6	13.8	13.7	14.6	14.0	13.8	17.5
6.5	17.2	14.2	15.7	15.6	15.7	16.6	16.0	15.3	19.5
7.5	20.0	15.0	17.5	16.7	17.9	18.1	17.5	16.9	20.6
8.5	22.4	18.8	20.6	18.4	19.1	19.9	19.4	19.1	24.0
9.5	25.0	20.0	22.5	20.2	20.9	22.3	21.1	20.6	27.0
10.5	27.3	22.6	25.0	22.0	23.7	24.1	23.0	22.6	30.0
11.5	29.8	27.0	28.4	26.8	26.6	27.6	25.0	25.5	34.5
12.5	32.2	27.5	29.9	30.4	27.6	30.7	28.5	27.9	39.0
13.5	35.0	32.5	33.8	34.5	31.1	38.0	30.0	31.9	43.0
14.5	37.8	36.3	37.1	36.0	36.6	39.9	38.5	34.7	46.5
15.5	40.3	38.8	39.6	40.7	35.8	44.8	41.0	37.8	48.9
16.5	43.0	40.0	41.5	40.4	40.9	47.2	43.5	40.0	50.0
17.5	45.0	39.7	42.4	44.6	41.5	46.1	44.0	41.1	50.0
18.5	46.3	39.5	42.9	47.7	43.1	47.8	44.4	41.8	49.8
19.5	46.8	39.5	43.2	46.3	43.1	46.5	45.0	41.5	50.0
20–24	47.3	40.3	43.8	46.0	43.2	47.0	45.0	[1] 42.5	48.9
25–29	48.5	39.1	43.8	45.8	43.5	47.8	45.2	--------	49.1
30–34	49.8	39.7	44.8	44.2	43.5	48.7	45.1	--------	49.6
35–39	50.4	39.5	45.0	46.1	42.5	48.4	44.5	--------	50.0
40–44	50.2	38.6	44.4	45.8	42.0	48.6	43.5	--------	50.2
45–49	50.2	38.7	44.5	44.6	42.0	47.5	--------	--------	50.1
50–54	50.0	38.5	44.3	43.0	40.5	45.4	--------	--------	49.4
55–59	49.0	37.9	43.5	40.9	39.5	46.8	--------	--------	48.3
60–64	46.9	36.6	41.8	40.8	39.1	45.8	--------	--------	46.9
>65	----------	36.4	----------	41.0	--------	44.4	--------	--------	46.1

[1] 20–21 years.

Source: See Table 6, Weight of Males by Age in 7 Asian Countries.

TABLE 8.—*Comparison of average weights of Japanese males and females by age in 1948, 1953, and 1963*

Age Years	Males (1) 1948	Males (2) 1953	Males (3) 1963	Females (1) 1948	Females (2) 1953	Females (3) 1963
0	7.13	------------	7.60	7.10	------------	7.29
1	9.41	------------	10.33	9.02	------------	9.99
2	11.36	------------	12.48	10.84	------------	11.84
3	13.28	------------	14.05	12.57	------------	13.65
4	14.63	------------	15.62	13.80	------------	15.25
5	16.04	------------	17.39	15.70	------------	16.80
6	17.79	17.5	19.18	17.23	16.8	18.43
7	19.55	19.6	21.17	18.91	19.0	20.60
8	21.46	21.6	23.29	20.70	21.0	22.50
9	23.63	23.8	25.83	22.79	23.1	25.11
10	26.13	26.0	28.08	25.21	25.5	28.46
11	28.04	28.4	31.38	28.10	28.3	32.37
12	30.84	31.0	34.91	31.51	31.9	37.50
13	34.32	34.5	40.36	35.53	36.0	41.29
14	38.63	39.0	46.10	39.67	40.0	45.00
15	43.38	44.9	50.65	43.57	44.1	47.83
16	47.38	49.9	54.09	46.50	47.2	49.57
17	50.79	52.8	55.19	49.04	49.0	50.41
18	53.02	54.4	55.76	50.48	49.8	49.81
19	54.11	54.9	56.27	51.08	50.2	49.86
20–24	55.66	------------	56.66	50.46	------------	49.44
25–29	55.23	------------	56.84	49.42	------------	49.11

Sources: (1), (3) Ministry of Health and Welfare, *Nutrition in Japan, 1964*, Tokyo, 1965; (2) Greulich, W. *Am. J. Phys. Anthro. 15*, p. 489, 1957 (from Japanese Ministry of Education, 1953).

TABLE 9.—*Comparative data on average weights of Indian males by age*

Age[b] Years	ICMR 1960[a, l]				Hyderabad[g]	Madras[g]	Mysore[h]	Amritsar (Punjab)[j]	Reference Man[k]
	Rural[c]	Semi-Urban[d]	Urban[e]	Wt. Av.[f]					
	kg	*kg*	*kg*	*kg*	*kg*	*kg*	*kg*	*kg*	*kg*
0.5	--------	--------	--------	--------	--------	5.8	--------	--------	--------
1.5	8.3	8.3	8.5	8.3	8.4	9.5	8.8	--------	--------
2.5	10.1	10.7	10.3	10.2	9.7	11	10.2	--------	--------
3.5	11.4	11.8	12.2	11.5	11.9	12.2	11.8	--------	--------
4.5	12.9	13.5	13.6	13.0	13.4	13.8	13.0	--------	--------
5.5	14.5	14.6	15.0	14.6	14.8	14.0	14.0	--------	--------
6.5	15.7	16.0	16.7	15.8	16.3	16.0	16.0	--------	--------
7.5	17.5	17.8	18.1	17.6	17.9	18.5	18.1	--------	--------
8.5	19.0	19.2	20.3	18.4	19.7	20.0	19.8	--------	--------
9.5	20.7	20.9	21.6	20.8	21.2	21.8	22.0	--------	--------
10.5	22.7	22.2	23.7	23.4	23.1	23.3	22.6	--------	--------
11.5	25.2	25.5	25.6	25.3	24.6	25.0	26.3	--------	--------
12.5	27.7	28.0	28.1	27.8	26.8	28.0	28.7	--------	--------
13.5	30.6	31.5	31.4	30.8	31.2	31.5	32.3	--------	--------
14.5	33.5	35.2	34.8	33.8	34.7	35.0	36.3	--------	--------
15.5	36.4	38.8	39.8	37.0	38.8	39.0	--------	--------	--------
16.5	40.7	42.6	43.9	41.2	42.9	42.0	--------	--------	--------
17.5	42.5	45.2	46.2	43.1	45.2	45.0	--------	--------	--------
18.5	45.2	46.5	48.3	45.6	47.2	46.9	--------	--------	--------
19.5	46.4	47.4	50.3	46.9	48.6	48.2	--------	--------	--------
20–21	47.7	48.5	52.9	48.3	--------	49.8	[i] 49.0	--------	--------
25–29	--------	--------	--------	--------	--------	--------	--------	--------	55
30–34	--------	--------	--------	--------	--------	--------	--------	65.9	--------

[a] Indian Council of Medical Research, Report of 42nd Meeting, Nutrition Advisory Committee, Hyderabad, December, 1960.

[b] Age based on documentary evidence in only 21% of sample; for the remainder age is based on statements of the parents.

	No. of Subjects
[c] Rural—villages with less than 5,000 population	7,282
[d] Semiurban—cities with population 5,000–100,000	8,658
[e] Urban—cities with population>100,000	14,780
Total	30,720

[f] Weighted average, rural data multiplied by 8.

[g] ICMR, from interim report of Growth and Development of Indian Children, New Delhi; number of subjects in Hyderabad City 29,886; number of subjects in Madras 4,487, no date given.

[h] Swaminathan, M. C. et al, Nutrition of People of Ankola Taluk, N. Kanara, Mysore, *I. J. M. R. 48*, p. 762, 1960, number of subjects, 925.

[i] Weighted average, 970 adults of 4 castes, ages 15+.

[j] Patwardhan V., *Dietary Allowances for Indians*, New Delhi, 1960, number of subjects, 100.

[k] Ibid, Table IV, number of subjects 169, no identification of place of origin.

[l] States covered by Survey: Uttar Pradesh, Himachal Pradesh, Madhya Pradesh, Madras, Kerala, Mysore, Andhra Pradesh, Delhi, Punjab, Kashmir, Rajasthan, Maharashtra, Orissa.

TABLE 10.—*Comparative data on average weights of Indian females by age*

Age [b] Years	ICMR 1960 [a] [i] Rural [c]	Semi-urban [d]	Urban [e]	Weighted Av. (1-3) [f]	Hyderabad [g]	Reference [h]
	kg.	*kg.*	*kg.*	*kg.*	*kg.*	*kg.*
0.5	----------	----------	----------	----------	----------	----------
1.5	7.8	7.7	8.1	7.8	7.9	----------
2.5	9.5	9.5	9.8	9.5	9.6	----------
3.5	10.9	11.3	12.1	11.1	11.5	----------
4.5	12.4	13.2	13.6	12.6	13.2	----------
5.5	13.7	14.4	14.7	13.9	14.4	----------
6.5	15.2	15.8	16.2	15.4	15.8	----------
7.5	16.8	17.4	17.9	17.9	17.5	----------
8.5	18.4	19.7	19.6	18.7	19.4	----------
9.5	19.9	21.0	21.2	20.1	20.8	----------
10.5	21.6	22.9	23.1	21.9	22.7	----------
11.5	23.9	25.7	27.1	24.4	26.1	----------
12.5	26.9	28.8	30.4	27.4	27.9	----------
13.5	30.7	32.4	34.6	31.3	33.3	----------
14.5	33.6	35.9	36.7	33.8	36.0	----------
15.5	36.6	37.8	39.9	37.1	38.8	----------
16.5	39.2	39.8	41.4	39.5	40.7	----------
17.5	40.7	41.4	42.6	41.0	42.0	----------
18.5	41.6	41.7	43.6	41.8	42.9	----------
19.5	40.9	41.0	44.5	41.3	43.0	----------
20-21	41.9	42.9	45.7	42.4	----------	45.0

[a] ICMR, *Op. Cit.*, Table 9.

[b] Age based on documentary evidence in only 19% of sample; for the remainder age is based on statements of the parents.

	No. of Subjects
[c] Rural	5,649
[d] Semi-Urban	7,073
[e] Urban	13,781
Total	26,503

[f] Weighted average, rural data multiplied by 8.

[g] ICMR, interim report, *Op. Cit.*, Table 6, number of subjects, 26,003.

[h] Patwardhan, V., *Dietary Allowances for Indians*, New Delhi, 1960; number of subjects, 102, no identification of place of origin.

[i] States covered: see (1) Table 9.

TABLE 11.—*Observed average heights and weights of males and females by age in West Pakistan*

Mean Age Years	Males		Females	
	Ht. Cms.	Wt. Kg.	Ht. Cms.	Wt. Kg.
.0	50.2	3.1	49.0	2.9
.5	65.1	6.8	63.8	6.3
1.0	72.8	8.0	71.1	7.5
1.5±0.5	77.6	9.4	76.9	9.2
3.6±0.5	90.4	12.9	----	----
3.5±0.5	----	----	87.8	12.1
6.9±1.4	111.1	18.8	----	----
7.0±1.3	----	----	111.5	18.7
11.6±1.4	136.5	29.8	----	----
11.8±1.4	----	----	137.6	30.3
18.0±2.0	163.5	49.7	----	----
17.9±2.0	----	----	152.1	44.7
28.1±4.4	166.8	55.6	----	----
29.9±4.1	----	----	152.8	48.6
41.4±3.6	166.5	56.7	----	----
41.7±3.3	----	----	152.0	50.2
60.4±10.4	165.1	53.7	----	----
60.3±10.4	----	----	150.1	46.9

Source: Personal communication, Dr. B. Underwood, Institute of Nutrition Sciences, Columbia University, New York.

TABLE 12.—*Summary of "t" tests*

	Males		Females	
	"t"	P [1]	"t"	P [1]
1. Difference between Latin America and Asian people:				
A. Mean weights:				
At age 25–29 years	4.26	<.01	4.51	<.01
Omitting Uruguay	4.88	<.01	5.11	<.01
Omitting Uruguay and Japan	5.28	<.01	4.72	<.01
At age 20–24 years	2.78	.02–.01	----	----
At age 5.5 years	3.15	<.01	4.92	<.01
Omitting Uruguay and Japan	4.71	<.01	2.80	<.01
Omitting Uruguay	----	----	3.50	<.01
At age 2.5 years	2.24	.05–.02	2.34	.05–.02
Omitting Uruguay and Japan	3.08	.02–.01	3.26	<.01
At age 1.5 years	1.46	.20–.10	2.01	.10–.05
Omitting Uruguay and Japan	1.77	~.10	2.26	.05–.02
B. Mean heights:				
At age 25–29 years	.43	>.50	.71	>50
C. Calorie supplies:				
USDA estimates	.36	>.50	----	----
ICNND surveys	.69	>.50	----	----
2. Age of maximum increment in weight:				
High calorie countries and low calorie countries	4.66	<.01	2.11	.05–.02
Omitting Thailand	----	----	3.91	<.01

[1] Probability that the difference between the means is due to chance.

TABLE 13.—*Mean of average weights of boys and girls, 5.5, 2.5 and 1.5 years of age in six Latin American and six Asian countries (omitting Uruguay and Japan)*

Age years	Latin America Mean Wt.	Latin America S.E.[1]	Asia Mean Wt.	Asia S.E.[1]	P[2]
5.5:	*kg.*		*kg.*		
Boys	16.9	.52	14.0	.36	< .01
Girls	16.8	.47	14.0	.36	< .01
2.5:					
Boys	11.7	.41	10.1	.33	.02–.01
Girls	11.3	.43	9.6	.31	< .01
1.5:					
Boys	9.7	.57	8.6	.30	~.10
Girls	9.2	.49	8.0	.29	.05–.02

[1] Standard error of the mean of the six countries.
[2] Probability that difference between the means is due to chance.

TABLE 14.—*Relative rank of Latin American countries according to weight of males and females at different ages*

Rank	5.5	10.5	15.5	19.5	20–24	25–29
			Males			
Slowest	Colombia	Ecuador	Ecuador	N.E. Brazil	N.E. Brazil	Ecuador
↓	↑Ecuador	Colombia	N.E. Brazil	Ecuador	Ecuador	N.E. Brazil
	↓N.E. Brazil	N.E. Brazil	Colombia	Colombia	Bolivia	Colombia
	Bolivia	Venezuela	Bolivia	Bolivia	Colombia	Bolivia
	Venezuela	Bolivia	Venezuela	Venezuela	Venezuela	Venezuela
Fastest	Chile	Chile	Chile	Chile	Chile	Chile
Growing	Uruguay	Uruguay	Uruguay	Uruguay	Uruguay	Uruguay
			Females			
Slowest	↑Ecuador	Ecuador	Ecuador	N.E. Brazil	N.E. Brazil	N.E. Brazil
↓	↓Colombia	Colombia	N.E. Brazil	Ecuador	Ecuador	Colombia
	N.E. Brazil	N.E. Brazil	Colombia	Venezuela	Venezuela	Ecuador
	Bolivia	Bolivia	Venezuela	Colombia	Colombia	Venezuela
	Venezuela	Venezuela	Bolivia	Chile	Chile	Bolivia
Fastest	Chile	Chile	Chile	Bolivia	Bolivia	Chile
Growing	Uruguay	Uruguay	Uruguay	Uruguay	Uruguay	Uruguay

TABLE 15.—*Relative rank of Asian countries according to weight of males and females at different ages*

Rank	Age years 5.5	10.5	15.5	19.5	20–42
			Males		
Slowest	E. Pakistan	Thailand	India	E. Pakistan	E. Pakistan
↓	Burma	E. Pakistan	E. Pakistan	Vietnam	Burma
	Thailand	Vietnam	Burma	↑Burma	India
	India	India	Vietnam	↓India	Vietnam
	Vietnam	Burma	Thailand	W. Pakistan	W. Pakistan
	Malaya	Malaya	Malaya	Thailand	Malaya
Fastest	W. Pakistan	W. Pakistan	W. Pakistan	Malaya	Thailand
Growing	Japan	Japan	Japan	Japan	Japan
			Females		
Slowest	E. Pakistan	Thailand	Vietnam	E. Pakistan	E. Pakistan
↓	Vietnam	↑E. Pakistan	India	India	India
	India	↓India	E. Pakistan	Vietnam	Vietnam
	Thailand	Burma	W. Pakistan	Burma	Burma
	Burma	Vietnam	Thailand	Thailand	Thailand
	Malaya	Malaya	Burma	Malaya	Malaya
Fastest	W. Pakistan	W. Pakistan	Malaya	W. Pakistan	W. Pakistan
Growing	Japan	Japan	Japan	Japan	Japan

TABLE 16.—*Summary of correlation coefficients*

Correlation of—	Males r [1]	Males S.E. [2]	Females r [1]	Females S.E. [2]
Latin America, weight (25–29 yrs.) and Calorie Supplies (USDA)	.93	.45	.81	.45
Asia, weight (25–29 yrs.) and Calorie Supplies (USDA)	.85	.45	.72	.45
Latin America, weight (25–29 yrs.) and Calorie Supplies (ICNND)	.61	.41	.92	.41
Asia, weight (25–29 yrs.) and Calorie Supplies (ICNND)	.28	.58	.57	.58
Latin America, height (25–29 yrs.) and Calorie Supplies (USDA)	.87	.45	.73	.45
Asia, height (25–29 yrs.) and Calorie Supplies (USDA)	.47	.50	.45	.50
Latin America, height and weight (25–29 yrs.)	.93	.41	.73	.41
Asia, height and weight (25–29 yrs.)	.41	.32	.69	.32
Latin America, weight (5.5 yrs. and 19.5 yrs.)	.85	.41	.68	.41
Latin America, weight (5.5 yrs. and 25–29 yrs.)	.88	.41	.94	.41
Asia, weight (6.5 yrs. and 19.5 yrs.)	.70	.38	.94	.38
Asia, weight (5.5 yrs. and 25–29 yrs.)	.86	.45	.73	.45
Age at Time of Maximum Increment and Calorie Supplies:				
Latin America and Asia	−.85	.32	−.30	.32
Omitting Thailand	------	----	−.48	.33

[1] Correlation coefficient.
[2] Standard error of the correlation coefficient.

TABLE 17.—*Age at time of maximum increment of growth in weight of males and females of high calorie countries (2,300+) and low calorie countries (below 2,300 calories)*

High Cal. Countries	Calorie[1] Supply	Age, yrs.		Low Cal. Countries	Calorie[1] Supply	Age, yrs.	
		Males	Females			Males	Females
Uruguay	3030	12	12	Colombia	2280	15	15
Chile	2610	13	13	Ecuador	2100	16	14
Venezuela	2330	13	12	N.E. Brazil	1600	14	13
Malaya	2400	14	13	Bolovia	2010	16	14
Japan	2360	13	11	Thailand	2120	15	11
				Burma	2170	14	14
	Mean	13.0	12.2	India	2060	16	13
	S.E.	.10	.38	Vietnam	1944	15	14
					Mean	15.1	13.5
					S.E.	.30	.42

[1] USDA estimate, except for Vietnam, ICNND Survey.

TABLE 18.—*Weight and percent mature weight attained by boys and girls at age of maximum increment of growth in high (2,300+) and low calorie countries (below 2,300 calories)*

Country	Boys		Girls	
	Weight	% Mature Weight	Weight	% Mature Weight
High Calorie:	*kg.*		*kg.*	
Uruguay	36.8	52.5	38.3	63.8
Chile	36.5	56.7	39.5	73.9
Venezuela	34.1	54.6	32.3	60.9
Malaya	32.4	58.8	30.7	64.2
Japan	37.4	65.8	30.0	61.0
Mean	35.4	57.7	34.1	64.8
S.E.	.95	2.3	1.9	2.7
Low Calorie:				
Colombia	37.3	62.6	40.1	81.1
Ecuador	39.5	68.7	33.9	66.1
N.E. Brazil	33.2	57.2	33.2	68.0
Bolivia	44.3	72.6	37.5	69.4
Thailand	33.7	63.3	----	----
Burma	29.7	59.5	30.0	66.4
India	34.6	71.7	27.9	65.6
Vietnam	33.7	68.6	31.1	71.4
Mean	35.8	65.5	33.4	69.7
S.E.	1.6	2.0	1.6	2.0

TABLE 19.—*Age at time of maximum increment of growth in height and weight of urban, semi-urban, and rural Indian boys and girls*

	Boys		Girls	
	Age at Max. Inc. of Height	Age at Max. Inc. of Weight	Age at Max. Inc. of Height	Age at Max. Inc. of Weight
Urban	15	15	11	13
Semi-Urban	13	16	10	13
Rural	16	16	12	13

TABLE 20.—*Age at time of maximum increment of growth in height and weight, and size of increment of growth of Japanese children, 1948, 1953, 1963, and American-Japanese children*

	Boys				Girls			
	Height		Weight		Height		Weight	
	Age years	Size of Max. Inc. cms.	Age years	Size of Max. Inc. kg.	Age years	Size of Max. Inc. cms.	Age years	Size of Max. Inc. kg.
Japanese Children:								
1948 [1]	14.5	5.3	14.5	4.8	11.5	5.1	13.5	4.1
1953 [2]	14.5	7.1	14.5	5.9	11.5	5.5	12.5	4.1
1963 [1]	12.5	7.8	13.5	5.7	10.5	6.2	11.5	5.1
American-Japanese:								
1956–7 [2]	10.5	8.2	12.5	7.9	9.5	7.2	12.5	7.7

Sources: [1] Ministry of Health & Welfare, *Nutrition in Japan, 1964.*

[2] Greulich, W. W., Comparison of Physical Growth and Development of American-born and Native Japanese Children, *Am. J. Phys. Anthropol., N.S., 15,* p. 489, 1957.

(Data on Japanese children from Japanese Ministry of Education, average measurements of school children throughout Japan, 1953).

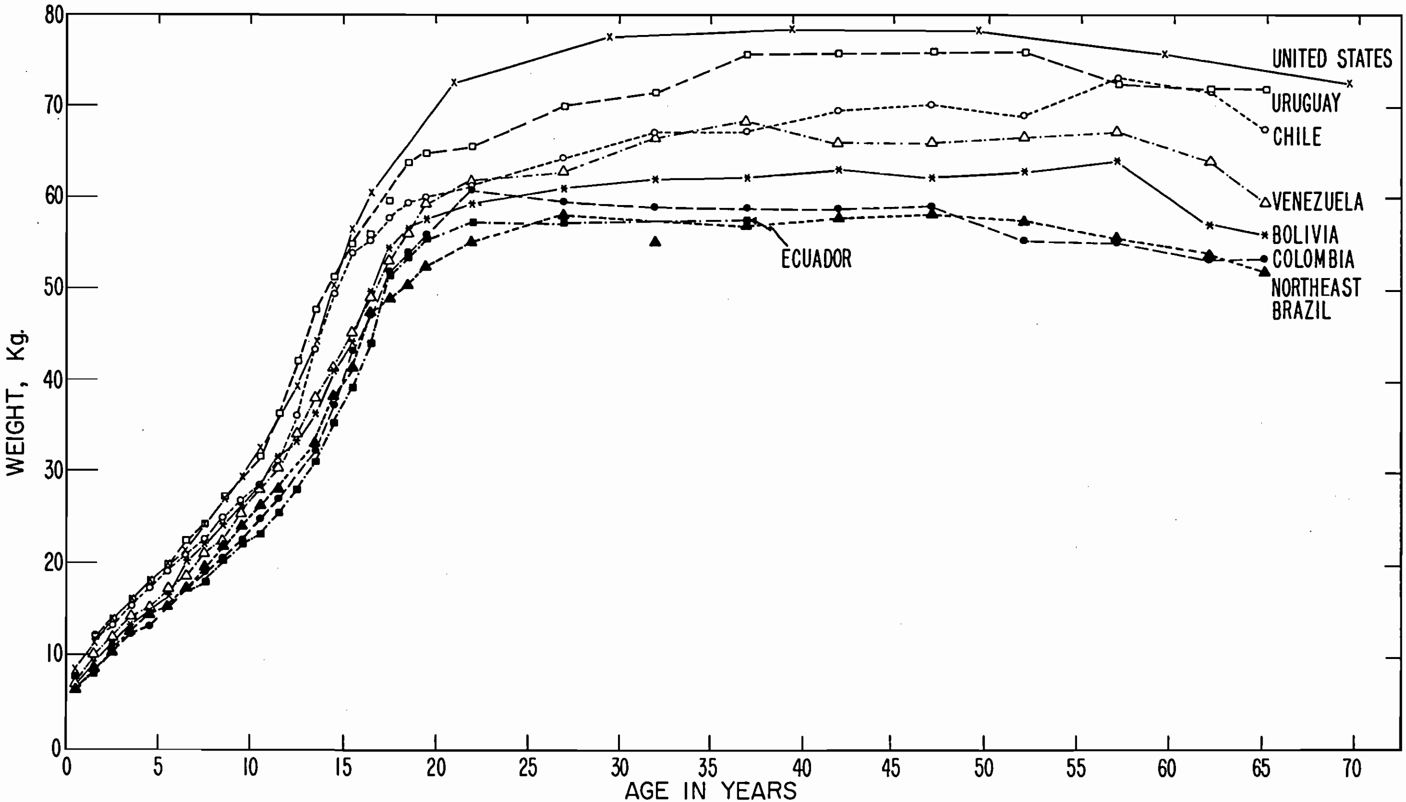

FIG. 1 WEIGHT OF MALES BY AGE, SEVEN LATIN AMERICAN COUNTRIES AND THE UNITED STATES

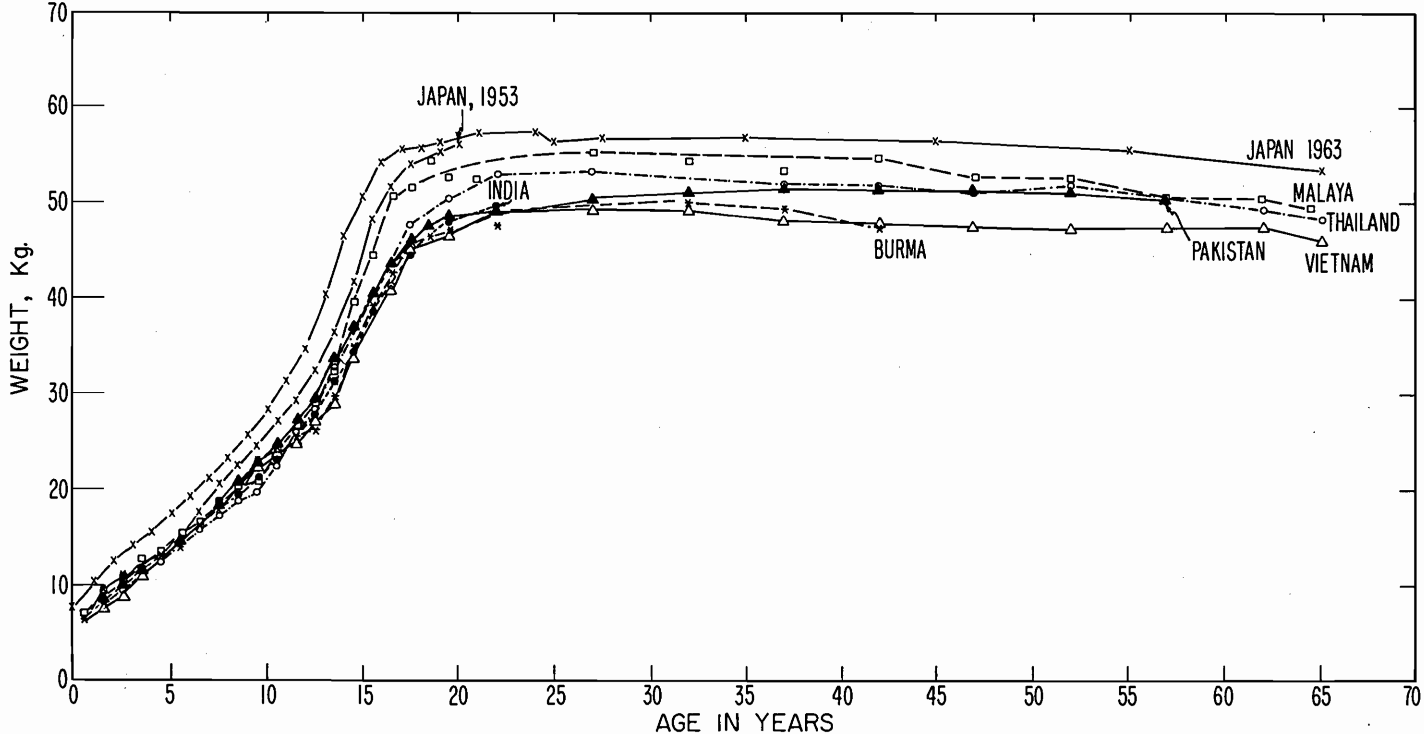

FIG. 2 WEIGHT OF MALES BY AGE, SEVEN ASIAN COUNTRIES

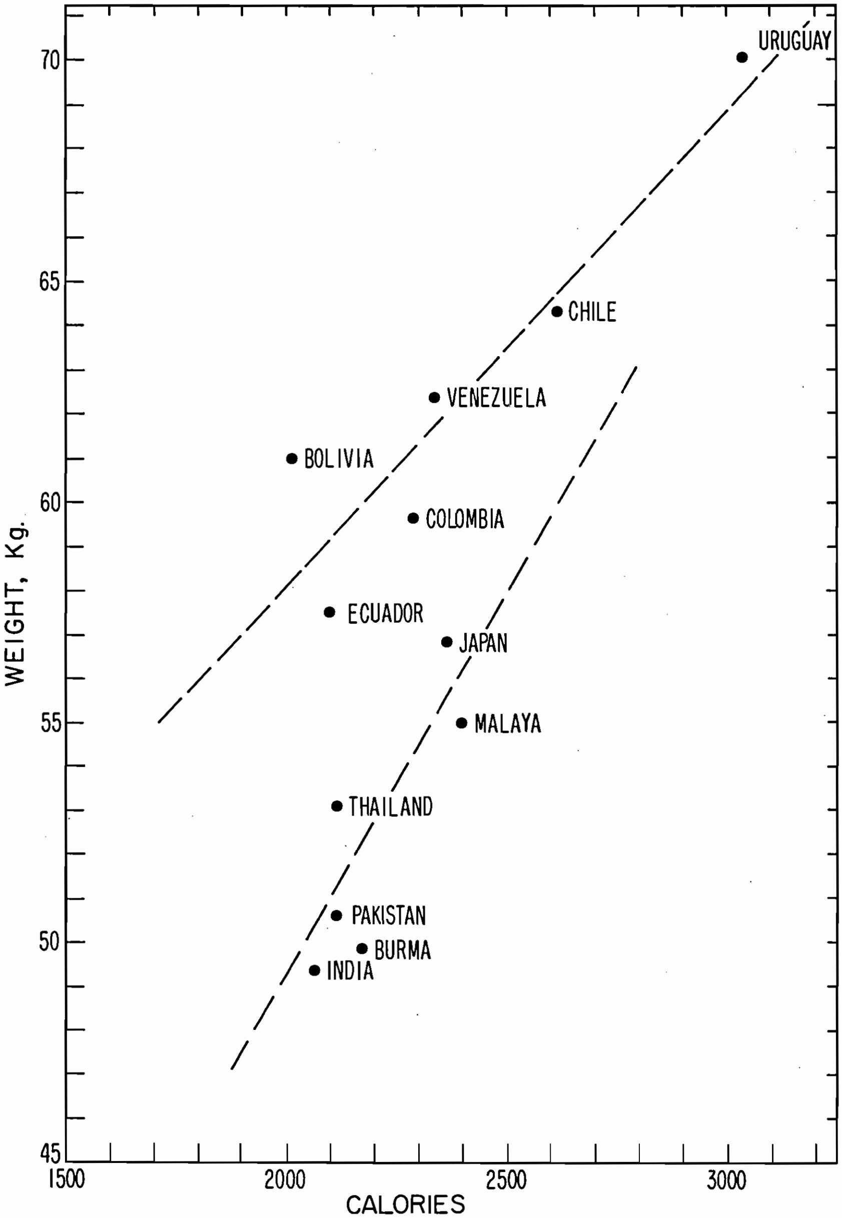

FIG. 3 WEIGHT AT MATURITY VS. ESTIMATED CALORIE SUPPLIES (USDA) SIX LATIN AMERICAN COUNTRIES AND SIX ASIAN COUNTRIES

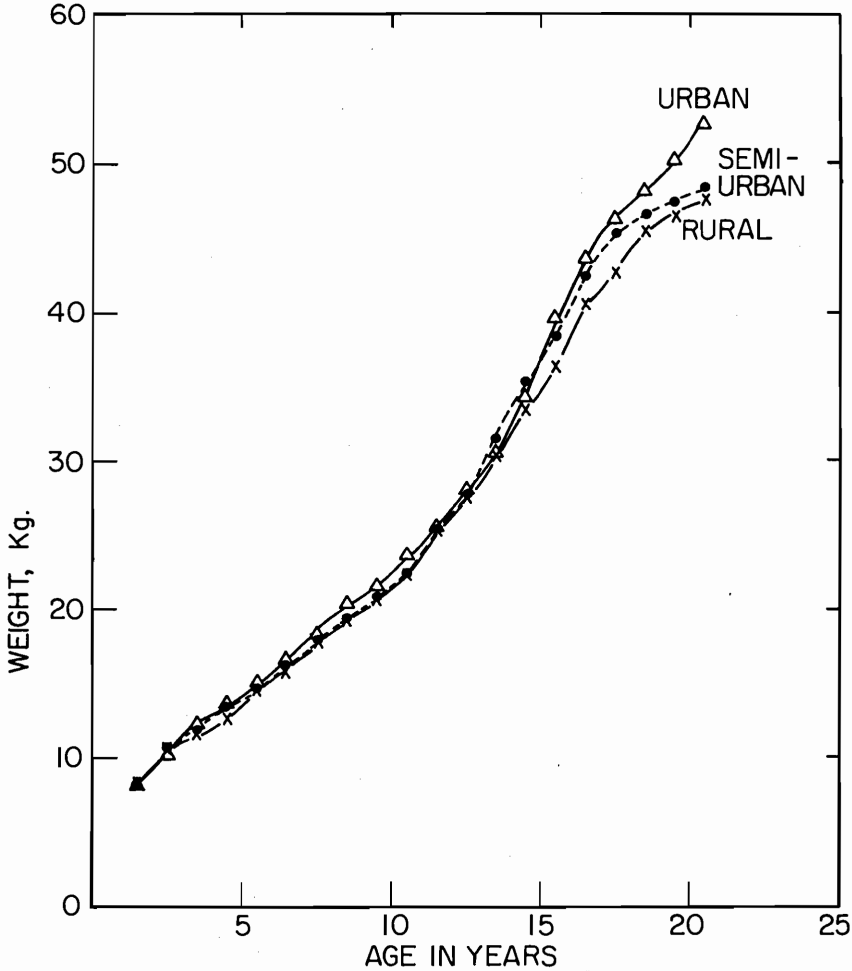

FIG. 4 INDIA: WEIGHT OF MALES BY AGE—RURAL, SEMI-URBAN AND URBAN 1960

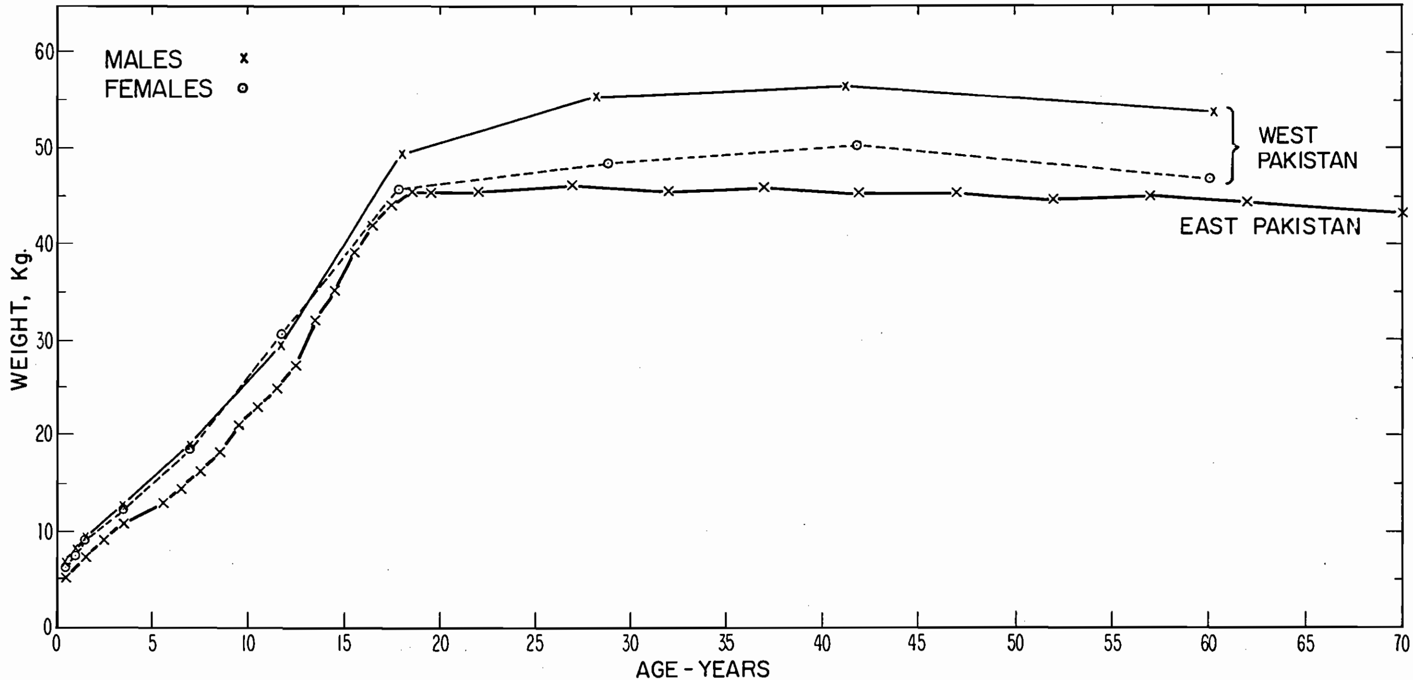

FIG. 5 GROWTH IN WEIGHT BY AGE, WEST AND EAST PAKISTAN

CHAPTER 2

DISTRIBUTION OF FOOD SUPPLIES BY LEVEL OF INCOME

By Roger Revelle and Rose Frisch, Center for Population Studies, Harvard University

In Western Europe and the United States, most persons at all income levels are able to obtain sufficient food to meet their physiological needs for calories, proteins, and other nutrients. For example, in the United Kingdom in 1955, families with incomes ranging from less than $870 to more than $3,500 per year had average daily caloric intakes varying by less than 3 percent from the overall mean of 2,640 calories (1). In the United States in the same year, rural families with a range of disposable incomes from less than $2,000 to more than $10,000 per year averaged over 3,000 calories per person per day in each income group. Among urban families, the average intake for the lowest income group was 2,790 calories per person per day while the highest obtained 3,260—a spread of about 15 percent (2).

The situation is quite different in the less developed countries. The incomes of the poorest classes are so low that they are unable to obtain sufficient food to meet their needs for energy, let alone for protein and other essential nutrients. Even though the average diet for the country as a whole may provide the required amounts of calories and proteins, the distribution of food is very uneven and is strongly skewed toward the higher income groups.

There is abundant qualitative evidence for this relationship between food and income. A study 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 (clarified butter), vegetables and fruits, and low income groups eating mainly inadequate amounts of cereals (3); 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 (4); the voluminous literature on malnutrition in children in the developing countries (5), (6) is a literature describing the children of the poor.

Some quantitative evidence on the relationship between income level and food intake in the poor countries also exists, but the data are

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fragmentary, of uncertain accuracy, and difficult to interpret. The best information comes from India where dietary surveys were begun before World War II and have been continued up to the present time. In a few of these surveys, the diets of different income groups were separately determined and recorded. Even here, the relative values for different groups in a single survey are uncertain, and intercomparisons among different surveys are doubly so. Although the dietary estimates are subject to considerable error, the chief difficulties come from attempts to estimate incomes. In a partially monetized economy such as India's, rural and urban incomes must be computed differently. Estimates of income for land-owning farm families include the gross value of the product from the family farm, less an estimated cost of production, plus any returns in money or in kind to labor off the farm, plus imputed rental on a house, plus rents, etc. For landless rural people, the principal source of income is return to labor, in money or in kind. The urban population can be similarly divided. For urban property owners, the returns to investment in a business or in real property must be estimated, together with any wages, and imputed rental on the family dwelling; for nonproperty owners, only wages or salaries need be considered. Some of the tables herein give "expenditures;" others give "incomes." (Whether before or after taxes is usually not stated, but for the low incomes we are concerned with, these are probably insignificant.) We have been unable to establish any simple relation between expenditure and income, but we believe the differences between them are small for the low income groups in India.

Table I shows the supply of calories and proteins available to different lower income groups in the State of Maharashtra in 1958. Persons with expenditures greater than about $30 a year obtained, on the average, enough calories and proteins, but those with lower expenditures did not. The poorest group had per capita expenditures under $20 per year; our calculations indicate that they received on the average less than 60 percent of their physiological requirements for calories and 64 percent of protein requirements. Those with expenditures from $20 to $28 per year obtained an average of 81 percent of needed calories. Their diets were also probably somewhat deficient in total protein intake. From Table 6 it can be seen that 20 percent of India's population in 1961 and 1962 had average annual expenditures of $28.40 or less. The per capita income in Maharashtra was slightly lower than that for all of India, over 60 percent of the population having per capita incomes under $45 per year (7) in contrast to less than 50 percent for the country as a whole. Hence it is likely that at least 20 percent of the people in Maharashtra obtained less than 80 percent of their physiological requirement for calories and less than 90 percent of their protein needs. Individuals in the highest income group received more than twice as many calories and nearly 2½ times as much protein as the lowest group.[1]

The most extensive information on diet and income was obtained in Madras during 1961 and 1962 (see Tables 2 and 3). In a sample of about 25,000 individuals the diets of the poorest 57 percent were deficient in both calories and protein while the top 15 percent obtained 15 to 26 percent more than their caloric needs and 11 to 37 percent more than required total protein. The calorie intake for the highest income group was 150 percent of that of the lowest and the protein intake was 163 percent. The average estimated per capita income of the sample of persons studied in the survey was considerably less than the value of $57 obtained by dividing the aggregate income of the entire State of Madras by the population of the State; hence the sample cannot be considered representative for the State or, more probably, the total "disposable" income of the persons in the sample were considerably underestimated. But comparison with Table 6 indicates that the two lowest income groups in the Madras sample fall within the bottom 10 percent of the range of Indian expenditures, and we may, therefore, conclude that at least 10 percent of the population of Madras were undernourished in terms of both calories and protein in 1961 and 1962. This was in spite of the fact that these poorest groups used more than 90 percent of their income for food. The two groups with average estimated per capita incomes of $29 and $39 also used more than 90 percent of income on food and this suggests that many members of these two classes likewise went hungry. Thus, if the income distribution in Madras was the same as the distribution of expenditures for India as a whole, between 10 percent and 40 percent of the people of Madras were undernourished.[2]

The quantity of animal protein (mostly in milk) obtained by this lower 40 percent was between 2 and 5 grams per person per day, less than half of the amount obtained by the two highest income groups in the sample. This may be an indication that the poor people were malnourished in terms of a proper balance of amino acids in their diets. As Table 1 shows, there was an equally wide range of animal pro-

[1] Table 6 shows that average per capita expenditures for the Indian population are about $57 per year. At such a low expenditure level, expenditures are most certainly not more than "disposable" personal incomes, which may include such items of consumption as home-produced clothing that are not counted as expenditures.

[2] We have taken the average per capita daily physiological requirements for all households as 1936 calories and 48.3 grams of protein (NPU=57). This implies that all households have the same average composition by age and sex, regardless of the size of the household. We are unaware of any reliable Indian data to test this assumption. Houthakker (9) found only a moderate elasticity of food expenditures by family size in developed countries, but this may not hold for India, with its characteristic extended families and numerous household servants. In any case, when the source data are given in "consumer units", as in Tables 2 through 5, any possible effect of differences in household composition is largely accounted for.

tein content in the diets of the people of Maharashtra, and the average was considerably smaller. Thus malnutrition may also have been prevalent among the poorest 60 percent of the people in this State.

Dakshinamurti and Devadatta studied the diets of 2,800 individuals in the town of Vellore, Madras, in 1955 (see Table 4) (8). The average per capita incomes of different groups ranged from $10 to $68 per year and the average daily intake of calories and proteins from 1,260 to 1,725 and 32 to 45 grams respectively. In terms of physiological requirements for the average person in India, the diets of all income groups in Vellore were deficient in both calories and proteins, ranging from 65 to 90 percent of the requirements. The range of animal protein intakes was even wider than in Maharashtra or in the Madras sample summarized in Tables 2 and 3, being from 0.3 gram per person per day for the poorest class to 7.6 grams per person per day in the highest income group.

The authors of the Vellore survey were depressed by the very low dietary levels they encountered. They report:

> The caloric intake for the poorest sections is appallingly low. Protein and fat intakes are also extremely low. The diet of the poor classes is generally deficient in quality as well as quantity. It is not only a question of lack of vitamins but also of fat, proteins, minerals, and even calories. . . . . . (This poses the question whether the continued scarcity of essentials and their consequent rationing during the war coupled with the almost famine conditions of the post-war years due to continued failure of monsoon, have left a permanent effect on the quantity of food eaten by people.

With an energy intake of only 1,260 calories per day, the poorest class, which consisted of unskilled laborers, must have been incapable of much heavy work. Their productivity, like their calorie intake, must have been "appallingly low."

The standard deviation of calorie intake for all income groups in the Vellore survey was relatively large, ranging from more than 25 percent of the average value up to 45 percent, as compared with Sukhatme's estimate of about 19 percent for India. This large variation in Vellore may reflect an adjustment of diet to variations in the level of physical activity among different individuals.

A sample of 4,655 households in the State of Andhra Pradesh was obtained over a period of 12 years by investigators of the Indian Council for Medical Research. The quantity of food used in each household over a seven-day period was weighed during house-to-house visits by health inspectors. A summary of results for different income groups is given in Table 5. As in Madras and Maharashtra, the average calorie intake of the poorest classes, with incomes from less than $20 to $34 per year per person, are well below the average Indian physiological requirement. The spread between the lowest and the highest income groups is relatively small, only about 14 percent, while the variance within each group is large. This is evident in Table 5, from which it can be seen that the difference in consumption between the first and third quartiles in each income group is about 600 calories. The large variance may be an artifact, resulting from the long time period over which the data were combined, during which incomes, dietary patterns, and requirements for necessities other than food may have changed significantly. Or it may reflect differences in the level of physical activity among different families in each income group. Owing to the marked skew of the distribution of calories among households, 50 percent of the households in each income group obtained considerably less than the average quantity of calories for the group as a whole, and in all instances less than the calculated physiological requirement for "normal" physical activity.

Income Elasticity for Food in India

Even for persons of average income, the fraction of total expenditures going for food in India is relatively high, ranging from 57 percent in rural areas of Rajasthan to 79 percent in Bihar. The proportion spent on food in urban areas is somewhat lower but still 55 percent or more in every state (Table 7). A direct relationship between the proportion spent on food and total expenditures is clearly indicated if we compare the fraction of expenditures on food by persons of average income in urban and rural areas with that of agricultural laborers. The latter have average total expenditures of $29.50 and spend 77 percent of this amount on food in contrast to $52.70 and 68 percent for all persons in rural areas and $76.50 and 60 percent for urban areas. The elasticity of demand for food in terms of personal expenditures for all of India is probably about 66 percent.

Income and Food Supply in Latin America

Inadequate nutrition for the poorest classes in India is clearly the result of inadequate income. Even if almost the entire income is used for food it is simply not enough to obtain the amounts required for physiological needs. But as Tables 8 and 9 show, the poorest classes in Chile and northern Brazil also have diets far below requirements in both calories and protein, even though their average incomes appear to be higher than those of lower class Indians. In a sample of 278 families in Chile, those with average per capita incomes estimated at around $160 per year or less were markedly deficient in calorie intake, and families with per capita incomes of about $130 or less received insufficient protein. These groups probably make up 10 to 20 percent of the population. The diets of "very poor" families in northeast Brazil, which may have per capita incomes comparable to the poorer classes in India, are low in both calories and proteins, but the "poor" income group also have a slight calorie deficiency, even though their per capita incomes could range from $50 to $100 per year, a level at which many Indians would receive adequate nourishment. A small part of the explanation may be that calorie requirements are somewhat higher in Chile and northeast Brazil than in India. The total explanation could involve different dietary patterns, higher costs of food distribution, and a higher fraction of expenditures for necessities other than food in South America as compared with India. It is perhaps equally likely that differences in exchange rates and methods of estimating income, and the quantitative inadequacy of the data from Chile and Brazil, have resulted in a distorted picture.

Conclusions

Two conclusions seem clear:

1. There is a direct relationship between income and quantity and quality of food consumed among the poor classes of less developed countries.

2. The amounts of calories and proteins obtained by poor people in these countries are inadequate to meet their physiological needs.

TABLE 1.—*Per capita food supplies in Maharashtra State, India, 1958, by expenditure level*

(1)	(2)	(3)	(4)	(5)	(6)
Per capita expenditure group $ per year [1]	Calories per day		Proteins, grams per day		
	Average value	Percent of physiological reqmt [2]	Average value	Percent of physiological reqmt [3]	Animal protein av. value
<20	1120	58	30.7	64	1.0
20–28	1560	81	45.0	93	1.8
28–33	1850	96	52.8	110	2.3
33–45 [4]	2190	113	60.4	125	2.9
45–60	2440	126	66.3	137	6.1
60–86	2530	131	71.7	148	7.1

[1] Computed at 1958 exchange rate, 1 Rupee=$0.21

[2] Per capita physiological requirement assumed equal to all-India average of 1936 Calories per day given in this Report, Vol. 2, Table 6, p. 97.

[3] Per capita physiological requirement assumed equal to all-Indian average of 48.3 grams per day of protein with an NPU of 57, given in this Report, Vol. 2, Table 12, p. 121.

[4] Over 60% of the population of Maharashtra have an income of less than $45 per year (Rs 18 per month).

Source: Columns (1), (2), (4), and (6), Sukhatme, P. V., Feeding India's Growing Millions. New York, Asia Publishing House, 1965, pp. 41–42 and p. 78. The data were obtained during the 14th Round of the Indian National Sample Survey, by the interview method.

TABLE 2.—*Household*[1] *and per capita incomes, and proportion of income used for food from a sample survey of 5,193 households in Madras State, India, 1961–1962*

(1)	(2)	(3)		(4)	(5)
Household income group $ per yr [2]	No. persons per household [3]	Total Persons		Av. per capita income $ per year [2]	Fraction of income used for food (percent)
		Number	Percent		
<65	3.3	3,820	15.4	17.2	93.0
65–125	4.6	10,250	41.3	20.8	91.2
126–190	5.5	3,620	14.6	28.8	91.1
191–250	5.7	3,430	13.8	38.8	90.9
251–380	6.4	1,625	6.6	49.2	81.1
381–500	6.7	940	3.8	65.8	69.9
501–1,000	7.8	725	2.9	97.0	50.7
>1,000 [4]	7.7	400	1.6	[4] 242.5	[6] 25.0
Total		24,810	100.0		
Average	4.8			[5] 33.4	77.3

[1] By Census of India definition, "a household is a group of persons living together and taking their meals from a common mess . . . not necessarily bound by ties of relationship".

[2] Computed at 1961–62 exchange rate, 1 Rupee=$0.21.

[3] The source data are "consumer units" per household, that is the equivalent number of adult males 20–29 years old having the same total physiological requirements for calories as the men, women and children in the household. In Madras, 76 consumer units are stated to be equivalent to 100 persons.

[4] The top 1% of households are in this income group. Such households in India as a whole receive 12% of all income. Applying this proportion to the total income for the Madras sample gives an average of $1,915 per annum for these households.

[5] The average per capita income in Madras State during 1960–61 is stated to be $56.50 per year. Hence this is a sample of the poorer segments of the population.

[6] Our estimate.

Source: Computed from data given by P. K. Nambiar, Food Habits in Madras State, Census of India, 1961, Vol. 9, part 11-B, Madras, 1964, pp. 1-96.

TABLE 3.—*Per capita food consumption in Madras State, India, 1961–62, for different income groups in a sample of 5,193 households*

(1)	(2)	(3)	(4)	(5)	(6)
	Calories per day		Protein, grams per day		
Av. per capita income $ per year	Average value	Percent of physiolog. reqmt [1]	Average value	Percent of physiolog. reqmt [2]	Animal protein
17.2	1600	83	40.8	84	2.0
20.8	1825	94	45.0	93	2.3
28.8	1900	98	48.1	100	4.2
38.8	2050	106	50.1	104	5.2
49.2	2205	114	53.4	111	6.7
65.8	2355	122	56.4	117	8.0
97.0	2355	122	56.4	117	9.9
242.5	2430	126	66.3	137	16.0
Average 33.4	1904	99	47.2	98	3.9

[1] Per capita physiological requirement assumed equal to all-India average of 1936 calories per day, given in this Report, Vol. 2, Table 6, p. 97.

[2] Per capita physiological requirement assumed equal to all-India average of 48.3 grams per day of protein with NPU of 57. See Vol. 2 of this Report, Table 12, p. 121.

Source: Column 1, See Table 4. Columns (2), (4), and (6) computed from data given by P. K. Nambiar, Food Habits in Madras State, Census of India 1961, Vol. 9, part 11-B, Madras, 1964, pp. 1–96. The data were obtained by home visits including interviews by questionnaire and weighing food actually eaten.

TABLE 4.—*Per capita food consumption in the town of Vellore, Madras State, India, 1955 for different income groups*[1] *in a sample of 507 households*

Per capita income group $ per yr [2]	Av per capita income $ per yr [2]	Fraction of total persons studied (percent)	Calories/day per capita [3]		Protein, grains/day per capita [3]		
			Average value	Percent of physiol. reqmt [4]	Average value	Physiol reqmt [5]	Animal protein
<12.5	10.4	29.0	1260	65	32	66	0.3
12.5-23	18.5	31.7	1480	76	38	79	1.0
28-35	32.6	13.8	1500	78	40	83	4.3
38-48	41.9	11.5	1575	82	41	85	5.0
50-75	67.9	14.0	1725	89	45	93	7.6
Average	27.7	----------	1460	75	38	79	2.6

[1] The different income groups correspond to groups of communities. The lowest income group consisted of 162 families, containing 816 individuals, of unskilled Hindu laborers; the next lowest included 162 families and 892 individuals of unskilled Christian and Muslim laborers and skilled Hindu laborers and artisans; the middle income group included 159 Muslim petty traders and 230 "lower middle class" Hindus, mostly minor government servants, a total of 64 families; the next to the highest group included 88 Hindu "conservancy" workers, 126 "lower middle class" Hindus, mostly businessmen, and 110 Christian minor government servants in 62 families; the highest income group contained 57 families and 394 individuals of Hindu businessmen and government officials. The total number of individuals studied was 2,815.

[2] Computed at 1955 exchange rate, 1 Rupee=$0.21.

[3] Food consumption is given in the source data for "consumption units". We have assumed that 76 consumption units equal 100 individuals. See Table 2.

[4] Per capita physiological requirement assumed equal to all-India average of 1936 calories per day per capita. See Tables 3 and 5.

[5] Per capita physiological requirement assumed equal to all-India average of 48.3 grams per day per capita of protein with NPU of 57. See Tables 3 and 5.

Source: Computed from data given by K. Dakshinamurti and S. C. Devadatta, Studies on the Nutrition of Urban Population Groups, Proc. Indian Academy of Sciences, Section B, Vol. 43, 1956, pp. 121-133. Each household was observed for a seven day period and food items were weighed.

TABLE 5.—*Distribution of per capita calorie consumption in Andhra Pradesh State, India, 1954–1962, for different income groups in a sample of 4655 households*

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Household income group dollars per year [1]	Estimated average per capita income dollars per year [2]	Calories per capita per day [3] value	Percent of physiolog. reqmt.	25% of individuals obtain less than	50% of individuals obtain less than	75% of individuals obtain less than
<125	20	1650	85	1080	1370	1710
125-250	34	1660	86	1160	1430	1710
250-500	55	1750	91	1230	1490	1800
>500	150	1895	98	1350	1610	1960

[1] Computed at 1962 exchange rate, 1 Rupee=$0.21.

[2] The number of persons per household and the average per capita income for household income groups was assumed to be the same as in the sample for Madras State given in table 4.

[3] The source data are given for "consumer units" and it is implied that about 80 consumer units=100 average individuals.

Source: Computed from data given by P. V. Sukhatme, Feeding India's Growing Millions. New York, Asia Publishing House, 1965, p. 83. The quantity of food used in each household over a 7-day period was weighed during house-to-house visits by health inspectors of the Indian Council for Medical Research.

TABLE 6.—*Per capita consumer expenditures in India in dollars per year,*[1] *1961–1962*

(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Rural areas		Urban areas		Combined urban and rural [2]	
Percentile group	Av for percentile grp	Share of total percent	Av for percentile grp	Share of total percent	Av for percentile grp	Share of total percent
0–10	20 4	3.9	25.3	3.3	21.3	3.7
10–20	26.9	5.1	35.0	4.6	28.4	5.0
20–30	32.4	6.1	41.9	5.5	34.2	6.0
30–40	36.9	7.0	49.2	6.4	39.2	6.9
40–50	42.5	8.0	55.4	7.2	44.8	7.9
50–60	47.3	9.0	64.3	8.4	50.3	8.8
60–70	53.6	10.2	69.7	9.1	56.6	9.9
70–80	62.4	11.8	90.0	11.8	67.3	11.8
80–90	75.5	14.3	110.7	14.4	81.8	14.3
90–100	129.0	24.5	224.0	29.2	146.2	25.7
0–100	52.7	99.9	76.5	99.9	57.0	100.0

[1] Computed at 1967 exchange rate, 1 Rupee=$0.21.
[2] Weighted according to proportions of urban and rural population, 0.82 rural, 0.18 urban.

Source: Columns (2) and (4), P. V. Sukhatme, Feeding India's Growing Millions, New York, Asia Publishing House, 1965, p. 69.

TABLE 7.—*Proportional expenditures on food in Indian States*

(1)	(2)	(3)	(4)	(5)
State	Rural areas fraction of total expenditures on food percent	Urban areas fraction of total expenditures on food percent	Agricultural Labor Households [1]	
			Per capita total expenditures dollars/year [2]	Fraction of total expenditures on food percent
Andhra Pradesh	66	63	29.6	78
Assam	68	58	53.6	75
Bihar	79	65	27.1	82
Bombay	70	60	29.0	75
Jammu & Kashmir	77	64	38.2	79
Kerala	67	57	24.5	73
Madhya Pradesh	62	55	27.7	75
Madras	69	59	25.2	75
Mysore	61	63	31.7	74
Orissa	73	62	24.2	80
Punjab	65	60	[3] 43.8	70
Rajasthan	57	59	34.8	76
Uttar Pradesh	72	59	28.0	79
West Bengel	74	62	35.5	79
Gujerat	([4])	([4])	32.0	78
Maharashtra	([4])	([4])	28.5	74
All India	68	60	29.5	77
Combined rural and urban [5]	66.4			

[1] 484 Sample Households, averaging 4.4 persons per household.
[2] Computed at 1961 rate of exchange, 1 Rupee=$0.21.
[3] Includes Delhi and Himachal Pradesh.
[4] Not available.
[5] Weighted according to proportions of urban and rural populations in 1961 census, 0.82 rural, 0.18 urban.

Source: Columns (2) and (3) Indian Statistical Institute, National Sample Survey Report No. 80. Calcutta, June 1961; Columns (4) and (5) National Sample Survey, 11th and 12th Rounds, August 1956–August 1957, Average budget of Agricultural Labor Households in Rural Areas, Government of India, 1964.

TABLE 8.—*Per capita food consumption in Chile, 1960, for a survey of 278 families, by income groups*

(1) Average Family Income Dollars per year [1]	(2) Percent of Families	(3) Total	(4) Percent of Requirements [2]
		A. Calories per day	
600	13	<1525	<65
960	24	1525–1990	65–84
1,200	38	1991–2700	85–115
>1,200	25	>2700	>115
		B. Protein, grams per day	
660	10	<42	<65
800	18	42–53	65–84
1,010	29	54–73	85–114
1,080	18	74–86	115–134
>1,200	25	>86	>134

[1] Average family size was 5.9 persons, ranging from 5.1 to 7.4 in the sixteen localities surveyed; hence individual incomes are approximately one-sixth of the values shown in column (1).

[2] The Survey Team computed the physiological requirements for the Chilean population as 2348 calories and 63.6 grams of protein per capita per day.

Source: Interdepartmental Committee on Nutrition for National Defense, Chile Nutrition Survey, March–June 1960, Washington, 1961. Family food consumption for one day and other necessary data were recorded by questionnaire interviews.

TABLE 9.—*Per capita food consumption in northeast Brazil, 1959–1960 for different economic classes among 56 families*

(1)	(2)	(3)	(4)	(5)	(5)
	Calories per day		Proteins, grams per day		
Economic Status [1]	Total	Percent of requirement [2]	Total	Percent of requirement [3]	Animal protein
Very poor	1606	80	43.5	90	23
Poor	1862	93	48.1	99	24
Middle income	2028	101	55.3	114	30
Well-to-do	2323	116	77.1	160	52
Average	1886	94	51.2	106	

[1] No quantitative measure given. In 1958 the average per capita income in Northeast Brazil was estimated as $100 per year. Presumably the "very poor" and "poor" groups have an annual income of less than $100 and the "well to do" have an income greater than this figure.

[2] Body weights for Northeast Brazil are somewhat higher than those for India. Therefore, a rough estimate of the average per capita physiological requirement is 2,000 calories.

[3] The quality of protein in the Brazilian diet is relatively high (NPU=65), hence the per capita physiological protein required is 48.3 grams, the same as for India, even though average body weights are higher. See this Report, Volume 2, p. 131.

Source: Columns (1), (2), (4), and (6) Interdepartmental Committee on Nutrition for National Defense, Northeast Brazil Nutrition Survey, March–May 1963, Washington, 1965, p. 165. Data over seven days were obtained by the Brazilian National Commission on Nutrition by home visits and questionnaires.

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CHAPTER 3

ENERGETICS OF WORLD FOOD PRODUCTION [1]

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Introduction

The problem of world food production and the population explosion is one of system design. How do we develop a network of food chains with as much stability as those which evolved earlier in some natural systems or in some of man's more primitive agricultural regimes now being displaced by war, competition, and overpopulation? How are the new energies now available to man's civilization to be best introduced? Which of the various kinds of possible new designs for systems of food production and consumption will lead to the survival of man in affluence, stability, and justice?

In recent years, studies of the energetics of ecological systems have provided points of view and means of dealing with complex food networks that combine the basic laws of physics and chemistry with the complex aspects of living systems such as self maintenance, self design, self control, self switching, self reproduction, and other properties that characterize forests, seas, anthropological systems, and modern societies. An energy network language is used to organize quantitative data on the parts and their exchanges with each other. Just as the parts of a radio are related to each other and to the whole system in a circuit diagram showing the flow of electric current, so an energy diagram can be constructed that illustrates the flow of energy among the populations using symbols for each component that are mathematically defined and have numerically measured magnitudes. Because energy is a common denominator for all processes, all forces and influences in the world system of food flows can be drawn and measured. When an energy network diagram is prepared, it can be simulated with electronic computing devices so that the consequences of one design feature or one external feature may be tested before some action program is attempted with a nation's food reserves.

When the relationships of world food production, consumption, and internation transfer are clarified with simple diagrams, some principles

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[1] Abbreviated from a book manuscript, *Power and Survival.*

of system analysis long known in biological, electrical, or chemical systems are found to be at the heart of the present world problems of food and population. Some action programs of food giveaway, for example, turn out to be competitive to closed-loop-reward flows that are required for stability. Understanding the world's food production system is essentially the same problem for the whole biosphere as understanding the natural systems that formerly predominated on the earth. Although the study of man's system in this way is new and the details worked out in only a few cases, let us consider from energy flow analysis what kinds of limitations there are on man and his programs of feeding the world.

Energy Network Diagram for a Native Cattle Keeping System

To illustrate the principles of the energy network diagram, consider in Figure 1 the pattern of food flow to man in a section of Uganda as described by Deshler (3). The parts of the system are grouped into logical compartments that contain populations of similar function and similar input-output flows of energy. The main pathways of energy flow are drawn, and their magnitudes are indicated in kilocalories per area of land per year. The storage of potential energy in each compartment is also indicated in kilocalories per area of land.

Energy flow starts with the allocation of light energy from the sun to a square meter of earth in Uganda which supplies energy for plant growth. The plants are grouped into two compartments, the natural range of mixed plants and cultivated crops. The photosynthetic conversions of food from these two groups pass next to consumers; the range production goes partly to wild consumers and partly to the cattle of the Dodo tribe, while crop production goes directly to storage for tribal man. The cattle provide protein supplement to man through meat, blood, and milk.

As required by the energy laws of the universe, a large fraction of the potential energy disperses into heat at each step as shown in Figure 1 by a heat sink symbol at each process indicating energy that is no longer available to the system. The work that is done by the sun in bringing rain, by the wild consumers, by cattle, and by man is indicated by a work symbol in another energy flow at the point where that work controls or predisposes necessary action. Note that many work actions result in small flows of energy from downstream back upstream providing the means by which downstream agents such as man and cattle can, with small but highly focused energies, stimulate flows in the main power stream that will lead to their own support. These are *reward loops* that are the key controls that permit evolution and self design of successful systems that have survival stability.

In the system, only 11 percent of the land is under cultivation and the cattle drain only 18 percent of the net crop and range plant production. Thus the diversity of animals, plants and microorganisms in the natural range system provides man a stable system of which man is a part. All net crop yields go to man. Any replacement of this system by one that used more of the natural range would (1) require the substitution of a control system at great energy cost, (2) raise the prospect of overgrazing the photosynthetic surfaces, and (3) upset the soil bases.

Small work expenditures of about three calories by man control and augment flows of much larger magnitude for grain prouction thus serving as gates so that their own work is amplified by the natural system.

The yield of protein to man is 0.06 percent of the range intake of the cattle which includes all the many stage processes of collecting sparse vegetation, putting it through the ruminant microbe systems of the stomach, and making not just organic matter, but high quality diversified proteins while refertilizing the range to further stimulate the system.

The input of rain involves a huge energy subsidy from outside the system, but its input is very irregular. In electrical networks, variable input is stabilized by introducing storage units (called pulse filters) that smooth out the energy flow. The cattle also serve as pulse filters as well as doing loopback work on the range through fertilization.

Basic Energetics and the Energy Flow Network Diagram

Let us interrupt our discussion of man's food support systems to indicate a few of the basic laws of energetics and force and illustrate the way they are represented in an energy network diagram. The basic symbols are given in Figure 2.

Everything that takes place on earth involves a flow of potential energy into dispersed heat through pathways driven by directed forces that originate from the energy storages. The essence of cause, Newtonian physics, and the laws of energetics are irrefutable on these principles. It is only recently that these laws, which were developed for simple physical systems, have been applied to the complex levels of nature's ecological system or the even more complex system of man's activities in the biosphere. The flows of energy through complex food chain pathways and through cultural economic systems follow the basic laws, and may be expressed quantitatively with the understanding that the flows in the large scale world are primarily populations of parallel flows of large and small parts including flows through populations of molecules, populations of cells, organisms, people, occupational groups, and other associations of active components.

A useful way of representing the networks of energy flows to include the limitations and requirements of the laws of energetics is through the energy network language illustrated in Figure 1. Here a pathway of potential energy flow is represented by a line; if it is inherently unidirectional and incapable of reversal, it is marked with an arrow symbol. The potential energy storages are marked with the tank symbol which indicates a source of causal force along the pathway lines. The mathematical equation that describes the relation of potential energy to storage varies and must be specified in each case. The force is in linear proportion to the storage quantity whenever the storage function is one of stacking up units of similar caloric content, a property common in ecological and large scale systems involving man.

One adheres to the second principle of energetics by drawing the network to illustrate that any process has some potential energy diverted into dispersed random motion of molecules (heat). The necessary heat flows are indicated by a downward flow into the heat sink which is symbolized with an arrow into the ground. The first law of energetics is adhered to by having all inflows balance outflows either into storages, into the heat ground, or into exports. The many kinds of work which are done against frictional forces are illustrated by arrows that flow from the potential energy storage tanks into the heat sink.

Where a work process is necessary to facilitate a second flow, the arrow crosses the second flow representing the work done on it. For example, the work of people on a farm facilitates the flow of light energy into food storage, although the energy of the workers' food went into metabolic heat during the time of work. A work flow which facilitates a second flow in proportion to its activity is mathematically a product function and thus is indicated with a box containing an "X." Such a box indicates a limiting factor process and the work is identifiable as a control gate on the flow. Many of these secondary flows derive their driving potential energies from a point downstream and are thus multiplicative reward feedbacks.

Odum and Pinkerton (11) showed that whenever an energy flow is transformed and restored into a tank at the optimum rate for maximum energy storage, 50 percent of it must go into the heat drain. Whenever a flow must cross an energy barrier, the energy carrier must increase in potential energy temporarily and hence must lose 50 percent to the heat sink (Figure 2D).

The Mathematical Functions Implied by Compartment Symbols; Simulation

Each symbol used has a mathematical definition and for each symbol, there is a graph of functional response of output with input variation. These response graphs are known in various branches of science under different names so that individuals using the relationship in one branch of science may be unaware that the same law is in independent usage in another branch. For example, the hyperbolic curve of limiting factor control, where there is a loop of necessary material being cycled and reused, is given different names in systems used in biochemistry, photosynthetic kinetics, photometry, economics, and chemical engineering. In Figure 1, each of the loopbacks of necessary work, if isolated, constitutes one of these hyperbolic responses.

Since each symbol represents something definite mathematically, the network diagram is also a statement of the computer program that has to be written for simulation in digital computers.

When the response of the groups of connected parts is to be studied, one may also model the system with electrical units on the passive principle where the flow of the electrical current simulates the flow of carbon, and heat energy losses in the real system are simulated by heat losses in the electrical system. The voltage simulates potential energy. There is an electrical unit for each of the symbols which are shown in Figure 2. For example, if the system in Figure 1 is constructed in electrical hardware, one may vary the input energy pulse and determine the pattern of arrival of energy to man in the course of the year. If something is omitted in drawing the circuit, the response will differ from that of the real system so that one may add features, gradually developing the model until it does indeed simulate the real system. Then one may use it for predicting responses to new situations. The importance of considering whole system functions together may be illustrated by the controversy over the utility and requirements of the sacred cow in India.

Sacred Cattle and Rice Production in Monsoon Climates

Another example of a primitive agricultural system of man and nature is provided by the system of rice and cattle in India and in other monsoon climates where the severity of the dry season essentially forces all systems of vegetation, whether controlled by man or not, to recommence each year. As shown in Figure 3, there is a flow of energy through rice and some grass, man, and the sacred cattle (work animals) with the loopback circuits of work control similar to those described in the Uganda example in Figure 1. Harris (7) opposes those who state that the sacred animals on the intensified, non-subsidized farms are superfluous. He mentions that they glean from a different plant base than man, serve as a source of critical protein, and especially facilitate mineral cycling and work on the plots necessary for a fast start on crop production when the wet monsoon begins. The energy network diagram (Figure 3) supports these contentions by showing the necessary reward loops, the work diversity in building protein and the storage function required where rain is irregular. Those who advocate removal of the sacred cows needed under the present agricultural system refer to the simple principle of shortening the food chain to save energy. In this case, a little knowledge about one process without understanding the complete system may be producing recommendations that endanger millions by upsetting a self-supporting system. Harris (7) cites Gandhi's comment that cows are sacred because they are necessary. The more general principle may be that religion is the program of energy control necessary for survival encoded in behavioral language.

Comparison of the Energetics of Primitive and Modern Food Production Systems

In elementary school textbooks, the expanding role of man on earth is often presented in terms of the evolution of his food producing systems and how they increased the number of people that it was possible to feed on a given area of land. First, man obtained food by hunting, fishing, and gathering fruits of the natural forests. Then came primitive agriculture in which man's labors, domestic animals, and crops are substituted for part of the natural environmental system of plants and animals. Finally, industrial man's agriculture is largely accomplished with aid of machines, chemicals, special varieties of plants and livestock and various kinds of industrial aids. The bulk of the persons who work to support the farming process are in cities far away from the farm but they are just as necessary to the farm as the man riding the tractor. Consider the network diagram for these three levels of complexity of food producing systems.

In Figure 4A is an energy diagram of the populations of a complex natural system in which man is supported by many converging food flows. Examples are the pigmy in the rain forest of the Congo and the Amazon Indian in the American Rain Forest. Many species at the various stages of photosynethetic production and consumption form one of nature's complex networks of loops, controls, and interactions most of which are still only slightly understood. The population density of man was about one person per square mile. The energy drains of man were small and man's influence on the system was small in terms of the energy he processed although his presence may have been important in the stability mechanisms because his effort was focused on specific components of the system. The complex of populations suggested in Figure 4A performed many work functions necessary for survival of man and the whole system. This situation is summarized in Figure 4B which emphasizes that all the necessary services such as receiving energy, cycling minerals, preventing epidemics, developing soil structure, controlling microclimate and light levels were done with feedback of small energies from the system's own resources. Man was the child under an umbrella of the stable forest system. Remnants of such systems still exist in the tropical forest belts.

The second level of complexity is the agriculture that is based largely on solar energy which was described in the examples from Uganda in Figure 1 and India in Figure 3. In these systems, man controlled a larger part of the energy budget by acting as a control gate on crops and cattle. The sharp fluctuations of rainfall required and permitted man to have a larger influence in comparison to his role in the forest from where his culture may have spread. In both systems, however, he was supported entirely from solar energy; the necessary work processes being performed directly or indirectly from energy from the sun. Man's role was limited by the amount of potential energy he could divert without weakening the system and permitting competing alternatives to displace the system or man himself. His activities were limited to those which would guide, reinforce, and improve the total power flows. Man's inputs in these semi-arid regions provided a measure of stability for him in an environment in which there were large seasonal variations in plant production.

The third level of complexity is illustrated in Figure 5. This is an entirely new system in which vast new flows of potential energy are made available from fossil fuels so that all the things that once had to be done as drains from the central budget may now be done with outside fuel. The original flow may produce vastly increased yields because the necessary work is being done on a different budget. This diagram shows how increases in agricultural yields have been achieved in modern times. Ninety-seven percent of farm production in the United States is exported from the farms for consumption in the cities by urban workers who are really farm workers but don't know it. Special new varieties of plants and animals have been developed which allow much of the food to be routed into net food storage rather than into disease prevention, protection, and other aspects of self work in the old system.

The diagram shows how one may be deluded into thinking some fundamental improvement has been made over the simpler systems, when in fact the apparent improvement has been due to use of an energy subsidy. There is little wonder that improved varieties sent to underdeveloped countries fail without the accompanying network of energy subsidies. One might as well send television tubes to a culture that has only crystal radios. *One must export whole systems, not a few parts.*

Energy Cost of High Quality Nutrition

One of the highest work costs in terms of energy is involved in diversifying food flows from a simple fuel to a variety of nutritional components sufficient to support man; a diet complete with amino acids, vitamins, and other necessary chemical compounds. The cost of 10 qualitatively different flows is much greater than the cost of the same organic mass produced in one form since all the specialized machinery and enzyme systems must be supported in each flow and many of the special molecules are produced through long chains of biochemical action. The advantages of mass production are lost. The diversity of species in nature's original habitats provided man with a broad nutritional base when he was a small part of the system. Later, when his agriculture concentrated on a few plants and replaced the natural system with a greater net yield of food, his population density increased but some of the energy was converted to increased yield at the expense of the former system's diversification. Special components were developed to supply the nutritional diversity either through transportation of products produced elsewhere or through local diversification systems such as the cattle in Figures 1 and 3.

A vegetarian may have a good nutrition provided he goes to the extra work and expense of gathering and combining enough kinds of plant foods to satisfy his dietary requirements. As an alternative he can eat more expensive meat products that provide a nutrition that is closer to his need. In meat, the combining has already been achieved by the integrating action of the animals and their systems of work and sustenance.

In natural communities, there is a convergance of separate food chains, each of which begins with a different plant, so that many higher animals are concentrations of the diversified nutritive composition required by man. The energy cost of such concentrating and combining may be inferred from the maximum yields of meat observed in some systems of food flow from plants to dependent larger animals (Figures 1 and 4). Those who claim that a calorie of diversified protein supplement can be made as cheaply as can a calorie of carbohydrate in terms of work done are leaving out the many energy subsidies of collection, combination and industrial aids from fossil fuel.

The Carrying Capacity for Man

In wildlife management, one sometimes uses the phrase "carrying capacity" to describe the ability of a grassland range to support a population of animals or birds. The carrying capacity is that population level which is compatible with the entire network of supporting plants, the mineral cycles, and especially the maintenance of the essential elements for effective support such as soil, water levels, diversity, and reserves that protect all parts against fluctuations. It is a population level for long-range survival.

The essence of the problem of food production for the world is in the question: "What is the carrying capacity of the earth's surface for man?" The same question arises in the discussions of man in space. What is the area of plant surface necessary to support man on solar energy? How much area is needed when solar energy is supplemented by some fuel energy from earth? The biosphere is really an overgrown space capsule and the questions about carrying capacity are similar. For projected levels of energy supplement from coal, oil, and nuclear power what is the carrying capacity of the earth?

This has been a much confused subject. Several years ago some extreme estimates of carrying capacities were made by those attempting to develop algal systems for man in space. The carrying capacity for a man was said to be half of one square meter. This was based not only on erroneous figures of photosynthetic efficiency but also on yields of laboratory algal systems which were heavily supported by fossil fuel energies through research appropriations, but the efficiencies were computed without the work of the researchers and industrial support even being mentioned.

Figure 6A and Figure 6B are network diagrams for an algal production system of pilot plant size. In Figure 6A all of the energy inputs are drawn including the sun and the work flows drawn from the industrial culture. As much fuel energy is apparently required as is produced as food. In Figure 6B, the energy subsidies are omitted and only the sun's energy is shown. This was the approach taken by the proponents of the extreme efficiency of algal culture and is very misleading. Often intensified agriculture is presented in the same way without adding the energy inputs of the many subsidies of city work and industrial inputs.

Calculations of carrying capacity for man must include all the work flows that provide stability, reserves, protection, organization, yield, special nutrition, recycling, and the controls necessary to the complex needs of man as indicated in Figure 4B. Man apparently evolved at a convergence of the many diverse food flows of the complex ecological systems in which he was imbedded (Figure 4A). Because of his original specialization as a mobile control unit and because his genetic inheritance of nutritional requirements has remained relatively stable, he still requires the food contributions of many chemical systems. He may live at the apex of a natural network of hundreds of species of plants and animals; he may keep a symbiotic nutrition factory such as cattle which utilize the ruminant stomachs containing many species of microorganisms to develop the complex nutritive convergence; or he may set up an economic system for convergence of a complex farm and grocery distribution system. Our modern system is based on the latter two alternatives. Disastrous consequences follow when workable systems of the first two types are discarded before an adequate system of the latter type is developed.

Summarizing, we conclude that the carrying capacity of man is determined by the energy source utilized to do the work necessary for the system to survive. When energy inputs are limited to those provided by the sun, the carrying capacity of men is apparently on the order of one individual per acre as in the rice-cattle system (Figure 3). Much greater densities are possible where the energy inputs are concentrated flows as when fossil fuels are used.

A Diagram for Classification of Countries, Takeoff

Industrialized civilizations support dense populations because their larger carrying capacity is based on the continued flow of concentrated potential energy derived from fossil fuels. Other sources such as nuclear energy may become important in the future. The present uneven distribution of wealth is really an uneven distribution in the application of fossil fuels. Primitive areas with rich oil deopsits can only sell the fuel since they have no network of advanced technology capable of accepting the subsidy directly.

For consideration of problems of world food suply, the diagram in Figure 7 may be used to scale countries ranging from those rich in in power to those that still survive on primitive food gathering systems. The vertical axis of the graph shows the net yield of food to man; the horizontal axis marks the rate of subsidy of concentrated potential energy from non-solar energy sources. The horizontal line at the top of the figure marks a production of 50,000 K cal/m^2/year, which represents the maximum gross photosynthetic rates of natural systems. The gross fixation of solar energy in photosynthesis (before one subtracts nature's use of its production in self-sustaining work processes) describes an upper limit which agricultural production approaches but does not exceed without fossil fuel supplementation. Even with fossil fuel supplementation, production never exceeds the maximum gross photosynthesis rate where light energy is the only limiting factor. Man may improve gross production with fossil fuels only by overcoming limitations other than light energy availability such as water or mineral shortages (see Figure 5). In Figure 7, we may draw the line corresponding to maximum gross photosynthesis in the unlimited natural system, or in the best agricultural system at about 150 K cal of organic matter fixed/m^2/day in growing seasons. Several levels of energy subsidy are indicated in Figure 7. The system of man in the deep forest described in Figure 4 is plotted in the lower left corner. Just above this is the farming system of man and nature without fossil fuel support as in Figures 1 and 3. Passing upward to the right, one finds present patterns of modern grain agriculture with considerable fossil fuel subsidy that serves to remove limiting factors and substitute for some of the self-controlling functions. These increases in yields that have been obtained by modern agriculture have been described as a yield takeoff by Brown (2) and are proportional to the auxiliary fossil fuel energy. The algal pilot plant (Figure 6) is found in the uper right of the diagram where the subsidy of concentrated energy is much higher than for agriculture.

The diagram shows the role of auxiliary fossil fuels and that man is eating potatoes indirectly made from oil. The progress made in providing food for the world's population results mainly from improvements in conversion of existing concentrated fuels into edible form by substituting outside work for self-maintenance in the solar agricultural systems.

If one locates the position of a country on this diagram, one is locating its degree of commercial complexity. One thus establishes the amount of auxiliary energy subsidy that can be utilized and the kind of system that can be immediately recommended.

Food Direct From Fuel

If highly concentrated, fuel-rich agriculture is really providing us potatoes where main system-support energies come from oil, one naturally asks the question if direct conversion of oil to food in chemical or microbiologically mediated industries would not provide the same or better yields. Since fuel-enriched agriculture is subsidized by natural light, it may continue to out-complete food production only from oil. Figure 8 is the results of an attempt to draw an energy diagram for direct conversion of fuel to food by microbial and chemical means. The energy source is petroleum and the control system is also from the fossil fuel-based industry. As physical laws require, energy transformations require dispersal of considerable energies as heat. Organisms in nature generally convert around 10 percent of their food input to protoplasm. Where system work is being subsidized as in egg, milk, and meat production, efficiencies approach the theoretical 50 percent at which maximum power delivery occurs. Where the organic substrate requires more energy for processing, efficiencies may be less. The diagram in Figure 8 reflects low yields in which energy input is approximately ten times output. Compare this with the increased yields obtained by using fossil fuel to overcome various limiting factors in agricultural systems (Figure 7) in which output is equivalent to energy input at the higher production levels. So long as areas of the world have agriculture with limiting factors that can be attacked with fossil fuel work supplements, one may achieve such a one to one conversion of fuels to food by substituting fuel based work for the loopback work in the solar-based food producing systems.

Loop Selection Principle and Food Give-Away

One of the principles emerging from ecological energy studies is the positive feedback loop by which a downstream recipient of potential energy rewards its source through the passage of a neccessary material, currency, or work back upstream. Thus the animals in a balanced system feed the phosphates, nitrates, and other requirements for plant growth back to plants in reward loops so that a plant which is in a food chain that regenerates nutrients in the form it needs is reinforced and the system continues. Species whose work efforts are not reinforced are quickly eliminated since they run out of raw materials or energy. They must be connected to input-output flows to survive.

Man's pollution production problem is related to his food production problem since there is an energy block when the wastes of civilization's metabolism do not get back into the fertilization of agriculture.

In man's complex system, he has arranged a feedback currency that is even more flexible than the geochemical recycling systems of natural ecosystems. He has invented money which is fed back in reward for work done. The action of money moving in opposite direction from the energy flows is indicated with the economic transactor symbol (Figure 2). The money flow of each population is thus looped to at least one other population, and by interconnecting loops the economic system provides rewards for each and a means by which productive circuit designs are rewarded by reuse. Reinforced and reused loops survive, replacing the possible alternatives which do not become reinforced. The "design" of systems in nature has occurred through this evolutionary mechanism. The networks of man are doing the same thing. An understanding of the role of closed loop selection allows us to use the principle to develop systems of feeding the world. Failure to understand the closed loop principle has been responsible for many failures where some system of food production was started but not continued.

Examples of the work loops that form reward controls in long-surviving successful systems of man and nature were cited in Figures 1, 3 and 4. Similar loops are required for system stability where the food systems of two or more countries are being joined. The serious problems of how to send food to India and Vietnam are examples. The food chains must have loops of work to be stable and surviving. Several ways of sending food from a food-rich country like the United States to an underdeveloped country are diagrammed in Figure 9 energy circuits. The give-away of food is indicated at B without a work loop, a system which will be eliminated either by decision or by loss of the effectiveness of participating agriculture of both countries.

Even the sale of food at market price by an industrialized country destroys old workable systems. The rise in standard of living that goes with fuel injections into an economy produces a lower standard of living among subsistence farmers and forces them to join the complex developing system. As standards rise, the amount paid to individuals for work increases. As a result, the cost of products including service work goes up. So long as an individual's work is part of the main system, payments increase with costs. However, the subsistence farmer who produces his own food and needs to purchase a few things with his small surplus cannot get them because prices have increased disproportionately to his production, principally because food is being produced at less cost elsewhere using fossil fuels. Unless a farmer produces a considerable cash crop surplus, there is no way for him to take advantage of the enriched main culture. His relative position is reduced. The cheaper food becomes anywhere in the world, the more the subsistence farmer loses.

Energetics of Cash Crop Monoculture Versus Fuel Subsidized Agriculture

The production of highly-specialized cash crops by developing countries presents a special problem in their relationships with developed nations. The rich countries, if they cannot or have not learned to manufacture a special commodity, may be willing to pay exorbitantly relative to the food value or energetic cost of the production and transportation of the commodity. When this is so, it may be smarter economy for developing countries to produce the complex product such as coffee, tea, chocolate, and spices for export and use the funds obtained to buy less exotic foodstuffs from countries that have fossil fuel subsidized agriculture. This is the relationship between many tropical countries and the United States at the present time. The energy diagram for such a system resembles part D in Figure 9 and has a reward loop.

The hazard inherent in a national economy based on monocultural production of a specialized commodity is its collapse if too much production is arranged. With the tropical countries disorganized and competing for markets for specialized products from plantations which require long-term capital investments, over-production has produced disastrous results. As world-wide food storages develop and cheap food exports from mass producing countries dwindle, the pressure on all nations to produce large quantities of basic foodstuffs will return. A lower standard of living will result unless food production everywhere receives some fossil fuel injection. The sooner notice goes out that food subsidies from rich mass production lines cannot be permanent, the sooner the change in plantings will be made. Will there be enough know-how remaining in specialty crop-producing countries to reinstitute basic food-producing agriculture?

Presently, the exportation of cheap food by developed nations is causing severe poverty among the non-industrial producers of food which further reduces the world food production capacity. As the rewards for farming decline, there is little incentive for farmers to make the kind of investments necessary for injecting fossil fuels into the network. The more low cost or free food that flows out from the fossil fuel rich centers, the more the developing countries are driven to drop subsistence farming and substitute specialty cash products or work services desired by the industrialized system. Little wonder that economic curtains of all kinds are put up to prevent lesser developed economies from becoming slave systems in which food producing capabilities are permanently lost (Figure 9A). Because the people in the towns can buy cheap food from abroad, they desert their own market production systems and become permanently dependent on foreign food. If domestic production is eliminated in this fashion and world food shortages develop, the resulting increase in prices will cause a sharp drop in living standards in towns whose progress was based on fossil fuel expenditures in rich countries far away.

The country that does not put up an economic curtain and stays with its subsistence past (Figure 9A) must do something of economic value for the world network of rich countries and do it just as cheaply as those countries can. If it enjoys no advantage due to location, climate, or resources, it must import a full-fledged fossil-fuel based activity if it is to compete, perhaps gaining some aid from cheap labor. Since the injection of fossil fuels into tropical agricultural systems has not been worked out for many food crops, these countries find it easier to become specialized industrial arms of the rich countries than to develop a food production economy. The patterns of tropical development so far have been of this nature.

Imperatives in Design of World Food Systems

If fossil fuels are the real means for feeding the world above the present and primitive carrying capacities, then the principal political issue is how to introduce a stable fossil fuel subsidy into the food networks of underdeveloped regions. There are several possibilities.

1. Suppose fossil fuels and nuclear power are first passed through the advanced cultures for food manufacture, the food being exported as a gift (Figure 9B). Such a system seems to leave control of the energies with the advanced cultures, but it is not a closed loop system and does not receive the reward reinforcement necessary to form a permanent structure. The donation of food without provision for loopback reward has a negative effect on the producing system, and the receiving system develops larger and larger populations whose unchanneled energies must go either into random and hence destructive activities, or be focused on some group action, that may have further negative effect on the donor or itself. To make such a food donation flow work, the circuit must be closed with a loopback of work, currency, or materials sufficient to make that a more stable loop than alternative ones (Figure 9D). The closing of such economic loops from rich countries to underdeveloped ones was the raw materials-manufactured goods production system of the colonial era. Unfortunately, inequities in distribution of wealth and other issues made that system unpopular and curtailed its further use.

2. An alternative way to develop food production based on oil is to design whole closed loop systems in the rich countries and export the whole loop process (Figure 9C). No food is exported, but the initial equipment and educational investments to start the loop within the less developed countries are exported along with arrangements for fossil fuel imports. A closed self-completing loop within a nation would

include a food production complex plus one or more industries that process insecticides, manufacture farm machinery, develop new crop varieties, and process fuel. In the loop, food goes into feeding the persons responsible for the work of the food augmenting process.

Such a development is not without hazard to the altruistic donor country since it involves setting up a fuel competitor which in effect dilutes the relative power of the donor in the world.

3. The third alternative is to do nothing, leaving the less developed countries and their burgeoning populations to their own fates (Figure 9A). Confronted with starvation and desperation, some form of totalitarianism could evolve which would set up its crash programs without the essence of democracy and peaceful development. Military ambitions may take the helm at considerable hazard to present democracies.

4. A fourth alternative involves a single, fuel-based economic system of food production, closed loops, and a one-world economy. No part is in competition if it is locked with direct and indirect reinforcing and stable currency loops. Since larger systems tend to dominate smaller ones, there is a tendency toward evolution of a one-world system. This solution may evolve, but cannot be initiated through the unilateral action of rich countries that control only limited parts of the earth's populations.

Summary

The design of a system of world food production and consumption can be aided by consideration of energy flow networks that show some hidden bases for man's progress and point up some delusions regarding the capacity of science to develop means for feeding growing populations.

For the future contingency of continuing increase of energy flows from fossil and nuclear fuels, maximum food production may be expected if our auxiliary energies are used as controls to overcome limiting factors wherever they exist in solar energy based agriculture rather than as direct substitutions for agriculture. To be effective, aid to new areas must introduce whole, self-contained systems that permit the effective use of auxiliary energies.

For the future contingency of failing energy flows from fossil and nuclear sources, a national program of research is needed now to plan for survival of man within simpler systems that will be induced by the reduction of our energy base. If we gain knowledge now of the operation of networks of nature and man that will support him in lesser numbers, we still might maintain our ascendancy through ecological engineering of small energies exerted at control points to cause the systems to provide yields for man. For future need, conservation of some of the workable primitive systems of man and nature is essential.

For either contingency, the ability of a nation to hold leadership will depend upon its ability to control flows of food and fuel.

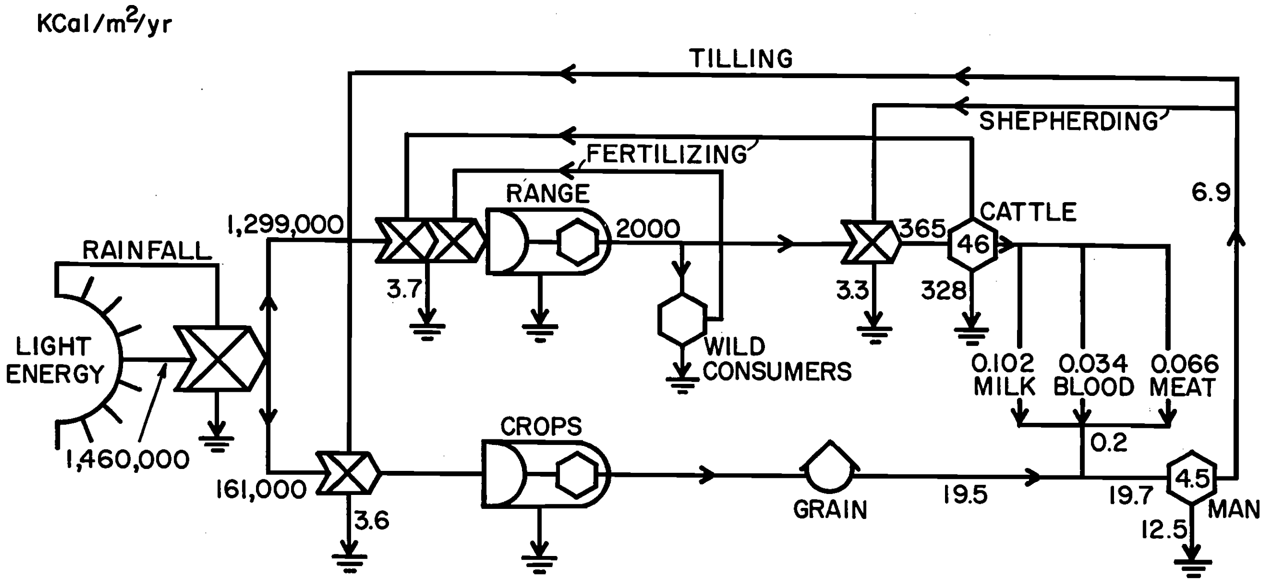

Figure 1
Energy circuit for tribal cattle system in Uganda

FIGURE 1

Example of a simple agricultural system in a pulse climate, the Dodo tribe in Uganda. Food is derived from grains, meat, blood, and milk. Animals serve as a storage filter smoothing the pulse and as a nutrition convergence. (Based on an account by Deshler, 1965 (3).) Numbers are Kilo calories per square meter per year. There are 70 people per square mile. Dry weights were converted to kilo calories using 4.5 K-cal/gm.

The basic net production of plant material for dry regions is given by Walter, 1954 (reproduced in Odum, E. P., p. 403(10)) as a function of rainfall. Using 21 inches of rainfall and Walter's diagram, one is able to determine that 500 g. of dry plant material matter are produced per square meter of land each year. As 1 acre is cultivated per person and there are 70 persons per square mile, one finds that 11 percent of the natural yield area is pre-empted by crops.

At 4.5 cattle per person and 560 pounds per cow, 33 percent of which is dry weight excluding ash and water, one is able to determine that 10.2 g of animal weight is produced per square meter.

Seventy people per square mile at 150 pounds per person of which 25 percent is dry matter is equivalent to 1.0 grams per square meter.

By integrating the area under curves given for monthly consumption of milk, blood, and meat, one obtains an annual caloric yield per person from the cattle of 3800 cal of milk, 2450 cal of meat, and 1265 cal of blood which provides the per area data in the figure. Calorie requirement per person is given as 2000 cal/person/day or 19.7 cal per square meter per year. The milk, meat, and blood supply only 0.2 of this requirement so crop intake is the remaining 19.5, a net yield much less than the net yield of vegetation of the natural range.

Total insolation in this area just above the equator is about 4000-cal/cm^2/day based on solar radiation maps for winter and summer for Africa given by Drummond (4).

The work of men in tending the crops and cattle can be taken as a percent of their time involved in this activity (primarily the daylight hours). As the culture is intimately involved with the cattle, one may assume that 1/6 of the daily metabolism of man is devoted to management of the cattle and the same amount is used for production of crops. The rationale for this procedure is that the maintenance requirements of man during his work are necessary to that work. The metabolic activities of 650 pound steers estimated from Kleiber (8) require 8000 Kcal per day or 365 Kcal/m^2/yr.

Some fraction of the cow's time and metabolism goes into refertilizing the range on which it grazes thus reinforcing and maintaining its loop. Part of a cow's day is spent on the move, and parts of its organ systems are involved in the nutrient regeneration system. One-tenth of its metabolism was taken as its work contribution to vegetation stimulation.

This system does not involve money and the economic transactor symbol does not appear.

Figure 2
Energy network symbols

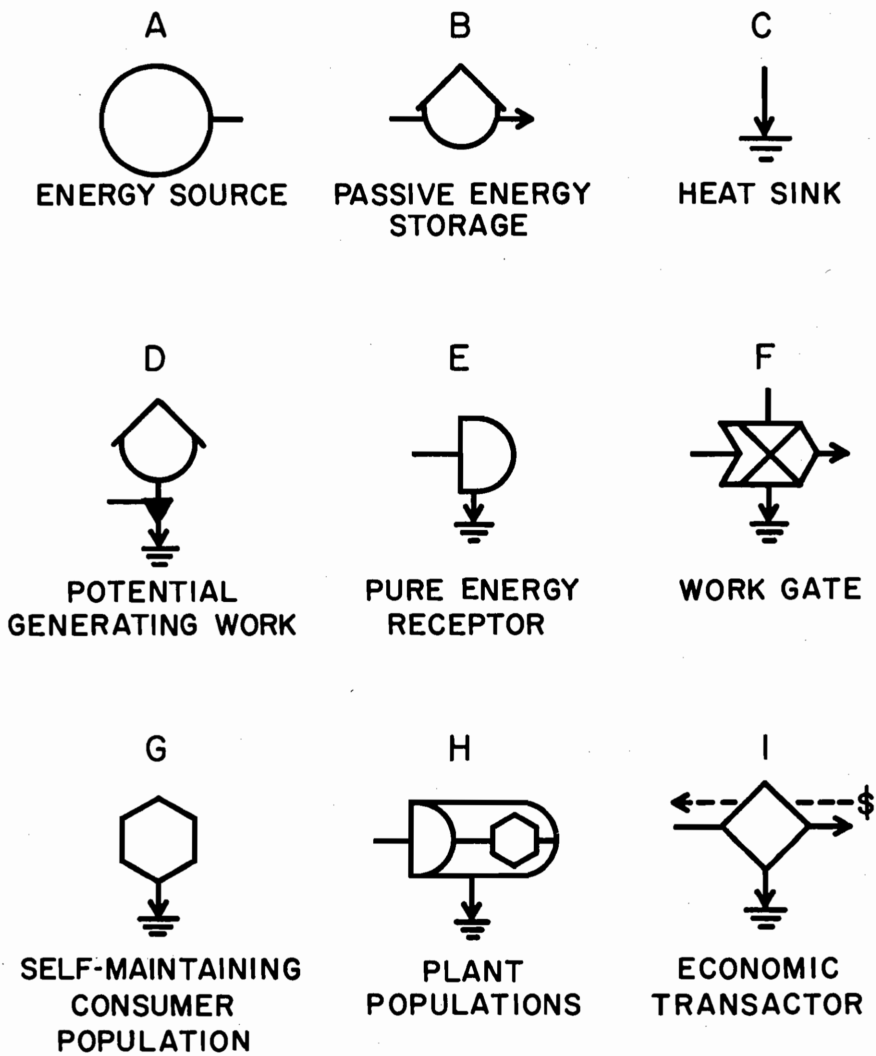

FIGURE 2.—Symbols used in energy network diagrams.

A. Energy source: A complete description requires that one specify the energy type and whether the source is constant force, constant flux, or follows some other delivery function.

B. When potential energy is stored without transformation and then removed, the simple tank symbol is used. For example moving grain into a warehouse and out involves no transformation of the chemical potential energy of the grain although some work must be done in the process utilizing energy from other flows.

C. This symbol shows the dispersion of potential energy into heat no longer usable for work processes by the system. This heat dispersal is required for any spontaneous process and irreversible entropy increases result.

D. When potential energy is stored with a transformation, the second energy law requires dispersal of part of it into heat. At optimum rates of potential energy storage, 50 percent is dispersed.

E. When incoming pure energy in the form of light or wave trains without matter flow is received and transformed into the potential energy associated with matter as in photosynthesis or in conversion of tidal energy, the receptor symbol is used. Heat energy is dispersed as in symbol D.

F. The work-gate symbol shows the work done by one flow against friction, or in acceleration and deceleration of work at rates that aid a second energy flow to cross an energy barrier. Work done in this manner has mass action kinetics, serves as a limiting factor, is a hyperbolic gate, and makes possible loops and hidden energy subsidies capable of system control. Work which induces a secondary energy flow increases the conductivity of the second circuit, and thus is mathematically a multiplier.

G. The hexagonal shaped symbol with heat sink drain is used for consumer populations which have the combined properties of symbol D for self storage and one or more work gates as part of their self maintenance system, including at least one work gate looped to an upstream circuit facilitation the introduction of fuel energy. This symbol mathematically has a logistic (autocatalytic) input-output function.

H. Plant populations are a combination of the functions of the energy receptor symbol E and the self-maintaining consumer symbol G.

I. The economic transactor symbol is used in human systems where economic transactions provide a low energy flow of symbols (money) in a direction opposite to the energy flow and in proportion to the work or potential energy flow. The economic transactor is one of the system control devices. The dashed line shows the flow of money according to the price-energy flow ratio. In energy diagramming, the dashed line can be omitted.

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Figure 3
Monsoon agriculture in India

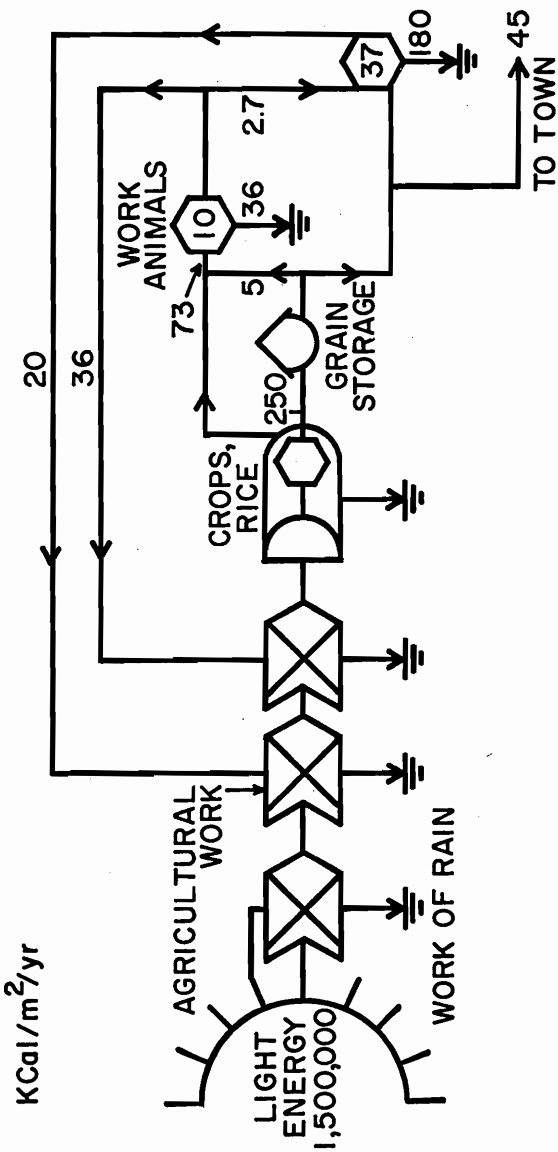

FIGURE 3

Man in unsubsidized agricultural systems in a climate such as India's which has a sharp seasonal pulse that prevents more diverse systems from excluding the simple one by competitive invasion. Data are based on tropical dense populations of 640 persons per square mile. Indian grain yields average 250 Kg/acre/yr. [Brown, (2)]. One farm animal is shown for each 10 persons. One-third of the food calories of the cattle remain in feces. One-half of animal metabolism is considered to be used for work and faecal fertilization. The animal protein intake for India is about six grams/person per day. [Brown, (2)]. From FAO data, 2 percent of the food crop is fed to animals. Animal metabolism is 8000 K cal/day [Kleiber, (8)]. Farm work occupies 0.1 of the total man-hours of the population.

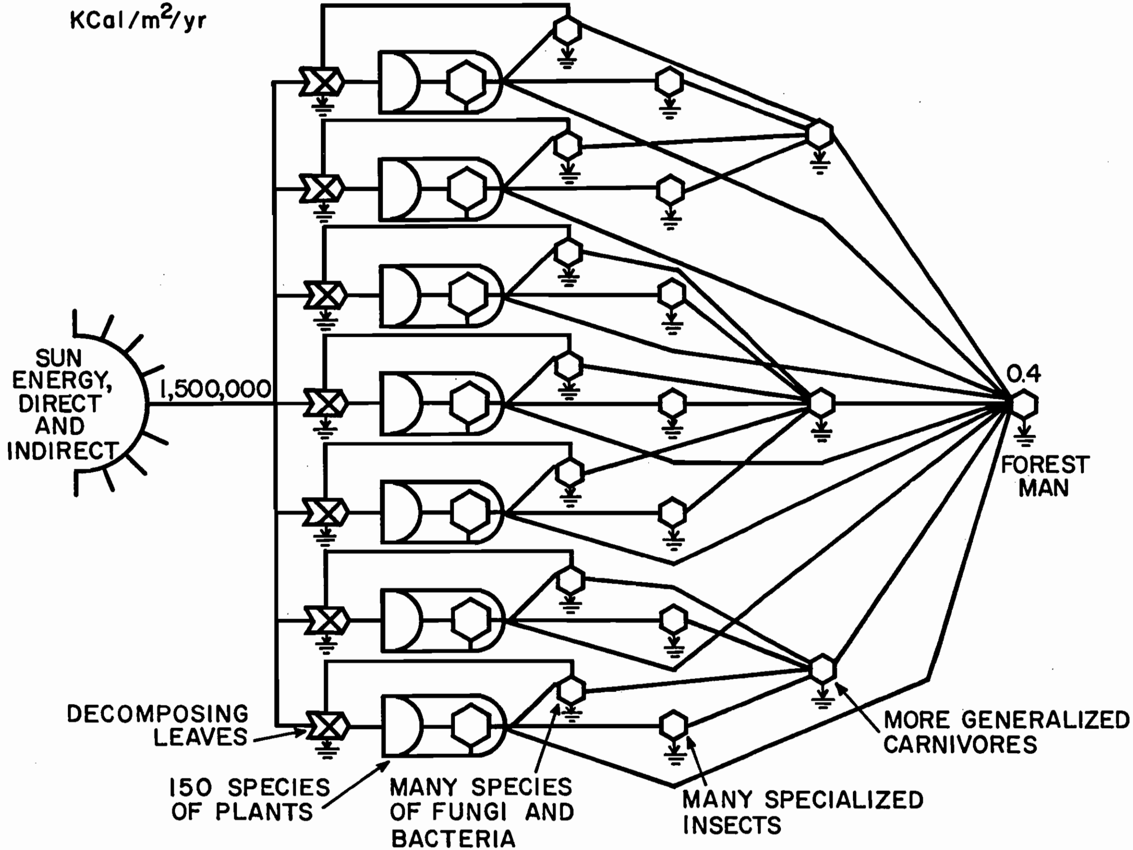

Figure 4a
Part of the rain forest system

FIGURE 4A

This is the kind of network one has with a complex natural ecological system with many species. Such systems are found where the climate does not have a sharp pulse in drought. temperature, or other factors that force the system to start over each year. Man is found in low densities of about one per square mile in many such systems: examples are the Indian in the rain forest of the Amazons, the rain forest pigmy of the Congo, and the aboriginal peoples of Australia. Hagen (6) gives a population in 1940 of 1.4 persons per square mile for the Amazon basin, including the towns.

Turnbull (12) gives a population of 40,000 pigmies for a rain forest area of 50,000 square miles, or 0.8 person/square miles.

Birdsell (1) finds aboriginal populations in Australia range in densities from 550 persons per 600 square miles in villages in high rainfall areas down to 550 persons per 40,000 square miles in dry central areas.

Rain forest gross photosynthesis at El Verde, Puerto Rico is 32 grams of dry matter/m^2/day.

Figure 4b

Rain forest system with components grouped

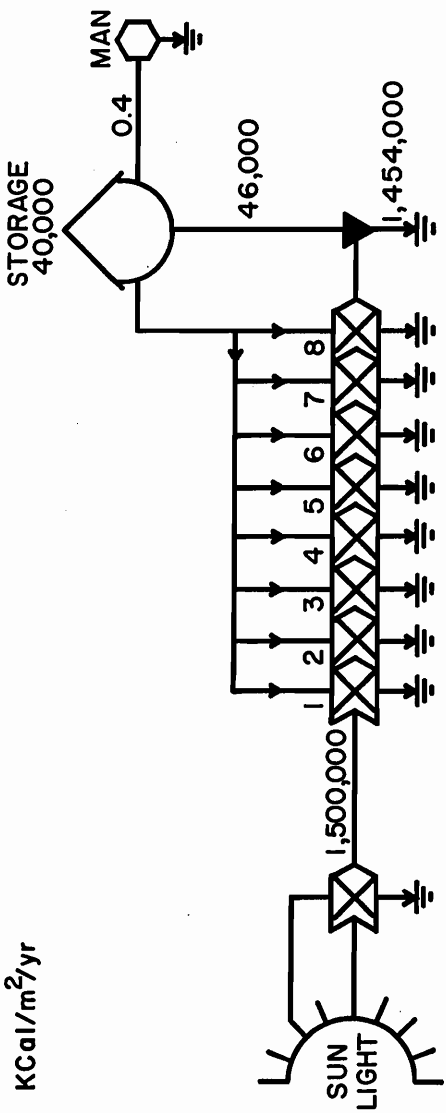

FIGURE 4B

Summarizing energy diagram for forest man in a tropical rain forest system. See Figure 3A for the type of network for which all the details are rarely known. The multiple species network of food chains and mineral regeneration routes accomplish the following work flows: (1) Regenerate plant materials; (2) provide epidemic protection with special biochemical substances in each plant species; (3) provide limit on any one microorganism or insect species by generalized carnivores and omnivores; (4) provide continuous chlorophyll receptors for maximum use of light; (5) provide stable programs of fruiting and other reproduction; (6) gather and converge specialized plant nutrition into organic constitution of higher organism meat; (7) provide shade to control ground invasion; (8) maintain soil structure with organic matter, burrowing animals, roots and microbes; (9) provide auxiliary energies from action of winds, rain, and other flows of the biosphere contributing to system function.

Figure 5

Fuel subsidized industrial agriculture

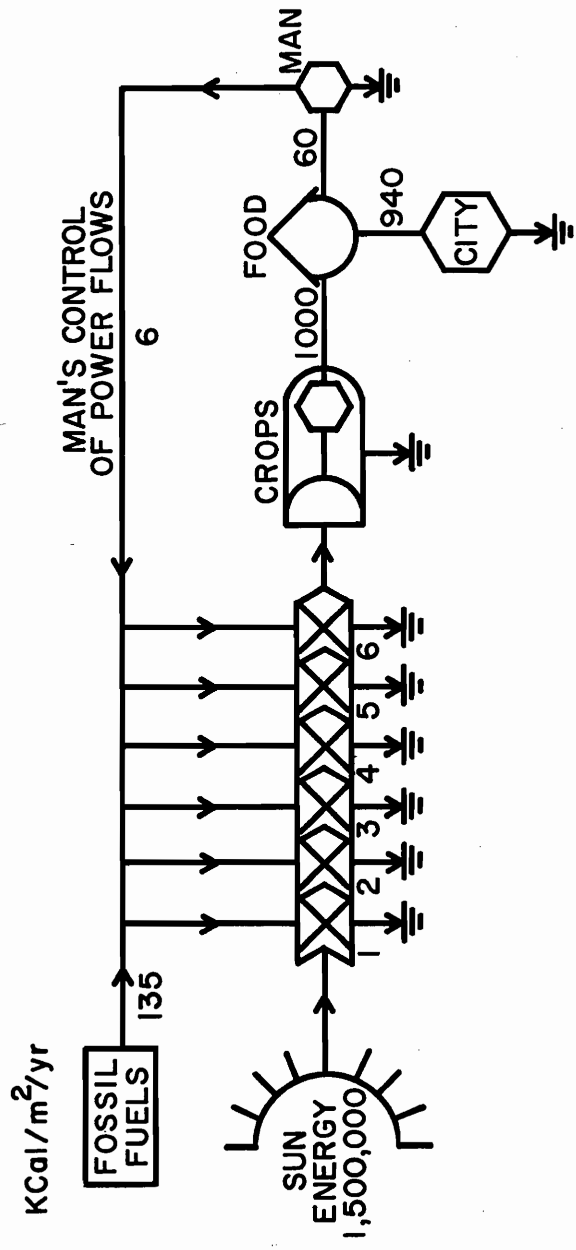

FIGURE 5

Man in a United States system of industrialized, high yield agriculture whose energetic inputs include some of the vast flows of fossil fuels which replace the work formerly done by man, his animals, and the network of animals and plants in which he was formerly nursed. Work flows include: (1) Mechanized and commercial preparation of seed and planting replacing natural dispersion systems; (2) fertilizer increments which replace mineral re-cycling system; (3) chemical and power weeding replacing the woody maintenance of a shading system; (4) soil preparation and treatment to replace the forest soil-building processes; (5) insecticides and fungicides which replace the system of chemical diversity and carnivores for preventing epidemic grazing or disease; (6) development of varieties which are capable of passing on the savings in work to net food storages; new varieties are developed as disease types appear, thus providing the genetic selection formerly arranged by the forest evolution and choice selection system. One hundred seventy persons per square mile support 32 x this number in cities. The level of United States grain production is about 1000 $Kcal/m^2/yr$. [Brown, (2).] The fuel subsidy is calculated using 10^4 Kcal/\$. If production yields \$60 per acre per year in United States production and if the costs were 90 percent of the gross, then \$54 per acre was the measure of use of materials and services from the industrialized culture. This becomes 54 x 10^4 Kcal per acre or 135 $Kcal/m^2/yr$.

Figure 6a

Algal pilot plant with subsidies included

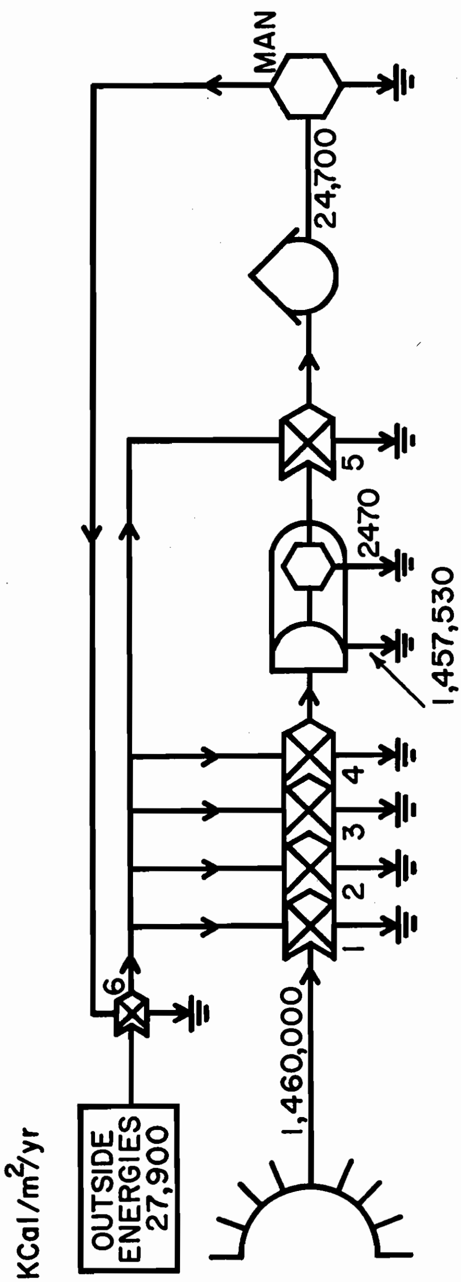

FIGURE 6A

Diagram of the flows per square meter per year which were actually involved in algal pilot plants. Work processes: (1) Mineral input which replaces natural recycling systems; (2) structure of tanks and tubes that replaced natural mixing and adaptations for moving cells relative to medium; (3) energy for pumping and stirring replacing the natural wind, wave, and current systems; (4) carbon dioxide injections replacing the respiratory feedback system; (5) energy for concentrating and drying algae replacing the gatherers and concentrators of the natural food chains; (6) control valves operated by man replacing the built-in control network of the larger species.

Figure 6b

Algal pilot plant without subsidies shown

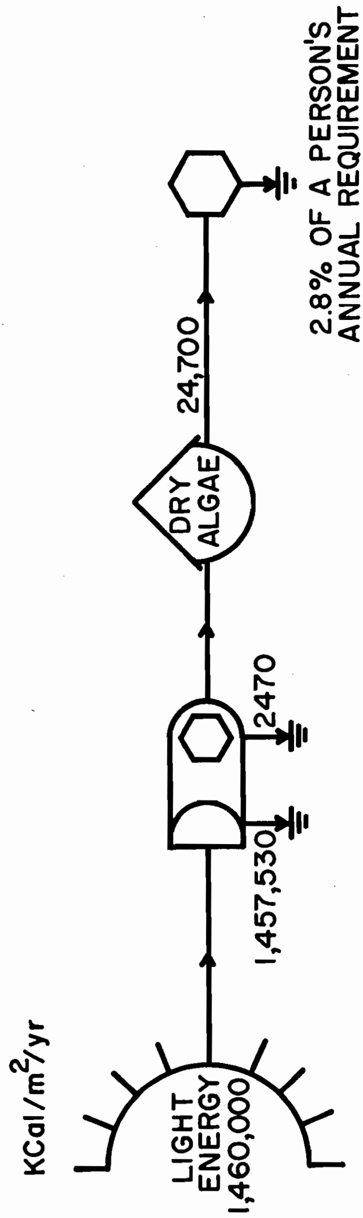

FIGURE 6B

Diagram of the flows per square meter per year which the algal protagonists included in their calculations, finding 4.2 percent efficiency of visible light that is one-half of the solar input energy shown.

Calculations for Figure 6 were taken from data on an algal pilot plant operated by Arthur D. Little Company. [Fischer, (5).] A yield of 20 tons per acre was obtained. A year of isolation provides 1,460,000 Kcal/m^2 input (400 langleys per day). Gross production is taken as 10 percent greater due to respiration, which is small in rapidly growing and harvested cells since they are not maintaining their own system. Five Kcal per gram dry weight was used to convert algal weight to potential energy of yield.

The work costs were given by Fischer in dollars including a depreciation of the cost of the installations over a ten year period. The dollar costs of $2.80 per m^2/yr. were converted to work energy values using the ratio of United States fuel consumption to United States dollar budget in 1960 of about 10,000 Kcal/dollar spent.

Figure 7

Food yields and fuel subsidies

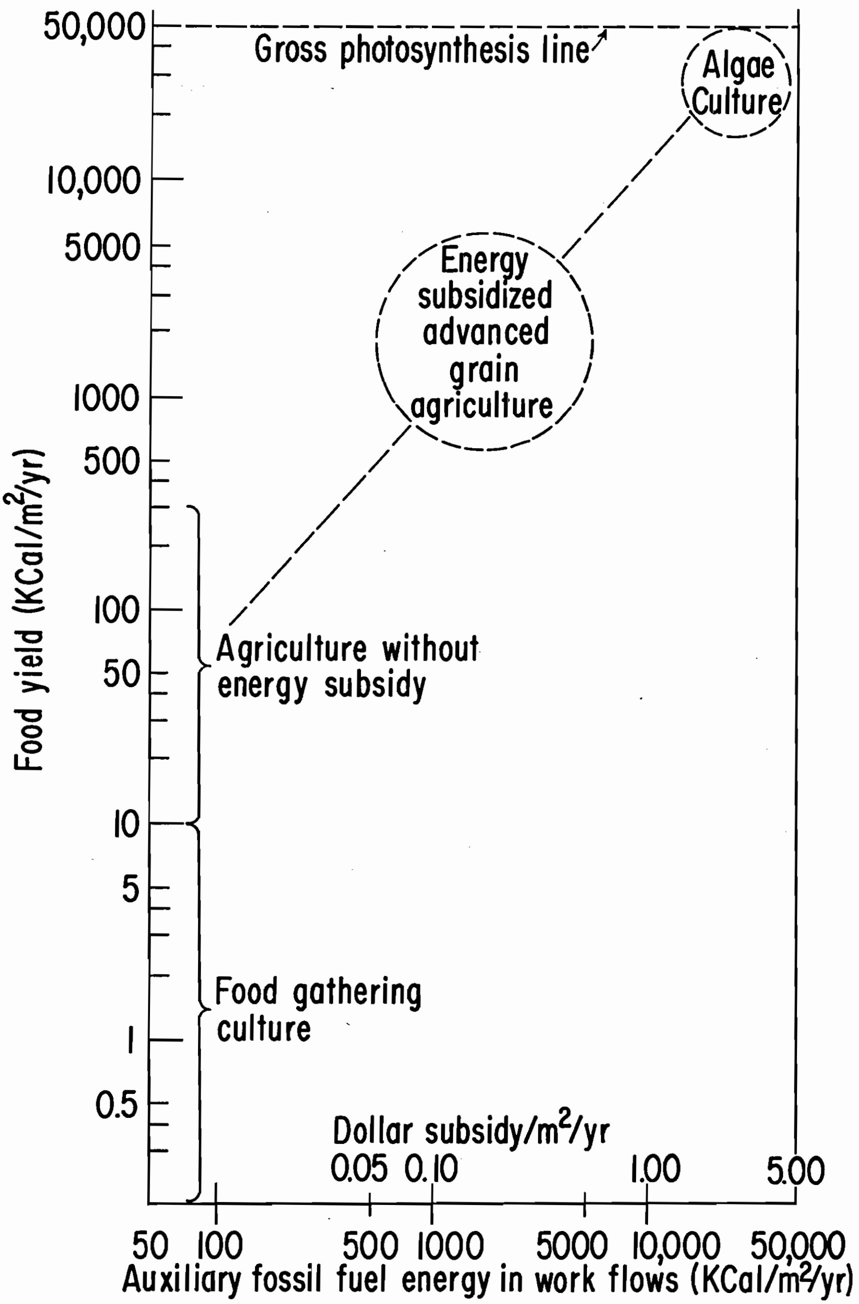

FIGURE 7

Diagram of the net yields possible for man from a photosynthetic system as a function of the auxiliary, fossil fuel energies being used to do work that would otherwise have to be done from the yield. As favorable environmental supplements and fossil fuel inputs become large, the net yield to man approaches the maximum gross photosynthesis ceiling inherently limited by the thermodynamics of photosynthetic cells. The ceilings for the gross photosynthesis of the best agriculture and the most productive natural communities are about the same, here written as around 150 kilo-calories per square meter per day.

Figure 8

Food from hydrocarbons

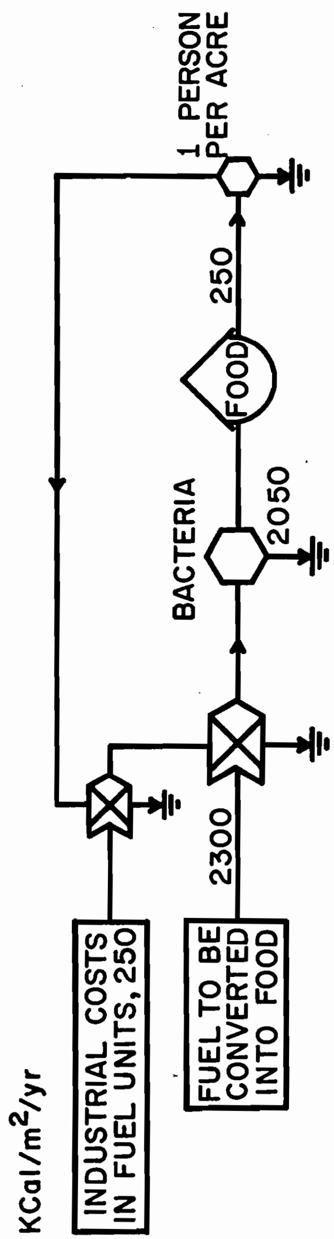

FIGURE 8

System of food production converting methane and/or petroleum to food using industrial microbiological means of growing bacteria on hydrocarbons. Calculations are prorated to indicate the amount of fuel required per area to support 640 persons per square mile. Fuel cost of the industrial subsidy is computed from the $0.55 per kilogram cost estimated by McPherson (9). Percent of fuel converted was obtained from a report on a Shell Co. pilot plant in which 10^7 g of food (50 percent protein) were produced from two million cubic feet of methane (4.6 x 10^8 kCalories) (J. van Overbeek, personal communication [2]).

[2] Dr. van Overbeek was formerly with Shell Development Company, Modesto, California. He is now with Texas A&M University.

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Figure 9

Systems connecting developed and developing countries

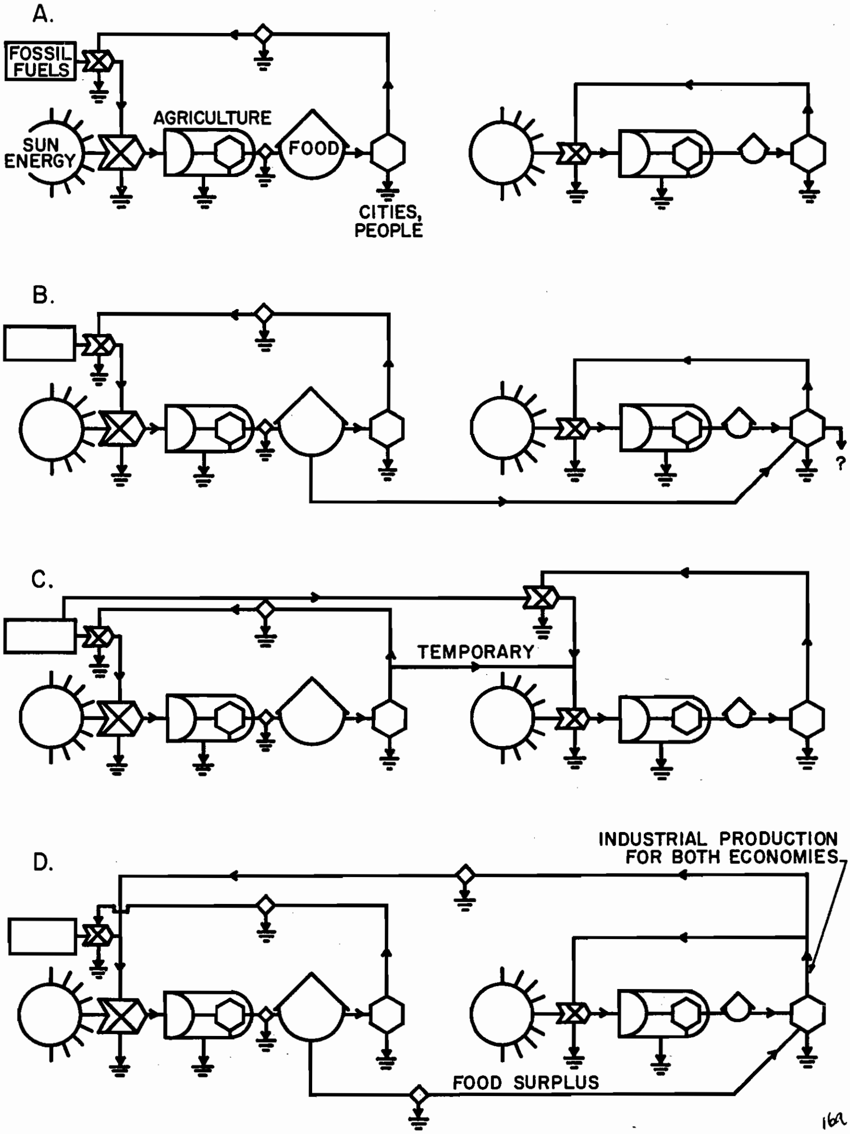

FIGURE 9

Four patterns expressing the relationship of an advanced, industrialized country to a less developed country.

A. Both systems with closed loops and separate.

B. Industrialized system donating food without loop back; system is non-rewarding and unstable; temporary subsidy of energies does harm to under-developed population.

C. Industrialized country aids second country to develop its own fossil fuel support as a separate loop system.

D. Industrialized country produces food but incorporates second country in a closed work loop of its economic system.

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CHAPTER 4

MANUFACTURED PHYSICAL AND BIOLOGICAL INPUTS

The subpanel of the President's Science Advisory Committee Panel on World Food Supply concerned with "Manufactured Physical and Biological Inputs" under the Chairmanship of Dr. John Kincaid, International Minerals and Chemical Corporation, developed papers on the topics of fertilizers, seeds, pesticides and machinery during the course of the study. Principal results for these documents were utilized in the preparation of the subpanel report which has been included in Volume II of the report. These reports were considered to be of sufficient importance and relevance to the problem of world food supply that it was decided to present them in detail in this volume.

FERTILIZER REQUIREMENTS FOR INCREASED FOOD NEEDS

By Lewis B. Nelson, Tennessee Valley Authority and Raymond Ewell, State University of New York at Buffalo

Introduction

Fertilizer is one of the essential inputs required to increase food production. Estimates by the United States Department of Agriculture indicate that 35 to 40 percent of the increased agricultural production in this country during recent years is directly attributable to increased use of fertilizer. In developing countries, where soils are less fertile, the use of fertilizers is even more important since food production can be increased very little without fertilizers. However, fertilizers alone without use of improved crop varieties, insect and plant disease control, and other improved cultural practices can have only minimal effect in increasing production.

World fertilizer consumption (excluding mainland China) during the fiscal year 1965–66 was estimated to be about 17.6 million metric tons of nitrogen, 14.5 million metric tons of soluble phosphate (P_2O_5), and 12.1 million metric tons of potash 12.1 (K_2O). Eighty-six percent of the world's consumption is in the more developed countries containing 39 percent of the world's total population, and only 14 percent is in the less developed areas which contain 61 percent of the population. Paradoxically, least use is in those countries suffering most from the population explosion and food deficits.

From the fertilizer production standpoint, the imbalance is even greater since the world's production facilities are still very much concentrated in the industrialized nations. For example, about one-third of the current capacity for fertilizer production is in the United States. Although the excess capacity of the developed countries can be used to manufacture fertilizers for the developing countries, these countries usually prefer to build their own plants and to import only the essential raw materials. If fertilizers are imported, they represent a heavy drain upon the limited funds available for foreign exchange.

This report attempts to assess the overall requirements for additional fertilizer needed by the developing nations to avert famine and feed rapidly increasing populations and to determine the capital costs required for facilities to produce this fertilizer. In projecting the fertilizer needs, it is assumed that increased fertilizer will be accompanied by increased use of other key inputs such as improved seeds, pesticides, machinery, and other cultural practices. Estimates are also made of the credit and skilled manpower requirements, and the adequacy of basic raw materials needed to produce the fertilizers is evaluated.

Methodology

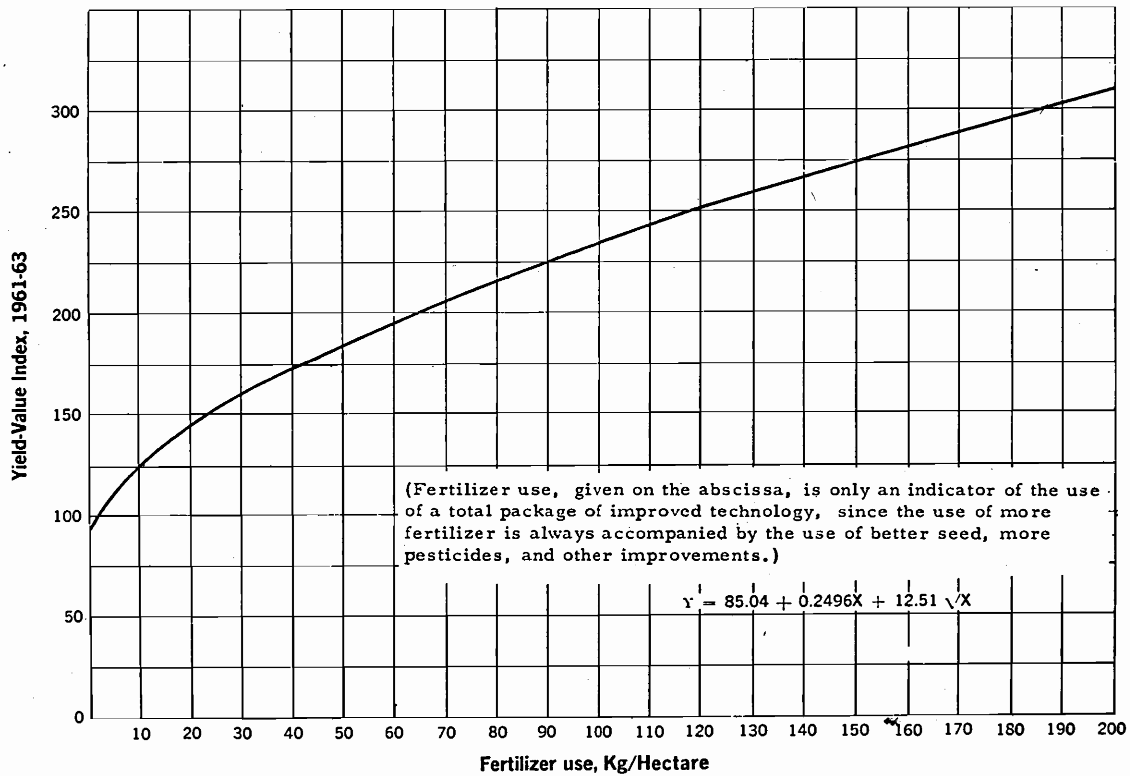
It was the objective here to determine the amounts of fertilizer required to increase agricultural production by various percentages, up to and including 100 percent. For this purpose, the approach described by Parker (3) used by the Food and Agriculture Organization of the United Nations, known as the "yield value index," was employed.

Essentially, the FAO method assumes that the level of fertilizer use of a country is related to the yield of crops per hectare of cultivated land. FAO used data from 41 developed and developing countries, and developed a curve (Figure 1) 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. It is possible to estimate from this curve the quantity of fertilizer a country will need to use in order to attain a given level of crop production per hectare.

Data collected by FAO show that the general relationships expressed by this curve are valid for most countries. The method has the advantage that it considers fertilizer use on all crops and also makes allowance for the introduction of improved agricultural practices. However, the procedure does not take into account the wide range of soil and climatic conditions that exist in many countries and thus may introduce obvious errors for any one specific country.

Figure 1

Yield-Value Index vs. Fertilizer Use—1961/63



In order to project the plant nutrient requirements, the panel accepted the yield-value indices developed by FAO for the 1961–63 period. Indices for later years and for all countries were not available. The Subpanel developed its own estimated yield-value indices for the missing countries covered in this report, by computing the actual kilograms of fertilizer used per hectare of arable land and plotting this statistic against the FAO formula:

$$Y=85.04+0.2496\ X+12.51\sqrt{X}$$

where Y=yield-value index

X=kilograms of plant nutrients per hectare

Using the procedure explained above, estimated plant nutrient requirements were developed for Asia (excluding Japan, mainland China, North Korea, North Vietnam and Mongolia), Africa, and Latin America for 0, 10, 25, 50, and 100 percent increases in food yield and these are presented in Table 1.

TABLE 1.—*Estimated plant nutrient requirements for varying percentage increases in food yield*

Country	Population (1961–63 average) [1] (millions)	Arable land and land under permanent crops [2] (mil hectares)	Percentage Increase in Food Equivalent Yield [3]: Estimated Yield Value Index [4] and Plant Nutrient Consumption (kg/ha) [5]					Fertilizer Requirements (000 tons of plant nutrients)				
			0	10	25	50	100	0	10	25	50	100
ASIAN SUBCONTINENT												
Pakistan	97	25.8	112	123	140	168	224					
			42	8	16	36	75	108	206	413	929	1,935
Turkey	29	26.0	105	116	131	158	210					
			2.4	6	12	29	74	62	156	312	754	1,924
India	451	162.9	106	117	133	159	212					
			26	6	13	29	75	424	977	2,118	4,724	12,218
Syria	5	6.7	110	121	138	165	220					
			3.7	8	16	33	83	25	54	107	221	556
Ceylon	10	1.9	181	199	227	272	362					
			45.7	62	90	144	276	87	118	171	274	524
Israel	2	.4	222	244	278	333	444					
			85.6	112	146	232	416	34	45	58	93	166
Burma	23	14.9	91	100	114	137	182					
			0.2	2	6	15	56	3	30	89	224	834
Thailand	28	10.6	103	113	129	155	206					
			1.9	5	11	26	70	20	53	117	277	742
Indonesia	98	17.7	105	116	131	158	210					
			2.4	6	12	29	74	42	106	212	513	1,310
Philippines	29	11.2	131	144	164	197	262					
			11.9	19	32	62	132	133	213	358	694	1,478

TABLE 1.—*Estimated plant nutrient requirements for varying percentage increases in food yield*—Continued

Country	Population (1961–63 average) [1] (millions)	Arable land and land under permanent crops [2] (mil hectares)	Percentage Increase in Food Equivalent Yield [3]: Estimated Yield Value Index [4] and Plant Nutrient Consumption (kg/ha) [5]					Percentage Increase in Food Equivalent Yield [3]: Fertilizer Requirements (000 tons of plant nutrients)				
			0	10	25	50	100	0	10	25	50	100
ASIAN SUBCONTINENT—Continued												
Korea Rep.	26	2.2	273	300	341	410	546					
			146.2	184	244	356	605	322	405	537	783	1,331
Taiwan	11	.9	314	345	393	471	628					
			203.4	252	328	464	774	183	227	295	418	697
Total for 12 Nations	809	281.2	--------	--------	--------	--------	--------	1,443	2,590	4,787	9,904	23,715
Remainder of Asian Subcontinent [6]	113	52.8	105	116	131	158	210					
			3	6	12	30	74	146	317	634	1,584	3,907
Grand Total	922	334.0	--------	--------	--------	--------	--------	1,545	2,907	5,421	11,488	27,622
AFRICA												
South Africa	17	12.1	150	165	188	225	300					
			22.4	33	53	88	184	271	399	641	1,065	2,226
Egypt	27	2.5	22.8	251	285	342	456					
			91.6	118	162	244	436	229	295	405	610	1,090
Total for 2 Nations	44	14.6	--------	--------	--------	--------	--------	500	694	1,046	1,675	3,316
Remainder of Africa [6, 7]	232	236.1	98	108	122	147	196	282	944	1,889	4,722	13,694
			1.0	4.0	8.0	20.0	58.0					
Grand Total	276	250.7	--------	--------	--------	--------	--------	746	1,638	2,935	6,397	17,010

LATIN AMERICA

Argentina	21	19.5	94	103	118	141	188					
			0.5	2	7	17	53	10	39	137	331	1,034
Colombia	15	5.0	122	134	153	183	244					
			7.7	13	25	47	110	39	65	125	235	550
Mexico	37	23.8	128	141	160	192	256					
			10.4	17	30	55	125	248	405	714	1,309	2,975
Brazil	75	19.1	130	143	163	195	260					
			11.2	18	31	58	130	214	344	592	1,108	2,483
Chile	8	2.6	140	154	175	210	280					
			16.5	25	40	74	156	43	65	104	192	406
Peru	11	1.8	188	207	235	282	376					
			52.1	70	100	157	300	94	126	180	283	540
Totals for 6 Nations	167	71.8	--------	--------	--------	--------	--------	648	1,044	1,852	3,458	7,988
Remainder of Latin America[6]	56	32.5	128	141	160	192	256	345	553	975	1,788	4,030
			11	17	30	55	124					
Grand Total	223	104.3	--------	--------	--------	--------	--------	1,024	1,597	2,827	5,246	12,018

[1] Reported by Food and Agriculture Organization of the United Nations, *Production Yearbook*, Rome, Annual reports 1962–1964.

[2] Latest data available. Reported by Food and Agriculture Organization of the United Nations, *Production Yearbook*, Rome, 1966. Total land area for each region estimated from 3-year average. Individual countries have varying years in which land surveys are made.

[3] Assuming the yield-value index will increase at the same rate as population. For example, a 100% increase in population will require a 100% increase in food yield which will result in a 100% increase in the yield-value index.

[4] Based on values calculated by Food and Agriculture Organization of the United Nations.

[5] Based on relationship of yield-value index to fertilizer consumption per hectare as developed by Williams, M. S., and J. W. Couston, *Crop Production Levels and Fertilizer Use*, United Nations, Rome, 1962, using 1956–58 data. The relationship used for the development of the above estimates is based on the yield-value index and fertilizer consumption for the period 1961–63, and based on the equation: $Y=85.04+.2496X+12.51\sqrt{X}$ when Y=yield-value index and X=fertilizer consumption in kg/ha.

[6] Consumption in kg/ha and the corresponding yield-value index for the remainder of the area calculated from land area and actual fertilizer consumption during the base period (ave. 1961–63). Because of estimates (see footnote "d") made for individual countries, the total consumption for the individual countries plus the remainder will not total the actual consumption for the region. Consumption data from Food and Agriculture Organization of the United Nations, *Fertilizers: An Annual Review of World Production, Consumption, and Trade, 1964*, United Nations, Rome, 1965.

[7] It is the opinion of the subpanel that the FAO Method probably gave unrealistically high estimates for the remainder of Africa.

These estimates were based on a yield-value index computed by FAO using a 1961–63 base period. In Table 1, the statistics are given by individual countries for which FAO had a computed yield-value index. All countries in each region for which no yield-value statistics were available are grouped under "remainder" using a yield-value index as estimated by the panel.

The projected total plant nutrient requirements were adjusted using 1966 as the base year. Using FAO population estimates as a guide, interpolated values of plant nutrient requirements for 1970, 1975, 1980, and 1985 were determined. The adjusted total plant nutrient needs by regions, years, and the corresponding percent increase in agricultural production are shown in Table 2.

TABLE 2.—*Fertilizer needed to increase agricultural production on acreage now under production in Asia,*[1] *Africa, and Latin America, by the percentage indicated*

Year	1966[2]	1970	1975	1980	1985	--------
Percent Increase in Agricultural Production	--------	10	26	43	63	100
Plant Nutrients Needed (millions of metric tons of N, P_2O_5 and K_2O):						
Asia	2.91	5.42	9.30	13.90	20.00	33.00
(India)	(.98)	(2.12)	(3.70)	(5.80)	(8.80)	(15.00)
Africa	1.64	2.94	5.20	8.00	12.00	20.00
Latin America	1.60	2.83	4.20	6.30	8.00	14.00
(Brazil)	(.34)	(.59)	(1.10)	(1.40)	(1.90)	(3.00)
Total	6.15	11.19	18.70	28.20	40.00	67.00

[1] Except Mainland China and Japan.
[2] Actual consumption in 1966.

Individual Plant Nutrient Requirements of Developing Nations

Inasmuch as the costs of facilities to produce the major plant nutrients differ, it was necessary to determine the relative proportions of N, P_2O_5, and K_2O that go to make up the total plant nutrient requirements.

Based on the best judgment of fertilizer experts, it was decided that a 4–2–1 ratio of N : P_2O_5 : K_2O would best meet the overall requirements of the soils and crops of the developing nations. This means that 57.1 percent of the total tonnage of plant nutrients would be in the form of nitrogen (N), 28.6 percent as phosphate (P_2O_5), and 14.3 percent as potash (K_2O).

The individual nutrient requirements on this basis are summarized for the developing countries as a whole in Table 3 and given in more detail by regions in Table 4.

TABLE 3.—*Estimated individual plant nutrient requirements in developing regions* [1]

[Million metric tons]

Plant Nutrient Requirements	Percentage Increases in Agricultural Production					
	(2)	10	26	43	63	100
Total	6.15	11.19	18.70	28.20	40.00	67.00
N	3.51	6.39	10.69	16.11	22.86	38.29
P_2O_5	1.76	3.20	5.34	8.06	11.43	19.14
K_2O	.88	1.60	2.67	4.03	5.71	9.57

[1] Assuming an overall ratio of 4–2–1 for Nitrogen, P_2O_5 and K_2O.
[2] Actual consumption in 1966.

TABLE 4.—*Estimated individual plant nutrient requirements, by region* [1]

[Million metric tons]

Region	Plant Nutrient	Agricultural Production Percentage Increase					
		(2)	10	26	43	63	100
Asian Subcontinent	N	1.66	3.10	5.32	7.94	11.43	18.86
	P_2O_5	.83	1.55	2.66	3.97	5.71	9.43
	K_2O	.42	.78	1.33	1.99	2.86	4.71
	Total	2.91	5.42	9.30	13.90	20.00	33.00
(India)	N	.56	1.21	2.11	3.31	5.03	8.57
	P_2O_5	.28	.61	1.06	1.66	2.51	4.29
	K_2O	.14	.30	.53	.83	1.26	2.14
	Total	.98	2.12	3.70	5.80	8.80	15.00
Africa	N	.94	1.68	2.97	4.57	6.86	11.43
	P_2O_5	.47	.84	1.48	2.29	3.43	5.71
	K_2O	.23	.42	.74	1.14	1.71	2.86
	Total	1.64	2.94	5.20	8.00	12.00	20.00
Latin America	N	.91	1.61	2.40	3.60	4.57	8.00
	P_2O_5	.46	.81	1.20	1.80	2.29	4.00
	K_2O	.23	.40	.60	.90	1.14	2.00
	Total	1.60	2.83	4.20	6.30	8.00	14.00
(Brazil)	N	.19	.34	.63	.80	1.09	1.71
	P_2O_5	.10	.17	.31	.40	.54	.86
	K_2O	.05	.08	.16	.20	.27	.43
	Total	.34	.59	1.10	1.40	1.90	3.00
Total (3 regions)	N	3.51	6.39	10.69	16.11	22.86	38.29
	P_2O_5	1.76	3.20	5.34	8.06	11.43	19.14
	K_2O	.88	1.60	2.67	4.03	5.71	9.57
	Total	6.15	11.19	18.70	28.20	40.00	67.00

[1] Assuming an overall ratio of 4–2–1 for Nitrogen, P_2O_5, and K_2O.
[2] Actual consumption in 1966.

Capacity Requirements of Plants To Produce Needed Fertilizers

In estimating the needed production facilities for fertilizers in developing countries, the existing capacity already installed must be considered. These installed capacities as they existed in 1965 are shown in Table 5. Deducting these installed capacities from the total capacities required for the different increases in food yield gives the needed additional capacities as shown in Table 6. The production capacity that will be required in the regions of chief concern in this report are given in Table 7.

TABLE 5.—*Estimated fertilizer productive capacities, 1965* [1]

[Thousand metric tons]

Area	N	P_2O_5	K_2O	Total
Asian Subcontinent	1,299	421	240	1,960
(India)	(534)	(245)	(–)	(779)
Africa	347	669	------------	1,016
Latin America	1,063	437	21	1,521
(Brazil)	(31)	(74)	(–)	(105)
Total	2,709	1,527	261	4,497

[1] Includes only fertilizer production units that were known to be operating as of July 1, 1965, according to McCune et al. (2)

TABLE 6.—*Additional fertilizer production capacity requirements, in developing regions* [1]

[Million metric tons]

Plant Nutrients	Percentage Increase in Agricultural Production				
	10	26	43	63	100
N	3.68	7.98	13.40	20.15	35.58
P_2O_5	1.67	3.81	6.53	9.90	17.61
K_2O	1.34	2.41	3.77	5.45	9.31
Total	6.69	14.20	23.70	35.50	62.50

[1] It is recognized that additional fertilizer production capacity is presently being built or planned for the regions under consideration. From published data available, however, no detailed estimate of the extent of the announced capacity for 1970 that has been completely financed and reached the final development stages can be determined. Thus, the data in this table represent the total additional fertilizer production capacity needed in excess of 1965 existing productive capacities.

TABLE 7.—*Additional fertilizer production capacity requirements, by region* [1]

[Million metric tons]

Region	Plant Nutrient	Agricultural Production Percentage Increase				
		10	26	43	63	100
Asian Subcontinent	N	1.80	4.02	6.64	10.13	17.56
	P_2O_5	1.13	2.24	3.55	5.29	9.01
	K_2O	.54	1.09	1.75	2.62	4.47
	Total	3.47	7.35	11.94	18.04	31.04
(India)	N	.68	1.58	2.78	4.50	8.04
	P_2O_5	.37	.82	1.42	2.27	4.05
	K_2O	.30	.53	.83	1.26	2.14
	Total	1.35	2.93	5.03	8.03	14.23
Africa	N	1.33	2.62	4.22	6.51	11.08
	P_2O_5	.17	.81	1.62	2.76	5.04
	K_2O	.42	.74	1.14	1.71	2.86
	Total	1.92	4.17	6.98	10.98	18.98
Latin America	N	.55	1.34	2.54	3.51	6.94
	P_2O_5	.37	.76	1.36	1.85	3.56
	K_2O	.38	.58	.88	1.12	1.98
	Total	1.30	2.68	4.78	6.48	12.48
(Brazil)	N	.31	.60	.77	1.06	1.68
	P_2O_5	.10	.24	.33	.47	.79
	K_2O	.08	.16	.20	.27	.43
	Total	.49	1.00	1.30	1.80	2.90
Total (3 regions)	N	3.68	7.98	13.40	20.15	35.58
	P_2O_5	1.67	3.81	6.53	9.90	17.61
	K_2O	1.34	2.41	3.77	5.45	9.31
	Total	6.69	14.20	23.70	35.50	62.50

[1] It is recognized that additional fertilizer production capacity is presently being built or planned for the regions under consideration. From the published data available (see Footnote (1), Table 6), however, no estimate of the extent of the announced capacity for 1970 that has been completely financed and reached the final development stages can be determined. Thus the data in this table represent the requirements for total additional fertilizer production capacity needed in excess of 1965 capacity.

Additional capacities for production of fertilizers are being completed within the developing nations. Capacities exceeding 6 million tons have been announced for construction by about 1970. Some of these have been completed. Some have already been financed and thus will require no additional investment costs. The Subpanel estimates that at least 1½ million tons of the announced capacities to be built are included in this category. Since there is no way to specify which have already been financed, the cost estimates presented by the Subpanel do not make allowance for these accomplishments. In the summary statistics of additional requirements (Tables 14, 15, and 16) the necessary allowance has been made for the additional existing productive capacity.

Present and planned production capacities in western Europe, Japan, and North America exceed the plant nutrient requirements of these countries. Some of this excess is in potash, produced primarily in North America and Europe, which must be exported to consuming areas having no potash reserves. Excesses of nitrogen and phosphate fertilizers now move to developing countries and will be extremely important in helping fill the fertilizer gap until these countries can construct facilities of their own.

Capital Requirements for Increased Fertilizer Production in Developing Countries

Estimates of the amount of capital required to provide the necessary production facilities in the developing countries are calculated from the costs for construction of facilities required to manufacture a given increment of plant nutrient. Allowance must be made also for combining the nutrients into the desired ratios and grades, and for providing storage at the plant, at the railhead, and at the retail outlet.

It should be noted that costs to develop fertilizer production facilities in developing countries greatly exceed those for similar facilities in developed nations. Not only must most of the critical parts of a plant be manufactured in an industrial nation, but it must be erected and operated without the benefit of an adequate supply of skilled labor. In addition, complementary or "grass roots" requirements such as rail spurs, unloading and storage facilities at ports, electricity, and medical and housing facilities often must be provided. All increase costs. Finally, costs will vary greatly among developing nations, and even within a nation.

For the purpose of this report, a detailed itemization of investment costs is shown in Table 8. "Battery limit" is a term used in segregating direct from supporting investment. Strictly defined, it is that continuous line circumscribed around any project or plant that encloses and lies at least 10 feet outside the boundary fences. Battery limit costs include all capitalized expenditures for installations within the project's battery limit. The "grass roots" concept, in contrast, includes the supporting utilities and general facilities that serve the project in addition to the installations within the battery limit. The information used in estimating costs for the battery limits portion of the data in Table 8 was taken from the report by McCune, et al. (2). These itemized costs should be used only as general guides and may well vary in specific instances. For policy guidance, an overall investment cost figure per ton of required plant nutrients might well be substituted. The weighted average investment cost figure per ton of plant nutrients is $500.

TABLE 8.—*Basis of estimating investment costs per ton of plant nutrient*

Item	Estimated Battery Limits		Estimated Grass Roots Cost, Overseas [2]	Rounded to
	U.S.A.	Overseas [1]		
N	$260.00	$338.00	$507.00	$500.00
P_2O_5	150.00	195.00	292.50	300.00
Mixing and storage [3]	50.00	65.00	97.50	100.00
Retail outlet [4]	26.00	34.00	51.00	50.00
Mining phosphate rock (cost per ton of P_2O_5) [5]	------------	------------	50.00	50.00
Mining potash (cost per ton of K_2O) [5]	------------	------------	100.00	100.00

[1] Estimated 30% increase in investment costs for overseas construction.

[2] TVA estimate of 50% increase in investment cost for building a complete fertilizer complex with all necessary facilities overseas.

[3] TVA estimates assume that 50% of the material will be mixed and that regional storage facilities will be required for 50% of annual capacity.

[4] Based on an estimated $20,000 investment cost for a U.S. retail outlet handling 1000 tons/yr. of plant nutrients plus 10% for facilities for pesticides sales and 20% for facilities for the sale of seed.

[5] Total investment for mining the required amount of plant nutrients. A portion of this production capacity will not be built in the regions under consideration; therefore, the entire cost of mining should not be considered in the total cost of the program.

Under normal situations, probably not over 50 or 60 percent of the total investment costs will require hard currency. A portion of the hard currency investment can and will be borne by private industry if a good investment climate and protection against expropriation or destruction are provided.

Supply of Basic Raw Materials

Four basic raw materials are required in the production of fertilizers. These are hydrogen for use in the synthesis of ammonia which is the basic ingredient of nitrogen-containing fertilizers; phosphate rock; potash; and sulfur which is used as sulfuric acid in the manufacture of most phosphate fertilizers. With the possible exception of sulfur, there is an almost unlimited supply of these raw materials although no one country is usually endowed with all of them.

Hydrogen: Practically all of the nitrogen used today in fertilizers is based upon synthetic ammonia. The source of the nitrogen used in the synthesis is the atmosphere and thus is available in unlimited quantities. The principal and cheapest source of hydrogen is natural gas. Other sources are naphtha from which the hydrogen costs about 20 percent more than from natural gas; fuel oil; refinery gases; and electrolysis. Coal and coke, which only a few years ago were the major sources of hydrogen, now are considered uneconomical in comparison with other sources.

The wide choice of hydrogen sources assures that almost any country can become sufficient in the production of nitrogen fertilizers. Production costs in some instances may be prohibitive and it may prove more economical either to import ammonia from countries where natural gas is very cheap or wasted, or to ship natural gas in ocean-going vessels from countries where it is cheap and plentiful. In the foreseeable future no shortage of economic sources of hydrogen is expected.

Phosphate ores: Deposits of phosphate ores of various origin occur in many parts of the world, but only a few can be mined economically under present technologies. The major producing areas are in the United States, Morocco, the USSR, Tunisia, Christmas Islands, and Nauru as indicated from production data given in Table 9. Other less important producing areas are in Brazil, Algeria, Israel, Jordan, North Vietnam, South Africa, Senegal, and Togo. Prospects for large developments exist in Israel, Jordan, Spanish Sahara, West Africa, Peru, and Australia. The possibilities of new discoveries are good since large areas of Africa, Canada, South America, and Asia have not been fully explored.

Known reserves of phosphate ores in the world have been estimated at different times, but it is generally accepted that those which can be mined fairly economically range between 25 and 50 billion tons of ore. One estimate is given in Table 10. Presently these deposits are being mined at the rate of about 60 million tons annually. Even with marked expansion in mining, lack of minable reserves should cause little concern for at least the next century or two. In addition, vast new deposits are being discovered at frequent intervals and further improvements can be made in the recovery of the phosphate from the ores that are mined.

TABLE 9.—*World phosphate rock production and capacity by 1970*

[Metric tons of material]

Country	Production [1] 1960	Production [1] 1964	Anticipated Capacity by 1970 [2]	Other Additional Capacity [3]
North America:				
United States	17,796,000	23,327,000	37,572,000	------------
Western Europe:				
France	36,000	19,000	15,000	------------
Eastern Europe:				
U.S.S.R.	8,000,000	13,000,000	25,000,000	------------
Poland	56,000	60,000	60,000	------------
Latin America:				
Brazil	300,000	127,000	100,000	------------
Chile	20,000	15,000	15,000	------------
Curacao	115,000	102,000	100,000	------------
Mexico	5,000	33,000	35,000	------------
Peru	------------	------------	------------	400,000
Asia:				
Indonesia	7,000	30,000	30,000	------------
Christmas Islands	578,000	861,000	800,000	------------
Jordan	392,000	565,000	2,000,000	------------
Israel	224,000	221,000	1,700 000	------------
China, N. Vietnam and N. Korea	1,320,000	1,900,000	2,500,000	------------
Africa:				
Algeria	524,000	73,000	1,000 000	------------
Tunisia	1,931,000	2,700,000	4,000 000	------------
Morocco	7,506,000	10,095,000	16,000,000	------------
Senegal	80,000	667,000	1,000,000	------------
Togo	------------	778,000	1,000 000	------------
Egypt	558,000	613,000	3,500 000	------------
South Africa	229,000	344,000	600,000	------------
Spanish Sahara	------------	------------	------------	10,000,000
Oceania:				
Makatea	362,000	388,000	350,000	------------
Ocean/Nauru	1,698,000	2,177,000	2,000,000	------------
Total	41,737,000	58,095,000	99,377,000	10,400,000

[1] Production data from International Superphosphate Manufacturers' Association *Phosphate Rock Statistics*, Annual Reports, London.

[2] Capacity estimates from various published sources and communication with industry.

[3] Plants that have not reached the firm planning stage but could be in operation by 1970.

TABLE 10.—*Estimated free world reserves of phosphate* [1]

Continent	Reserves of P_2O_5 (Millions of Metric Tons)
North America	2,000
Europe (exclusive of Russia)	Negligible
Asia	1,000
South America	200
Africa	4,000

[1] International Mineral & Chemical Corporation estimates of mineable reserves under today's economic conditions, allowing for mining and refinery losses.

The major problem facing many developing countries is that no minable deposits occur within their borders. As a result, foreign exchange must be used to purchase the needed ores on the world market.

Potash: Commercially suitable deposits of potash, like phosphate, are limited to a relatively few locations. The major producing countries, as shown in Table 11, are the United States, Canada, France, West Germany, East Germany, U.S.S.R., Spain, Israel, and Italy. Finland, Netherlands, Sweden, Chile, and Peru also produce small amounts. Recent developments indicate that Africa and the Near East can be expected to furnish sizable quantities in the future, and there are possibilities for further developments in Latin America.

TABLE 11.—*World potash production and anticipated capacity by 1970*

[Metric tons of K_2O]

Country	Production [1] 1960	Production [1] 1965 [2]	Capacity July 1, 1966	Total Anticipated Capacity by 1970 [3]	Other Additional Capacity [4]
North America:					
United States	2,303,000	2,700,000	3,851,000	4,767,000	----------
Canada	----------	800,000	1,743,000	4,781,000	1,959,000
Western Europe:					
Finland	----------	[5] 900	900	900	----------
France	1,521,900	1,950,000	1,950,000	1,950,000	----------
West Germany	1,845,800	2,229,000	2,400,000	3,000,000	----------
Italy	11,425	168,500	230,000	590,000	----------
Netherlands	800	[5] 2,500	2,500	2,500	----------
Spain	248,507	325,600	325,600	748,000	----------
Sweden	1,944	[5] [6] 235	235	235	----------
Eastern Europe:					
East Germany	1,644,000	1,757,000	1,984,000	2,400,000	----------
U.S.S.R.	1,040,000	1,800,000	1,875,000	2,400,000	[7] 4,050,000
Latin America:					
Chile	13,964	[5] 25,000	25,000	25,000	----------
Peru	2,185	[5] 9,000	9,000	9,000	120,000
Brazil	----------	----------	----------	----------	120,000
Asia:					
India	960	----------	----------	----------	----------
Israel	75,465	200,000	240,000	480,000	----------
Jordan	----------	----------	----------	----------	300,000
Africa:					
Congo	----------	----------	----------	----------	540,000
Ethiopia	----------	----------	----------	----------	75,000
Morocco	----------	----------	----------	----------	60,000
Total	8,709,950	11,967,735	14,636,235	21,153,635	7,224,000

[1] Production of K_2O as reported by Food and Agriculture Organization, *Fertilizers: An Annual Review of World Production, Consumption, and Trade,* United Nations, Annual Report.
[2] Preliminary estimates by FAO.
[3] Capacity estimates from various published sources and communication with industry. Data for 1970 include only plants that have firm plans for construction.
[4] Plants that have not reached the firm planning stage but could be in operation by 1970.
[5] Byproduct production and organics. Future capacity estimated based on 1965 production level.
[6] 1964 production level.
[7] Based on added capacity necessary to reach production target.

Known reserves of potash in the world are very large, as indicated in Table 12. With present (15 million metric tons of K_2O annually) and anticipated requirements, there seems little likelihood of any shortage developing for several hundred years. However, since minable deposits are limited to a very few countries, most of the world will have to depend on exports from these countries.

TABLE 12.—*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] International Mineral & Chemical Corporation estimates of minable reserves under today's economic conditions, allowing for mining and refinery losses.

Sulfur: Sulfur, unlike the other basic raw materials required for fertilizers, may present a shortage problem. Known reserves of sulfur are less plentiful; and underground deposits suitable for Frasch-type mining, the most economical, are limited primarily to the Gulf Coast areas of Mexico and the United States. Other sources are sour gas (containing hydrogen sulfide) with the major fields being located in Canada, southern France, and the western United States. Sour gas deposits exist also in Iran, Saudi Arabia, Kuwait, Iraq, and Spain. Frasch and sour gas sulfur dominate the world export markets. These sources of sulfur and the production capacity for 1966 and 1970 are shown in Table 13.

Sulfur is mined in nonelemental form, largely as pyrites, in Spain, Italy, Japan, Canada, the United States, and to a lesser extent in many other countries. Nonelemental sulfur also is obtained from stack gases of smelters.

Recently the sulfur supply, particularly from the low-cost Frasch fields, has not kept pace with demand. Considerable activity is developing relative to opening up new off-shore fields in the Gulf Coast area and to the recovery of more sulfur from abandoned fields. Also, as price and demand increase, exploration activities, aimed toward discovery of new Frasch fields, will increase and more sulfur will be recovered from sour gas and pyrites sources. Present indications are

TABLE 13.—*Estimated free world sulfur capacity, 1966 and 1970*

[Long tons of S/year]

Country	Capacity July 1, 1966	Total Anticipated Capacity by 1970
United States:		
Frasch	7,500,000	8,500,000
Recovered	1,335,000	1,599,000
Smelter Gas	[1]	[2] 558,000
Canada:		
Recovered	1,674,000	3,124,000
Smelter Gas	[1]	[2] 634,000
France:		
Recovered	1,500,000	2,200,000
Mexico:		
Frasch	1,825,000	2,731,000
Rest of World:		
Recovered	[3] 1,125,000	2,461,000
Iran	------------	(525,000)
Saudi Arabia	------------	(250,000)
Kuwait	------------	[4] (350,000)
Iraq	------------	(153,000)
Spain	------------	(58,000)
Pyrites, Smelter, Gas & Other	[3] 9,300,000	9,472,000
Sweden	------------	[2] (56,000)
Japan	------------	[2] (116,000)
Total free world	24,259,000	[5] 31,279,000

[1] Included with pyrites, smelter gas and other.

[2] Based on announced sulfuric acid capacity. (TGS plant at Timmons, Ontario, included in U.S. Data because it is believed that sulfur will be used in North Carolina sulfuric acid plant.)

[3] Production level 1965. Literature cited as given by Gittinger (1).

[4] Estimated.

[5] Total does not include estimates for the following Frasch mines which are now being considered and could be producing by 1970:

Hooker Chemical—Bryan Mound.
Phelan Sulphur—Nash Dome.
Allied Chemical—Sulphur Mine.
Standard Sulphur Co.—Damon Mound.
U.S. Sulphur Co.—High Island Dome.
Texas Gulf Sulphur—Gulf Dome.
Duval Corp.—Pecos County.
Jefferson Lake Sulphur—Stewart Dome.

In addition, Texas Gulf Sulphur, Freeport Sulphur, and Esso are engaged in exploration for sulphur in the offshore area of Texas, and exploration in Nova Scotia and Costa Rica have revealed the possibility of Frasch sulfur production. Costa Rica estimates show a possible production level of 300,000 tons per year. (*Sulphur* (*64*)—June-July, 1966.)

that by 1970 supply again may balance demand. However, there is no assurance that low-cost sulfur supplies can continue to meet the increasing demand.

Lack of sulfur does not mean that soluble phosphate fertilizer will not be produced in adequate quantity. Alternative processes are available in which nitric acid can be used instead of sulfuric acid. If the sulfur shortage persists, the nitric acid processes undoubtedly will be improved and used increasingly. The electric furnace process also requires no sulfur.

Credit Requirements of Farmers Buying Fertilizers

Past experience in developed and developing countries has indicated the absolute necessity to provide some form of short-term credit to farmers buying fertilizers (even when fertilizer prices are subsidized). Unless this is done, most farmers will not or cannot use fertilizers. The credit must be made available to farmers at the time they purchase fertilizer, and extended until they sell the crop on which the fertilizer is applied. Usually it is not in the best interest of farmers to sell their crops at harvest when crop prices frequently are at their lowest. For fertilizer to be purchased in adequate amounts by farmers, credit must be extended at minimum cost either through the fertilizer seller or a sound credit institution and not through local moneylenders charging usurious rates. In some countries such as the Republic of China, barter arrangements have proven desirable. Under these arrangements the farmer gives an agreed-upon amount of product at harvest in payment for the fertilizer he uses. This method of payment requires that the fertilizer producer or dealer be prepared to store and market the produce of his farmer fertilizer customers.

For retail prices of $260 per metric ton of solid nitrogen (N), $200 per metric ton of P_2O_5, and $100 per metric ton of K_2O, which are roughly the United States retail prices, the short-term credit needed to purchase the required nutrients shown in Table 3 for approximately a 4–2–1 plant nutrient ratio would be as indicated in Table 14. In arriving at these credit requirements, it should be recognized that retail prices of fertilizers to farmers vary widely between regions and countries depending on procurement costs, transportation, and amount of subsidy. Actual subsidies range from none to as high as 50 percent of the cost of fertilizers. Most countries provide subsidy of from 10 to 20 or 25 percent. Under this wide range of situations, the United States prices, although frequently lower than in most countries without subsidies, seemed about as satisfactory as any to use for this estimate.

TABLE 14.—*Estimated additional requirements for farmer credit*

Approx. Year	Percent Increase in Agricultural Production	Metric Tons of Nutrients (000's)	Billions of dollars	
			Approximate Cost of Fertilizer	Credit Required [1]
1966	--------------	6,000	1.3	.65
1970	10	11,000	2.4	1.20
1975	26	19,000	4.2	2.10
1980	43	28,000	6.2	3.10
1985	63	40,000	8.8	4.40
----------	100	67,000	14.8	7.40

[1] Based upon one-half of retail cost of fertilizer to farmers.

Actual prices paid by farmers in different countries have been compiled by FAO.[1]

It should be noted that these credit requirements refer solely to farmer credit. Additional amounts of credit may be required to cover inventories of finished fertilizer materials—the working capital for producers and wholesale distributors. If these additional credit requirements were included, it would increase the total credit requirement by 50 to 75 percent. It must be emphasized that the credit requirements are not outlays of cash but should be considered as a type of loan fund.

Requirement for Skilled Manpower

There is no definite answer as to the numbers of skilled and unskilled workers required to operate a fertilizer industry in a developing nation. Individual plants vary greatly in size, type, and efficiency. Also, public sector industries in developing countries are noted for their extravagant use of manpower as compared to private industry.

For purposes of this study, the following estimates were made of the manpower requirements needed to produce and provide wholesale and retail distribution of the additional fertilizer requirements:

Production	Skilled	Unskilled
Production	1	1
Wholesale distribution	1	1
Retail distribution	1	3
Total	3	5

On this basis, the number of personnel required to meet the estimated increased requirements for plant nutrients are given in Table 15.

TABLE 15.—*Estimated requirements for additional skilled and unskilled workers*

Approx. Year	Percent Increase in Agricultural Production	Metric Tons of Nutrients (approx. 000's) [1]	Approximate Number of Workers	
			Skilled	Unskilled
1970	10	5,000	15,000	25,000
1975	26	13,000	39,000	65,000
1980	43	22,000	66,000	110,000
1985	63	34,000	102,000	170,000
---	100	61,000	183,000	305,000

[1] Assuming productive capacity in 1965–66 period at approximately 6 million tons.

To operate a fertilizer plant, three-fourths of the skilled personnel probably can be adequately trained to an operating level in six months,

[1] FAO, in "Fertilizers, Annual Review," 1965.

if they have the equivalent of a high school education, providing there is an existing plant for training purposes. The remaining one-fourth would require college level people having practical experience in a fertilizer plant.

Within the wholesale distribution function, most of the skilled people should have training equivalent to the college level. Approximately one-half should be trained in agribusiness, one-fourth in chemical engineering to give attention to technical problems relating to the handling and storage of fertilizers, and one-fourth with knowledge of transportation and logistics.

For retail distribution, the majority of the people should have at least a high school level of education with practical and intimate knowledge on the use of fertilizers on farms. These would be the men giving practical advice to the individual farmer, arranging for distribution, and possibly arranging for credit. These men would also serve as specialists for seeds and pesticides.

Lack of skilled manpower, more than anything else, will impede the development of fertilizer industries and the wise use of fertilizer in developing countries.

Summary and Comments on Fertilizers

The projections summarized in Table 16 must be considered as very rough estimates; however, they are believed to be realistic for conditions existing in the developing countries. A number of the estimates could be refined if more time were available. It is expected that the United Nations will publish data within the next year projecting fertilizer needs and these should be more refined than the ones given in this report.

TABLE 16.—*Summary of additional requirements of developing nations for required increase in plant nutrient use*

Year	Additional Plant Nutrient Requirement [1] (000 tons)	Capital Needed [2] (billion $)	Additional Farmer Credit (billion $)	Additional Skilled Personnel (000's)
1966			.65	
1970	5,000	2.5	1.20	15
1975	13,000	6.5	2.10	39
1980	22,000	11.0	3.10	66
1985	34,000	17.0	4.40	102
	61,000	30.5	7.40	183

[1] Allowance has been made for an estimated 1.5 million tons' capacity completed and/or financed during 1966 and rounded to the nearest thousand tons. Thus, requirements may vary from former tables.

[2] Based upon a weighted average cost of $500 per ton of total plant nutrients.

The timing of actions required if the increased fertilizer program is to be successful cannot be overemphasized. The investment cost requirements as set forth herein must be met within certain time periods. For example, to increase food yields by 25 percent, a requirement to be met by early 1970,[2] the total additional investment cost requirements are estimated at an approximate $2.5 billion. This *does not* mean that there should be this amount of investment available for 1970. It *does* mean that this amount should have been invested *prior* to 1970 and the resulting facilities should be on stream and operating at full capacity by that date.

In developed countries not less than a three-year period is required to plan, design, construct, and bring on stream a facility. In developing countries this process usually requires no less than five years. In short, it is already too late to start planning for and making finances available for projects designed to furnish fertilizer product for the crop year 1970. It is not too early to start planning for 1975.

The physical facilities needed to meet the fertilizer requirements of developing countries can be provided if adequate capital is made available and if conditions are made favorable for private investment. There is abundant evidence to show that the chemical industries of developed nations are quite willing to make investments in fertilizer production in developing countries if a satisfactory return on investment is possible and risks of expropriation and destruction are minimized.

Obtaining the necessary skills and trained personnel to operate the fertilizer plants is entirely another matter. There must be provided or the plants will not produce the amounts of fertilizers for which they were designed or operate at a competitive cost.

Getting the fertilizer, once it is produced, into use by the farmer presents major problems. A good marketing system is needed which will assure that farmers can obtain fertilizers when and where needed. Trained personnel are needed to provide educational and technical service to farmers at the village level. Such service must include not only advice on the use of fertilizers, but also on seeds, pesticides, and related practices. This will require men who will go to the farmers rather than wait for the farmers to come to them.

The marketing organization will need to work closely with the agricultural credit agencies, and may, in fact, handle part of the credit. Further, the credit must be provided at reasonable cost and for a period of time sufficient for the former to market his produce.

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[2] At least 25 percent increase in food needs is anticipated for Brazil, India and Pakistan before 1975. See Volume II, Chapter I, "The World Food Problem" PSAC Study of the World Food Supply, May 1967.

Policies must be set and adhered to which will assure that the farmer can purchase fertilizer at reasonable cost and in return receive a reasonable price for his products. Unless there is sufficient margin between returns and costs, probably five to one initially for fertilizers, farmers will not use fertilizer regardless of the amount of coaxing.

It must be recognized that in many developing nations, severe fertilizer deficits will exist until plants can be brought on stream. In these cases, care should be exercised to import the same kinds of fertilizers that will eventually be produced in the country. For example, no country is likely to base most of its nitrogen production on ammonium sulfate. Yet this is the only kind of nitrogen fertilizer now being sold in quantity in many of them because ammonium sulfate already is outmoded and in surplus in developed countries. Smaller countries with limited agricultural potential may not be able to support economically-sized fertilizer plants, at least initially. It would seem desirable for neighborhood countries to share the output of economically-sized units and not try to develop a complete fertilizer complex within each country until demand has grown sufficiently to support the large-scale, efficient plants.

Need for Liming Materials

Closely associated with but separate from fertilizers are liming materials. Lime is likely to be needed on soils in areas where more than 30 inches of rainfall are received annually. Application of lime on acid soils is essential to high yields of most crops since soil acidity limits yields and also effectiveness of fertilizer nutrients, especially phosphorus. Rates of application up to 4 or more tons per acre are common. Quantities of this order of magnitude are difficult to transport and apply using the primitive methods usually found in developing countries.

Calcic limestone or dolomitic limestone are the most frequently used materials to decrease 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 considerable distance from soil areas where needed. Principal difficulties are (1) grinding limestone to a fineness required to ensure effectiveness, (2) transporting to the area where acid soils occur and (3) applying to the soil.

An energetic educational and demonstrational program would have to be conducted in many cases to convince farmers who are engaged in traditional agriculture to adopt good liming practices. To illustrate the magnitude of this problem, the educational efforts that have been conducted in the United States over a relatively long period of time have resulted in use of only 50 percent of the total amount of lime actually needed.

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INPUTS FOR SEED

By Richard F. Holland, DeKalb Agricultural Association, Inc.

This report assesses the present status of seed production and distribution in Latin America, Asia, Africa, Europe, and Oceania. Examples of results obtained through the use of improved crop varieties are given and problems and potentials are outlined.

Present Status

The use of improved crop varieties has a major effect on yields per acre. The countries with the most favorable factors for production and distribution of improved varieties and consequently the greatest proportion of crop acreage in improved varieties have shown the greatest yield increases (Table 1).

Additional information on the use of improved varieties of wheat, rice, and cotton in selected countries in 1964 is given in Table 2. Several countries have a favorable climate for the development of commerce in seed of improved varieties and this has resulted in a large proportion of the crop area being planted to improved varieties.

Another indication of the effect of the use of seed on improved varieties is shown in Table 3.

Countries that have adapted improved varieties and that have favorable climate for seed commerce have shown dramatic yield increases in production while other countries have shown very small increases or in some cases a decline in production.

Dr. A. H. Moseman, formerly of AID, has declared that the nine maize hybrids adapted to conditions in India that have been released since 1961 have the possibility of resulting in doubling the production of corn in the country in the next five years if only 50 percent of the maize acreage can be planted with improved seed. Similarly, sorghum hybrids that are being released in India could increase production by

TABLE 1.—*Relationship between seed status, proportion of crop area in improved varieties, and crop yield changes for rice, wheat, and maize, selected countries, 1948–62*

Commodity & country	Seed status [1]	Proportion of crop area in improved varieties	Yields per hectare 1948–52	Yields per hectare 1960–62	Yields per hectare Change
Rice:	*Rating*	*Percent*	*100 Kg/Ha*		*Percent*
Japan	1	100	40.0	50.5	26
Taiwan	1	95	19.1	25.4	33
Venezuela	2	90	11.4	15.1	33
Chile	3	65	29.0	27.0	–7
UAR	3	35	37.9	52.8	39
Pakistan	4	5	13.8	15.9	15
Iran	4	3	19.3	19.6	2
Wheat:					
Japan	1	100	18.5	26.1	41
Netherlands	1	100	36.5	43.8	20
Mexico	1	85	8.8	16.7	90
Chile	2	80	11.9	13.7	15
Pakistan	2	7	8.1	8.1	–7
UAR	3	30	18.4	25.1	36
Colombia	3	20	7.2	9.1	26
Iran	3	10	9.0	7.8	–13
Jordan	4	15	7.0	5.4	–23
Maize:					
Venezuela	2	20	11.4	11.0	–4
Pakistan	2	8	9.8	10.0	2
Chile	3	50	13.8	20.7	50
Colombia	3	20	10.7	11.2	5
UAR	3	7	20.9	24.1	15

[1] Index of present efficiency in the chief factors influencing development production, distribution, and use of better seeds, using rating of 1 to 4 with quality highest for rating of 1.

Source: Statistics Division, FAO, Rome, and special FAO "Seed Status" inquiry.

TABLE 2.—*Rating of seed status of wheat, rice, and cotton in certain countries, 1964* [1]

Crop and commodity	Plant breeding [1] (a)	Use of improved varieties (b)	Production of improved seed (c)	Seed certification (d)	Seed testing (e)	Seed distribution (f)	Seed laws (g)	Area under improved varieties percent (h)
Wheat:								
Argentina	2	2	1	1	1	1	1	100
Mexico	1	1	2	3	3	2	2	98
Poland	1	1	1	1	1	1	1	90
Yugoslavia	1	1	1	1	1	1	1	50
UAR	2	2	3	3	3	3	5	30
Jordan	3	3	4	5	4	4	5	15
Tunisia	1	1	1	1	1	1	1	100
Turkey	2	2	2	2	2	4	2	35
Pakistan	2	2	2	2	2	2	5	7
Iran	3	3	3	4	4	3	4	10
India	2	2	3	5	4	2	5	44
Netherlands	1	1	1	1	1	1	1	100
Rice:								
Argentina	2	2	2	1	1	1	1	90
Costa Rica	1	1	1	3	3	2	3	33
Venezuela	2	2	4	2	2	2	2	90
UAR	3	3	3	3	3	3	5	35
Pakistan	4	3	4	4	4	4	5	5
Iran	2	4	4	4	5	4	4	1
India	2	2	3	5	4	2	5	37
Cotton:								
Costa Rica	2	3	3	3	3	3	3	75
Venezuela	2	2	3	2	2	2	2	90
Yugoslavia	3	3	1	1	1	1	1	100
UAR	1	1	2	3	3	2	4	80
Pakistan	2	2	2	2	2	2	3	75
Iran	3	3	3	4	4	3	4	20
U.S.A	1	1	1	1	2	1	2	90

[1] The ratings 1, 2, 3, 4, and 5 designate excellent, good, fair, poor, and none, respectively. The following criteria were considered by plant scientists when they replied to each of 8 questions asked in the survey:

a. *Plant breeding:* an appraisal of local breeding facilities for the crop concerned, including experimental stations and institutes, professional staff, and the quality of the work done by the professional staff.

b. *Improved varieties:* availability of improved varieties, locally bred or imported, ready for commercial use.

c. *Seed production:* facilities available to provide commercial quantities of improved seeds. This includes state farms, private farms, cooperatives for seed multiplications, and facilities for processing and storing seed.

d. *Seed certification:* an appraisal of existing official organizations specially concerned with supervising seed production by certification schemes.

e. *Seed testing:* existing control of seed quality during production process, including an appraisal of seed testing laboratories.

f. *Seed distribution:* organization of the method of seed distribution from the breeding station to the farmer.

g. *Seed laws or regulations:* an assessment of the effectiveness of existing laws or regulations relating to seed; (if no laws were in existence, a status rating of zero was given).

h. *Area under improved varieties:* latest estimate (in percentage of total crop).

Source: Special survey made for ERS, USDA, by FAO, Rome, 1964.

TABLE 3.—*Yield changes of selected crops resulting from use of new and improved varieties, selected countries, 1948–62*

Country	Crop	Seed status [1]	Proportion of crop area in new or improved varieties	Yields per hectare		
				1948–52	1960–62	Change
		Rating	*Percent*	*100 kg.*	*100 kg.*	*Percent*
Taiwan	Pineapple [2]	1	100	[3] 97.3	[3] 174.7	80
	Sugarcane [4]	1	100	[3] 64.4	[3,5] 97.5	51
Israel	Sorghum [6]	1	95	[3] 6.6	[3] 21.1	220
Venezuela	Sugarcane	2	95	[3] 100.0	[3] 486.0	386
Colombia	Maize	3	20	[7] 10.7	[7] 11.2	5
Pakistan	Jute	4	5	[7] 14.2	[7] 15.0	6
	Chick-peas	3	25	[7] 6.1	[7] 5.4	−12
Venezuela	Coffee	2	10	[7] 1.5	[7] 1.7	13
	Maize	2	20	[7] 11.4	[7] 11.0	−4

[1] An index measuring existing efficiency in the chief factors influencing production, distribution, and use of better seeds, using rating of 1 to 4 with quality highest for rating of 1.

[2] 64 per cent of pineapple area was in Smooth Cayenne in 1950, compared with 100 per cent in 1959.

[3] Mainly new varieties.

[4] Introduction of N:Co 310 strain was made in 1951–52; 91 per cent of the crop was in this variety by 1956–57.

[5] White sugar.

[6] Native strains have been almost completely replaced by crossbreed Hazera 610 in most areas on unirrigated land.

[7] Mainly unimproved varieties.

Source: Statistics Division, FAO, Rome.

25 to 50 percent in five years if grown with improved cultural practices. Hybrids or pearl millet have similar potential for India. Dr. Moseman also stated that adapted, improved crop varieties of most of the principle food grains can be made available for almost any part of the world within a period of six years if proper attention is given to the necessary adaptive research. He indicated that this should be possible in breeding improved corn hybrids or synthetic varieties. Dr. Norman Borlaug, Head of the International Wheat Improvement Project of the Rockefeller Foundation, is convinced that average wheat yields on 12 million acres in Pakistan can be doubled within five years.

There are two outstanding examples of what can be accomplished with dynamic adaptive research programs and corresponding usage of improved varieties. In 1943, a wheat improvement program was initiated in Mexico. At that time, the average wheat yield was 11 bushels per acre. By 1964, yields had increased to 37 bushels per acre, a 3.5-fold increase, and Mexico had a surplus of wheat. Mexico not only has increased yields, but they are training young scientists and loaning these men to other countries. A necessary part of this dramatic increase in wheat production was the recognition and corresponding use of better cultural factors, fertilizer and irrigation.

Kenya provides another example of dramatic yield increases through a similar program of adaptive research and seed production with maize. A varietal hybrid between a local maize variety and a Central American type increased yields 50 to 100 percent above the widely grown local variety. Along with the seed, fertilizer and insecticide are provided to the farmer, and even though the seed supply has been doubled each year, the supplies never equal the demand.

It is apparent that the potential for increased yields per acre can be realized, but it also is apparent that production and distribution of improved varieties must be handled correctly in order to realize the maximum benefits.

Seed Production and Distribution

The production and distribution of seeds are vast and complex undertakings when considered on a global scale. The production of seed for each species and even for different varieties within a species requires special skill, knowledge, and unique equipment.

At the present time, seeds of agricultural and horticultural crops are distributed by various means. Private enterprise in the seed trade is the main outlet in some countries while distribution by co-operative societies, government agencies, or direct distribution from farmer to farmer is important in other areas.

The production of improved varieties starts with the plant breeder's development of an improved hybrid or variety, and continues with the seed producer providing essential quality control and, finally, effective distribution to the ultimate consumer—the farmer. The technical factors involved in the production of seed have been studied and excellent publications have been prepared. This can be obtained from the Food and Agriculture Organization of the United Nations, and the United States Department of Agriculture. In the case of the latter, the 1961 Yearbook of Agriculture is a useful document.

Several factors are unique to the seed business, whether private or public. Seed is a semi-perishable product and care must be exercised in its storage and distribution. To maintain high quality and capacity for germination, seed is usually produced in areas with low relative humidity which may necessitate production of seed some distance from the area of actual use. Vegetable seed production requires special environmental conditions and vegetable seeds frequently are transported long distances. Usually one crop a year is produced which gives a 12-month cycle between planting and use of seed and ties up the capital of the seed handler for long periods of time. Seed is bulky and has a relatively low value per pound, which tends to discourage seed production in one country for use in other countries. Seed is also unique in that the appearance of seed to a farmer cannot be used as an indicator of quality. A great deal of faith must be placed in the seed handler because results will not be known until the crop is grown. In most countries certification and labeling laws have been established to protect the consumer against fraud.

Seed Requirements and Cost

Reliable data are not available for determining exact seeding requirements for different crops in individual countries. The experiences of seed companies can be used to estimate average seeding rates and total seed requirements. Table 4 gives the area planted, total production, average yield per acre, average seeding rate, and total seed requirement for cereals, oil seeds, pulses, and sweet potatoes and yams for different regions of the world. Average seeding rates vary widely for different crops, but an attempt has been made to develop an estimate by weighting seeding rate with area planted for each species.

TABLE 4.—*Area, production and seed requirements for certain crops and regions, 1964–65*

Regions	Area planted (million hectares)	Total production (million metric tons)	Yields 100 kg/ha.	Average seeding rate kg/ha.	Total seed requirement (million metric tons)
Cereals: [1]					
Latin America	43.3	58.8	13.6	40	1.9
Asia	187.6	234.7	12.5	55	10.3
Africa	55.3	48.2	8.7	30	1.6
Europe	71.2	159.2	22.3	140	10.5
Oceania	9.9	13.4	13.5	80	0.9
Oilseeds: [2]					
Latin America	10.6	7.3	6.9	25	0.3
Asia	31.1	16.0	5.1	25	0.9
Africa	10.5	7.1	6.8	25	0.3
Europe	2.6	3.0	11.5	25	0.1
Oceania	0.1	0.1	10.0	25	0.003
Pulses: [3]					
Latin America	6.0	3.5	5.8	75	0.5
Asia	21.9	9.5	4.3	75	1.7
Africa	2.8	2.1	7.5	75	0.2
Europe	6.0	2.7	4.5	75	0.5
Oceania	----------	----------	----------	----------	----------
Other: [4]					
Latin America	1.7	11.9	70.0	75	0.1
Asia	2.9	29.5	101.7	100	0.3
Africa	2.9	19.6	67.6	70	0.2
Europe	8.4	141.7	168.7	250	23.3
Oceania	----------	----------	----------	----------	----------

[1] Wheat, rye, barley, oats, maize, millet and sorghum, rice.

[2] Soybeans, groundnuts, cottonseed, linseed, rapeseed, sesame, sunflower seed.

[3] Dry beans, dry peas, dry board beans, chick-peas, and lentils.

[4] Potatoes, sweet potatoes and yams.

Basic data from Production Yearbook, FAO, Rome, Vol. 19, 1965 and Agricultural and Horticultural Seeds, FAO, Rome, 1961.

Average seeding rate and total seed requirement extrapolated from existing data. Data shown has been weighted by average area planted to different species of each group.

275-253 O—67——10

From the average seeding rate, total seed requirements can be estimated from the total area seeded.

For cereal crops, three to five percent of total production is needed to replant the next crop. For oilseeds, four to five percent is used but in pulses, the amount needed to plant a new crop averages 15 percent of the production. The average planting rate of potatoes for the different regions included in this study varies between 10 and 15 percent.

A ten percent loss for clean-out and handling has been added to the total seed requirement figures. Experience shows that at least this amount of seed is cleaned out and lost in the handling processes.

In Table 5 the actual costs are given for processing plants erected by the DeKalb Agricultural Association in India and Argentina. The plant in India has a capacity of 3,000 metric tons per year, while the one in Argentina can handle 5,000 metric tons. These are small plants, but have sufficient capacity to operate efficiently, and do provide actual examples of the cost of constructing processing plants in foreign countries. Land costs are extremely high in India which is a major factor in the capital outlay for a seed processing plant. Otherwise, the costs for building, machinery, and equipment are comparable in the two countries.

TABLE 5.—*Cost of seed processing plant*

[U.S. dollars]

	India (3,000 metric tons capacity)	Argentina (5,000 metric tons capacity)
Land	$20,000	$2,500
Buildings	92,900	106,600
Machinery and equipment	95,600	113,931
Total	208,500	223,031

In Table 6, the costs of producing hybrid corn and a synthetic variety of corn are compared in three countries. Part of the data are derived from actual experience, while some are calculated from market price and an estimate of the extra cost of production, certification and handling. In the calculations, a contribution of 15 percent of sales for educational activities and profits has been added. Educational activities include cost of demonstration plantings, and advisory services for improved cultural practices.

One unique feature of any seed business is the necessity of purchasing seed from the contract seed grower and holding this seed until it is delivered to the farmer at planting time. Usually this seed is held by the company for about six months and the Table 6 shows interest charges that can be expected as a result of holding seed for that period of time. Interest is based on a rate of 8 percent. In most of the developing countries, it is very difficult to obtain interest at this rate; bankers will typically ask 20 to 25 percent interest because of inflationary pressures. It is also common for seedsmen not to be able to obtain loans at any price for buying and holding seed since the seed industry is a relatively small part of the economy.

Losses in storage, bag breakage, and miscellaneous losses to insects or rodents are included in Table 6. These losses usually average about 5 percent.

In addition, a charge has been included for the overhead expenses such as taxes, administration, and licenses.

TABLE 6.—*Examples of seed costs for hybrid corn and corn variety for three countries*

[U.S. dollars per metric ton]

	India		Argentina		Italy	
	Hybrid	Variety	Hybrid	Variety	Hybrid	Variety
Production and warehousing	216	160	150	68	168	116
Marketing and distribution	71	71	40	40	96	96
Educational activities and profits (15%)	48	39	35	23	43	36
Interest (purchase of raw seed and storage—6 months)	9	6	6	3	7	5
Losses in storage, breakage, misc. (5%)	10	8	8	3	8	2
Overhead (taxes, administration, licenses)	30	30	44	44	31	31
Total	384	314	283	181	350	286
Ratio—market price: seed price	1:4	1:3	1:7	1:4	1:5	1:4

The costs and ratios in the above table should be considered minimum figures because no attempt has been made to include the important expenses of adaptive research, if this is to be performed by the seed firm, or the initial cost of "getting started." A vital part of the initial expense is obtaining the capital required to build the processing plant.

The costs of research and development as performed by private industries in the United States and Europe would add approximately 10 percent to the price of seed. Additional "getting started" expenses would be incurred also to build research facilities and to purchase land for research and development work.

The ratio of market price to seed price (Table 6) could increase to 1 : 7 or 1 : 8 for hybrid crops and 1 : 4 or 1 : 5 for non-hybrid crops when all costs are included, but the ratios are typical of many private and co-operative seed enterprises. A ratio of market price to seed price is, of course, influenced a great deal by the market price of the crop that is being grown. For instance, the price of corn in India is very high at the present time. The ratio of market price to seed price could be low and still provide an adequate profit for the seed firm.

The costs by regions of supplying seed of the major food crops are given in Table 7. The average market price to seed price ratio for corn is used to estimate seed cost for other cereals, oilseeds and pulses. This in turn is weighted by the area planted to the different crops in the regions indicated. The costs of supplying enough seed to plant 10, 25, 50, and 100 percent of the crop area are given also.

TABLE 7.—*Cost of supplying total seed requirements of cereals, oilseeds, and pulses*

	Total seed requirement (million metric tons)	Seed cost [1] (U.S. dollars per metric ton)	Percent of requirement supplied (millions of U.S. dollars)			
			10	25	50	100
Latin-America	2.7	360	97.2	243.0	486.0	972.0
Asia	12.9	328	423.1	1,057.8	2,115.6	4,231.2
Africa	2.1	315	66.2	165.4	330.8	661.5
Europe	11.1	260	288.6	721.5	1,443.0	2,886.0
Oceania	0.9	251	22.6	56.5	113.0	225.9
Total	----------	----------	897.7	2,244.2	4,488.4	8,976.6

[1] Figure calculated by using ratio of market price to seed price for corn and weighting cost by area planted in different regions. Price for cereal seed—$251 metric ton; pulses—$601; oilseeds—$554.

A large proportion of the area in Europe and Oceania is already planted to improved varieties while lesser amounts are planted to improved varieties in Latin America, Asia, and Africa.

Knowledgeable people have estimated that yields can be increased 50 to 100 percent if only half of the acreage in the developing countries are planted to better seed varieties that are available now. A reasonable assumption would be that no more than 50 percent of the acreage in Asia, Africa, and Latin America could be expected to be planted to improved crop varieties purchased from seedsmen by the year 2000. A larger percent of the acreage in Europe and Oceania, at least 85 to 90 percent, is already planted to improved varieties. If 25 percent of the seed requirements are supplied by seed organizations, outside the farm where the seed is to be used, it would be reasonable to expect that 50 percent or more of the acreage would be seeded to improved varieties because farmers typically save and trade a large amount of seed.

The number of seed plants, the capital required for building these plants, and the annual operating expenses have been estimated for supplying the required seed to plant 10, 25, and 50 percent of the acreage to improved seeds of cereals, oilseeds, and pulses (Table 8).

TABLE 8.—*Number of plants, capital expenditures, and operating costs for supplying seed of cereals, oilseeds, and pulses for 10%, 25% and 50% of the area shown*

[Capital costs and operating expenditure are in millions of U.S. dollars]

	10 percent			25 percent			50 percent		
	No. plants[1]	Capital[2]	Annual Operating[3]	No. plants	Capital	Annual Operating	No. plants	Capital	Annual Operating
Latin America	90	15.8	97.2	225	39.4	243.0	450	78.8	486.0
Asia	430	89.9	423.1	1,075	224.6	1,057.8	2,150	449.4	2,115.6
Africa	70	14.6	66.2	175	36.6	165.4	350	73.2	330.8
Europe	370	83.2	288.6	925	208.1	721.5	1,850	416.2	1,443.0
Oceania	30	6.8	22.6	75	16.9	56.5	150	33.8	113.0
Total	------	--------	--------	------	--------	--------	------	1,051.4	4,488.4

[1] 3,000 metric ton annual capacity.
[2] Initial cost of plant (20-year life expectancy).
[3] Cost of labor, seed, bags, tags, upkeep, 15 percent profit, marketing, distribution, and administration.

Plant and Manpower Requirements

An estimate has been made of the technical and unskilled personnel required to operate an average-sized seed plant. These estimates are given in Table 9.

TABLE 9.—*Manpower required for operating a 3,000 metric ton capacity processing plant*

	Technical	Unskilled
Production and warehousing	2	5
Marketing and distribution	5	3
Administrative	2	2
Total	9	10

The manpower requirements and the number of processing plants can be estimated from the total seed requirements, for plants with a capacity of 3,000 metric tons. We assumed that not more than 50 percent of the acreage will be planted with seed supplied by seedsmen. Table 10 shows the number of plants and the number of technicians required to operate the plants if 10, 25, and 50 percent of the seed requirements are supplied.

TABLE 10.—*Technical manpower requirement for supplying seed to plant 10, 25, and 50 percent of the area of cereals, oilseeds, and pulses*

Region	10 percent		25 percent		50 percent	
	No. plants	Technicians	No. plants	Technicians	No. plants	Technicians
Latin America	90	810	225	2,025	450	4,050
Asia	430	3,870	1,075	9,675	2,150	19,350
Africa	70	630	175	1,575	350	3,150
Europe	370	3,330	925	8,325	1,850	16,650
Oceania	30	270	75	675	150	1,350

If the seed firms conduct research and development for new and improved crop varieties at their own expense, this would require approximately 10 percent more technical manpower. The technically trained people operating the seed firm can also exert considerable influence in promoting improved cultural practices through their contacts with seed growers as well as their contacts with customers.

Successful seed firms in Europe and the United States could be major factors in training the technical manpower needed to operate the seed firms in the developing countries. Through the use of their existing facilities, they could effectively train personnel in the skills required to produce, process, and distribute seed. Agricultural universities, of course, must train the men in the basics of agronomy. A man with reasonable knowledge of agronomy can be trained in a fairly short time in the rudiments of producing and handling seed.

Training would have maximum effectiveness if it were conducted in the country in which the seed were produced. Possibly, private or co-operative seed firms should be encouraged to place pilot seed operations in some of the developing countries, with the stipulation that these firms train as many persons as possible.

No estimate of the number of processing plants, costs, or manpower requirements is included for production of vegetable and tuber crops because data are inadequate. The production of improved seed for these crops would, of course, add to the magnitude of the task.

No shortages of machinery and equipment for equipping seed plants are anticipated if adequate planning and lead time are given to the machinery manufacturers. Equipment for handling and processing seed is not too complicated and simple machinery can be made available quite rapidly. In many cases, the necessary equipment is available in the developing countries.

Conclusions

1. The use of improved varieties and quality seed can increase yields greatly. Countries with favorable factors for the development of seed

commerce produce higher yields and use greater quantities of quality seed than countries with an unfavorable climate.

2. Producing, handling, and distributing seeds require a medium-sized initial investment, but turnover of capital is slow and seed is semi-perishable. Adequate long-term financing is essential.

3. The maximum benefit from the use of good seed will be realized when combined with the use of fertilizers, pesticides, and adequate farm equipment.

4. A large number of plants for handling seed and a considerable number of technical personnel will be required to produce and distribute seeds of the major food crops.

5. If 50 percent of the acreage is seeded to improved varieties, it is reasonable to expect a 100 percent increase in yield. It is also reasonable to assume that 50 percent of the acreage would be seeded to improved varieties if only 25 percent of the seed moves through regular commercial channels.

6. The following actions should be taken in the developing countries if they are to realize maximum benefits of improved seeds:

a. Promote an awareness of the value of quality seed of improved varieties in countries with inadequate seed industries. A clear commitment must be made by the government concerned since this type of development tends to be downgraded by more glamorous projects.

b. Seed laws and regulations should be developed to allow for maximum development of private enterprise. Government restrictions should be limited to the protection of the consumer against fraud. No attempt should be made to control pricing, supply, or variety used. Seed produced by public agencies must be realistically priced.

c. Plant quarantine regulations should not be allowed to discourage importation of germplasm and varieties.

d. Monopolies should not be allowed to develop—either public or private. There are many examples of failures in which governments try to monopolize or overly restrict private development.

e. A concentrated and sustained effort should be made to train agronomists for producing, distributing, and marketing seeds. Private companies should be encouraged to develop seed plants and train personnel through their existing operations. Many companies have subsidiaries, or more typically, partnerships with local firms at the present time which could be used as a logical base to extend knowledge and experience to many areas.

INPUTS FOR PESTICIDES

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Importance of Pest Control to Food Production

A large complex of pest species share man's requisites for food. Among his most successful competitors for vital requisites are species of viruses, bacteria, fungi, and protozoa; nematodes; mites, ticks, and insects; weeds; and vertebrates, especially birds and rodents. Crops and livestock are under continuous attack by various species of these organisms during all stages of their growth, development, transportation, and storage. The direct loss of food as a result of their combined attack has been impossible to estimate with an accuracy that is generally acceptable. For example, estimates presented at a symposium held in early 1966 varied by as much as 100 percent. Nevertheless, it is generally recognized that the overall impact of losses from the complex of agricultural pests is a major factor in limiting yields of crops and livestock throughout the world, and that the continued development of human society will be seriously handicapped if the losses are not reduced.

Pests compete with man for water, mineral nutrients, light and space, as well as for plant and animal food. Pests also parasitize humans, domestic animals, and wildlife and damage their health. Pests cause losses in: (*a*) productivity and efficiency of land use; (*b*) crop quality; (*c*) efficiency of water management; and (*d*) human efficiency. Weeds harbor diseases, insects, and nematodes which damage crop plants and insects harbor and transmit diseases to plants, animals, and man.

The range of annual losses in production of food crops in the United States from 1951 to 1960 was 2 to 38 percent due to plant diseases, 2 to 31 percent due to insects, 2 to 8 percent due to nematodes, and 3 to 25 percent due to weeds. In spite of advanced farming technology and mechanized methods of crop production, it has been estimated that pests reduce agricultural production in the United States by at least 30 percent annually.

The annual loss in the United States from infectious and noninfectious diseases of cattle, sheep, swine, and poultry has been estimated at about $1.52 billion. Another one-third billion dollars is lost due to external parasites. When the cost of drugs and treatment is added to this $1.85 billion, losses are even more impressive, amounting to about 11 percent of our total livestock production.

Detailed data on the nature and extent of losses caused by pests in foreign countries are largely unavailable but indications are that the overall loss in developing countries is greater than in the United States. According to FAO estimates, preharvest losses to food and industrial crops due to insects and diseases in 11 developing countries of the Near East Region are equivalent to 23 percent of the crop production. In South Africa, losses in sorghum yields due to plant diseases have recently averaged about 1 million tons a year. The average losses in potato yields due to late blight in Chile have been estimated at about 23 percent per year. Plant diseases have caused severe losses of cocoa in Ghana and Nigeria. Rust disease epidemics in coffee frequently cause losses of as much as 80 percent of total production in Ceylon, 70 percent in South India, and 30 percent in East Africa.

In the Philippines an original planting of 250,000 coconut trees was reduced by a disease epidemic to only 80 trees which produced fruit. In São Paulo, Brazil, 4.5 million out of 6 million citrus trees were killed by a virus disease in 1949. Surveys in Latin America during 1965–66 showed that 50 percent of the bean crop and 40 to 50 percent of the cantaloupe crop were killed by plant diseases; corn rust caused a 60 percent loss in corn production.

The devastating effects of plant diseases can be clearly demonstrated by the reductions in wheat yields due to stem rust. In spite of the long history of research on the pathogen and the development of a series of varieties of wheat resistant to stem rust, the new race of the disease organism, 15–B, which first appeared in commercial wheat fields in 1950, built up to massive proportions in 1953 and 1954 when 60 and 75 percent, respectively, of the potential durum wheat crop in the United States was destroyed.

The losses caused by insects, weeds, nematodes, and other pests have been equally striking.

Approximately 250 animal pests of crops occur in India, the majority of which are insects. It is estimated that insects, rodents, and other animal pests of food grains in the field reduce food production over 10 percent, while losses in storage account for an additional 5 percent. Weeds are estimated to cause losses of another 10 percent in food grains in the field. Diseases take a further toll. Of the 87 million tons of food grains produced in 1963–64, in India, about 56 million tons were stored by the rural population. A total loss of 15 percent in grain would approximate 13 million tons or nearly twice the wheat imports of India during 1965. At an average of 400 rupees or $84 per ton, this loss alone in the 1963–64 crop amounts to about $1 billion.

In many countries in Africa and Asia, the Quelea grain-eating bird has caused serious losses in the production of rice, millet, sorghum, and wheat crops. Each Quelea bird may consume from 2 to 3 grams of grain per day while destroying 17 or 18 grams as it picks the grains from the heads of plants. In the Sudan area, daily consumption by these birds is of the magnitude of 3,000 tons of grain, or 4 million tons per year. This represents a loss of value in cultivated crops of over $200 million per year, not including the time and costs of controlling the birds.

The tsetse fly, which is responsible for the transmission of trypanosomiasis in livestock as well as man, represents one of the major obstacles to economic development of approximately 3 million square miles in Africa. Other pests and vectors of diseases constitute additional obstacles to livestock production in Africa. In much of this area, the only livestock that can be produced profitably is poultry.

Throughout Latin America, vampire bats are an important vector of rabies. The cattle industry in Venezuela is reported to have declined 50 percent since World War II, from 20 million head to about 10 to 12 million because of rabies transmitted by the vampire bat.

Weeds also cause serious yield reductions of the major crops in foreign countries. In the subtropics and tropics of Mexico, if weeds are allowed to grow in competition with maize for a period of 4 weeks, the yield is reduced over 50 percent. It has been estimated that maize yields are reduced an average of about 30 percent by weed competition in the subtropic and tropical climates in the world. These losses occur even though water and plant nutrients are amply supplied. In Argentina, Brazil, and other Latin American countries, thistle species are known to reduce alfalfa yields as much as 50 percent, and the productive capacity of grazing lands more than 30 percent.

In the U.S.S.R. the annual crop losses during recent years due to pests amount to about 20 percent of total production. Reportedly, economic benefits from chemical control amount to 10 to 20 times the cost, but less than 50 percent of the demand for pesticides is being satisfied. By 1970, production of plant protection chemicals in the U.S.S.R. is expected to be about 7 times that of 1963.

Carefully controlled farmer demonstrations in the Philippines, West Pakistan, and Brazil on the chemical control of weeds in rice clearly demonstrate that losses in yield are caused by weeds even when the best cultural practices are followed. In the Philippines, when conventional weed control practices were followed by farmers, the average yield of rice was 2,309 pounds per acre. When propanil was used selectively for control of weeds in rice, the average yield was 3,410 pounds per acre, an increase of 45 percent. In West Pakistan, hand-weeded rice fields yielded 1,049 pounds of rice per acre, while those treated with propanil for weed control yielded 1,515 pounds of rice per acre, an increase of 44 percent. In Brazil, rice fields in which weeds were controlled by conventional methods yielded 1,885 pounds of rice per acre compared to those which received propanil for weed control which averaged 2,851 pounds per acre, an increase of 51 percent. If the 46 percent average increase in yields of rice that resulted from chemical control of weeds in that crop in the Philippines, West Pakistan, and Brazil is typical of the increase that might be expected in other areas, the use of herbicides for selective control of weeds could have a significant worldwide impact on world rice production.

Interrelations of Pest Control to Other Production Inputs

When man converted native land to the production of agricultural crops he changed his environment irreversibly. When native vegetation is disturbed or when cultivated fields are abandoned, there is a sequence of events that alters not only plant life but populations of other organisms as well. Weeds, insects, diseases, nematodes, parasites, predators, birds, rodents, and other organisms often find conditions much more favorable for their reproduction, growth, and existence in large areas of specialized crops than in undisturbed regions. When man creates ideal conditions for the multiplication of pests, he must also create efficient means of controlling them.

Pest control (or the lack thereof) will continue to have a far-reaching impact on all phases of crop production in the developing countries. New methods and programs of pest control will affect the selection of crops and the varieties; seedbed preparation; method of seeding; seeding rates; row spacing; plant spacing in the row; plant populations; fertilizer practices; cultivation, irrigation practices; harvesting; seed cleaning operations; erosion control; fallow practices for pest control;

pasture renovation; pasture and range management; clearing new lands for crop or pastures; forest management; the utilization of farm water resources for irrigation and recreation; and the maintenance of drainage ditches, ditchbanks, irrigation canals, and farm roadsides.

There are important interrelations among each production input and pest control measure. Inputs that increase plant growth and crop productivity may also favor an increase in the populations of many kinds of pests. It should also be emphasized that none of these production inputs contribute their maximum to productivity if any of the other inputs are limiting. For example, irrigation practices are less efficient when aquatic weeds clog irrigation channels and drainage ditches. The advantages of efficient production and harvesting are lost if insects cause 15 to 20 percent losses in grain storage. The advantages of disease-resistant grain varieties are not realized if uncontrolled populations of rodents are allowed to devastate grain in the field and in storage. The advantages of all production inputs in increasing crop production are lost if Quelea birds are allowed to destroy grain crops ready for harvest.

There is much evidence that pest problems are greatly intensified as levels of fertilizer, water, and other production inputs are increased. If maximum benefits are to be obtained from these increased production inputs, they must be accompanied by effective crop protection methods. For example, irrigation water in rice fields in California commonly has been maintained at a depth of 6 to 8 inches to control aquatic weeds and other weed species. However, the development of selective herbicides such as 2,4-D, MCPA, and propanil has made the control of aquatic weeds possible without the use of expensive water management techniques. When herbicides rather than deep water are used to control weeds, the water level in rice fields can be reduced from 6 to 8 inches to approximately 2 inches. The use of herbicides in this instance has resulted in an annual saving of billions of gallons of water which can be diverted for irrigating other crops and for nonagricultural uses. Lowering the water level has also permitted the development of shorter-stemmed rice varieties which can effectively utilize higher levels of nitrogen and other production inputs. The high-yielding, shorter-stemmed varieties of rice cannot be grown unless herbicides are used to control weeds. Reducing the water devel in rice fields has also corrected a large number of physiological conditions that inhibit rice production.

Increased levels of fertilization may make a crop more susceptible to damage by pests. For example, rice crops in India have been more extensively damaged by the rice hispa beetle following application of nitrogen than has unfertilized rice. In Arkansas, uncontrolled barnyard grass in highly fertilized rice reduced yields 50 percent, as compared to 25 percent in rice that had a low level of fertilization.

There is little to be gained from increasing yields through the use of fertilizers, irrigation, and improved varieties without providing the necessary levels of pest protection. For example, in India the sorghum hybrid CSH–1 is greatly superior to indigenous varieties in yielding capacity. In 1965, yield increases of 3 to 4 tons per hectare were obtained when the stalk borer, *Chilo zonellus*, was controlled. However, CSH–1 is much more susceptible to damage from this pest than local varieties. In this instance, the realization of full yield potential depends on the institution of an effective borer control program.

Losses in Human Energy, Health, and Efficiency of Production

The control of malaria, which was responsible for almost incalculable losses in human energy, health, and work efficiency, is one of the truly remarkable achievements of mankind. Worldwide estimates indicate that by 1953, 5 million lives were saved from malaria because of the introduction of DDT during World War II. The use of DDT in India for malaria control has reduced the number of cases from an estimated 75 million in 1952 to about 100,000 in 1964. In the Soviet Union the number of cases of malaria fell from about 35 million in 1946 to 13,000 in 1956.

Thousands of people still fall prey to mosquito-borne encephalitis for which there is no cure or specific treatment. The only current method of controlling this dreaded disease is to prevent mosquitoes from breeding or to use insecticides to control them. Insect-borne diseases such as filariasis, typhus, African sleeping sickness, and bubonic plague still bring sickness and death to thousands, and insecticides and other control measures are required to keep these diseases in check. However, the control of human disease increases the need for pesticide use in agriculture and food storage to prevent those who are saved from malaria or typhus from dying of starvation or malnutrition. Although the control of human diseases undoubtedly results in a higher level of production efficiency, the net effect of this use of pesticides is an increased demand for food.

Poison ivy, poison oak, ragweeds, and other weeds produce toxins and allergenic pollens. In the United States, poison ivy and poison oak cause nearly 2 million cases of skin poisoning and other skin irritations resulting in an annual loss of 333,000 working days. In addition, these weeds cause 3.7 million days of restricted activity among the people who are susceptible to the toxins. Reduced working efficiency due to all weed and plant allergies is undoubtedly many times greater.

Benefits From Pest Control

Many crop-destroying pests can be kept under control only by the use of chemical pesticides. For example, ravaging insects such as the desert locust, armyworms, boll weevil, codling moth, seed weevils, and borers attacking sugarcane, rice, maize, cotton, fruit and many other crops can be controlled presently only by use of pesticides. Plant diseases such as potato blight, seedling disease complexes, downy mildews, fruit rots, and many others destroy food crops if fungicides are not available to keep them in check. Similarly, rodents, nematodes, and weeds would cause even greater losses in food production if pesticides were not used to control them.

The use of herbicides for weed control permits successful cultivation of a larger number of acres of food producing crops of higher quality and releases manpower for other production inputs. Labor requirements for cotton production can be cut nearly in half by the use of chemical methods of weed control. Similar reductions in manpower requirements have been reported for the major food crops in other countries.

According to Dr. P. C. Raheja, Director, Central Arid Zone Research Institute, Jodhpur, the loss due to weed infestation in crops in India ranges from 30 to 100 percent. The response to weed control is of the order of about 15 to 20 percent in increased production. Herbicide usage is considered economical, and it also increases crop response to irrigation and fertilizer application.

In the few experiments in India in which the yield of rice grown in soil naturally infested with nematodes was compared with that of adjacent areas where nematodes were controlled by soil fumigation, the rice yield is reportedly reduced by as much as 50 percent.

Herbicides differ from other pesticides in that they can be used to reduce labor and power requirements in crop production. In effect, herbicides represent a substitute for other sources of energy for increasing farming efficiency. For example, in Japan the use of herbicides to control weeds in rice production has resulted in a reduction of manpower required from 2160 hours per hectare in 1949 to 1520 hours in 1962, a reduction of 30 percent. These savings in manpower for rice production in Japan were also accompanied by reductions in manpower requirements brought about by improvements in other production inputs.

Why Are Pesticides Needed?

This question has been asked with increasing frequency during the last decade. Also, why are biological control methods not used exclusively for control of pest populations? The simple answer to both questions is that, in most instances, neither method is sufficiently effective. Much of the increased reliance upon chemicals for pest control since World War II has come about for several reasons:

1. A large number of synthetic compounds have been developed which are highly effective for pest control.
2. In plants and animals, genetic resistance usually does not provide adequate control, and many years of research may be required to solve adequately pest problems by this means.
3. Pesticides provide immediate and effective control at practical costs.
4. Nonchemical methods frequently do not provide adequate pest control without the supplemental use of pesticides.

There are outstanding examples of successful pest control by use of biological techniques. The cottony-cushion scale has been controlled in the United States for more than 70 years by the Vedalia beetle introduced from Australia. Grape phylloxera has been controlled completely by use of resistant American rootstocks on European varieties. Washington varieties of asparagus have retained rust resistance for over 50 years. Klamath weed in the western United States and pricklypear in Australia were virtually eliminated as major pests following the introduction of insect parasites. Over 110 cases of successful or partially successful biological control of different insect pests have been reported in 60 countries. One of the great accomplishments in biology has been the breeding of resistance to stem rust into varieties of wheat. Even with the success of this effort and the continuing emphasis that has been devoted to it, the wheat crop in North America received adequate protection for no more than 20 of the 50 years from 1904 to 1954. Generally, resistance of crop varieties to plant pathogens is lost within 5 to 15 years.

The potential of various techniques of pest control that do not rely solely on repetitive applications of chemicals is great, and deserves more attention than it is receiving. However, their current effectiveness for a great majority of pest control problems may be summarized by the expression, "too little and too late." In general, these methods reduce pest populations more slowly, and they are almost invariably less dependable than chemical pesticides. However, future long-range approaches to pest problems should give increasing attention to the development and application of alternate methods of pest control that can be substituted for, or supplement the use of, chemical pestcides.

There is reason to believe that, in the future, agricultural producers will have to rely somewhat less on conventional chemical pesticides to deal with pests. Moreover, improvements in chemical pesticides can be expected. More highly selective and biodegradable chemicals will undoubtedly replace some of the persistent pesticides currently used. For some important pests, the use of attractants and sex-sterilant methods or other insect population suppression techniques may prove highly effective, desirable, and economical.

A striking example of a new approach to insect control is the use of a male-sterility technique to control the screwworm in the Southern United States. Crop varieties which are resistant to insects, diseases, and nematodes will also continue to be developed. Bioenvironmental approaches will be employed to deal with problem weeds in crops as well as other pest problems. For the foreseeable future pesticides will nevertheless be essential for production of food and fiber, forest, fish, and wildlife, and for other needs in adapting man to his total environment.

Present Levels of Pesticide Usage

Pesticides are used extensively in most countries that have adequate sources of food. These same countries also utilize more fertilizer, better seeds, and more and better machinery than the countries with food shortages. The results in Table 1 give the estimated amounts of pesticides used on crops in different areas and countries in 1963 and the relationship between pesticide usage and crop yields. More pesticides were used on about 6 million hectares of arable land in Japan in 1963 than on the 391 million hectares or arable land of Africa, Latin America, and Oceania. The average production per hectare of all major food crops in Japan was three to four times the yield level being obtained in Africa, Latin America, and Oceania, respectively.

A high percentage of the insecticides used in the developing countries is applied in order to control insects that carry human diseases such as malaria. For example, 28,400 metric tons of DDT, technical grade, were exported from the United States to Asia in 1963 for use in malaria control programs. In the same year 10,200 and 540 metric tons of DDT were exported to Latin America and Africa, respectively, for

TABLE 1.—*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] FAO Production Yearbook (1963).

malaria control. Future requirements for pesticides to combat health problems are not considered in this study.

At present the developing countries are using little or no pesticides on the majority of crops. Of the compounds being used, insecticides are the most prevalent with fungicides second in importance.

In developed countries such as Japan and the United States all kinds of pesticides are used. In 1963 the proportion of the different kinds of pesticides used, on a total weight basis, was as follows:

Kind of pesticide	Percent of total	
	Japan	United States
Fungicides	40.6	35.9
Herbicides	24.5	22.7
Insecticides	24.2	38.5
Nematocides and fumigants	10.6	2.9
Rodenticides	.03	----------

As the developing countries expand their food production through increased fertilization, improved seed, and other production inputs, there is every reason to believe that patterns of pesticide usage will approach those given above for Japan and the United States.

Estimated Future Pesticide Requirements

As pesticides have been used only sparsely in the developing countries, data on patterns of usage of different kinds of pesticides are incomplete. Within the time period available precise information could not be obtained on those crops and pests which have been treated with the limited amounts of pesticides used. Thus, pesticide requirements were based largely on the more adequate data from developed countries.

Linear relationships between yields and fertilizer and pesticides usage were found for those areas of the world where adequate data were available. These relationships were used to calculate pesticides requirements. In making these calculations the following assumptions were made:

(1) If increased yields are to be attained, pest control is necessary;

(2) Improved varieties, adequate fertilization, improved machinery and irrigation, and other improved production and management inputs will be introduced;

(3) Pesticides will provide some measure of control of the pests that reduce crop yields regardless of the specific geographical area involved;

(4) The future requirements for different classes of pesticides (i.e., fungicides, herbicides, insecticides, etc.) can be approxi-

275-253 O—67——11

mated by calculations described later. The proportions of the different types used change as agricultural production improves in the developing countries and as newer and more effective pesticides are developed;

(5) Pesticides will be required for the forseeable future for the control of most major pests; and

(6) The spectrum of pesticides to be used will have about the same pesticidal potency per unit weight as the pesticides now in use.

Should significant new breakthroughs rapidly replace conventional pesticides with alternate nonchemical control measures, the estimates given in the pesticide requirements in this report will have to be appropriately reduced.

Methods Used for Calculation of Pesticides Requirements

In developing prediction equations of pesticide requirements, it was further assumed that total usage of pesticides and fertilizers are related to the total arable areas of the countries for which reported and that the average aggregate yield of the selected principal crops is assumed to be representative of the total food productivity of the country or geographical area. Statistics reported in FAO Production Yearbooks were used to calculate average usage of pesticides (g/arable hectare) and fertilizers (kg/arable hectare), and average aggregate yield (kg/hectare of production) of the principal food crops—all cereals, pulses, oilseeds, potatoes, sweet potatoes and yams, cassava, onions, tomatoes, and sugar crops (raw sugar).

Preliminary graphic analysis, by trial techniques, demonstrated apparent linear relations between pesticides and yields, fertilizers and yields, and pesticides and fertilizers in log-log plots of data for Japan, India, and the United States for the years 1952, 1957/58, and 1962/63 (FAO Yearbooks, Vols. 8, 14, and 19; 1954, 1960, and 1965, respectively). Linear regression equations were calculated by substituting logarithmic values for average pesticide usage (P, g/ha), fertilizer usage (F, kg/ha), and aggregate yield (Y, kg/ha). The paired relations of these values are described by the following equations and correlation coefficients (r):

$$\log P = 2.575 \log Y - 5.683;\ r = 0.977$$
$$\log P = 0.949 \log F + 1.532;\ r = 0.989$$

and

$$\log F = 2.716 \log Y - 7.612;\ r = 0.989$$

All correlations are significant at the 1% level of probability.

Future applications of pesticides technology by developing areas will undoubtedly be based on the current state of usage in the more developed countries. Since the United States currently uses over one-third of the world's total pesticides production (Table 2), the value of the above regression equations for projecting future needs can be improved by slight adjustments to coincide with the 1963 usages of the United States (Figures 1, 2, and 3.). The corrected equations thus become:

$$\log P_y = 2.575 \log Y - 5.620 \quad \text{[Equation I]}$$
$$\log P_t = 0.949 \log F + 1.585 \quad \text{[Equation II]}$$

and

$$\log F_y = 2.716 \log Y - 7.602 \quad \text{[Equation III]}$$

Thus, given any one of the three parameters—yield (Y), pesticides (P), or fertilizers (F)—the other two can be calculated.

Figure I
PESTICIDES/YIELD REGRESSION
Japan, India, & United States — 1952, 1958, 1963

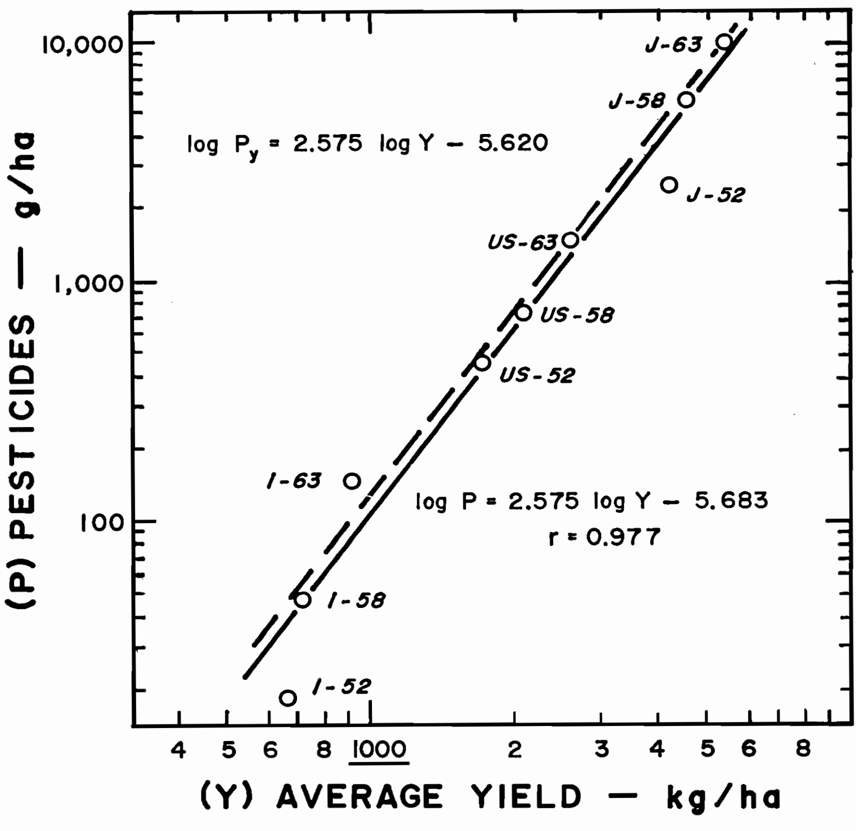
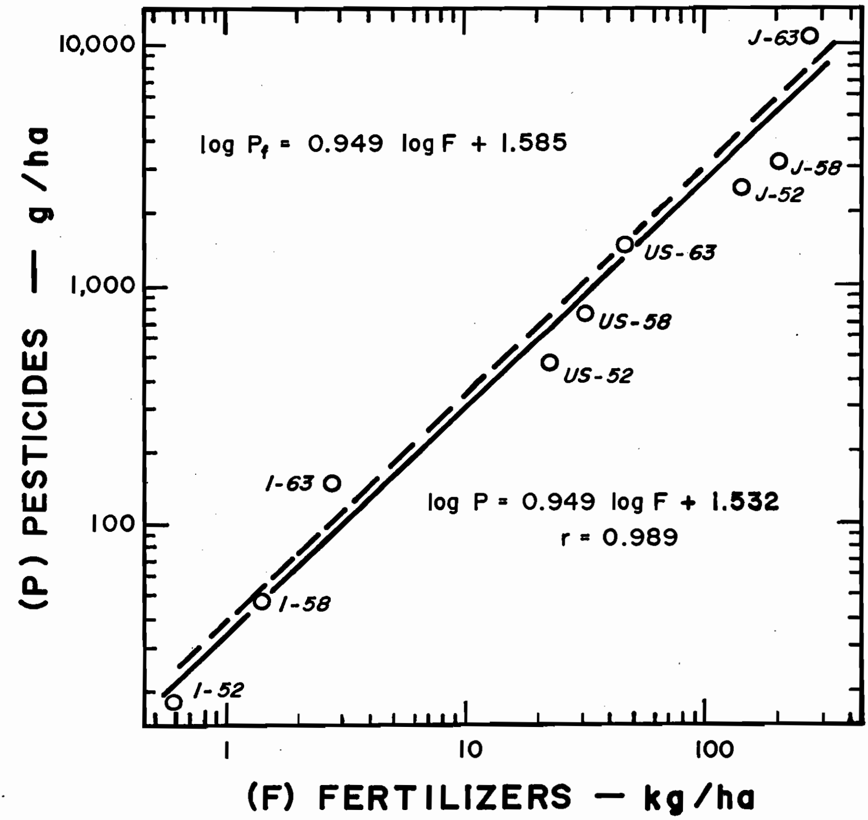


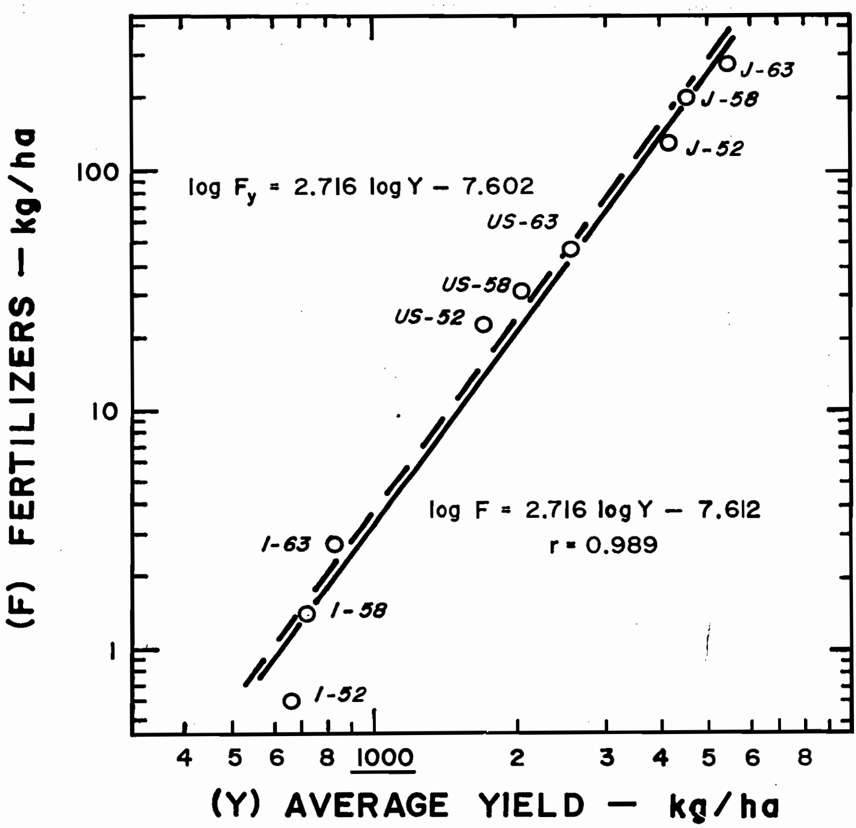
Figure 2
PESTICIDES/FERTILIZER REGRESSION
Japan, India, & United States — 1952, 1958, 1963



Adjusted Yields and Disproportionate Usage of Pesticides and Fertilizers

The regression equations described imply a programed technological input of agricultural chemicals in food crop production. Non-food

Figure 3
FERTILIZER/YIELD REGRESSION
Japan, India, & United States — 1952, 1958, 1963



crops, particularly export crops, also received these inputs. Some countries and areas, however, adopt fertilizer and pesticide advances disproportionately, or apply them only to certain crops, often to non-food crops where the increased production would not be reflected in the aggregate average yield for food crops.

TABLE 2.—*Pesticide usage in metric tons of active ingredients, by class and geographical area, 1963*

[Computed from data in FAO Production Yearbook, vol. 19, 1965]

Pesticide—class and type	Asia (except mainland China)	Africa	Latin America	Oceania	Europe (except U.S.S.R.)	United States	Class and type totals
Insecticides:							
Chlorinated hydrocarbons	27, 052	8, 278	6, 038	114	15, 733	64, 375	121, 590
Organophosphorus compounds	4, 004	2, 258	2, 105	4	12, 106	34, 437	54, 914
Arsenicals	3, 283	*n*	286	200	952	4, 950	9, 671
Mineral oils and dinitro compounds	8, 888	619	246	500	8, 759	--------	19, 012
Botanical insecticides	153	178	6	22	141	2, 490	2, 990
Total insecticides	43, 380	11, 333	8, 681	840	37, 691	106, 252	208, 177
Fungicides:							
Sulfur and compounds	21, 185	17, 540	2, 971	540	109, 739	78, 250	230, 225
Copper compounds	13, 617	48	3, 210	1, 850	74, 724	15, 974	109, 423
Mercury compounds	1, 691	--------	18	12	2, 775	884	5, 380
Carbamates and others	3, 300	73	4, 526	150	35, 527	3, 854	47, 430
Total fungicides	39, 793	17, 661	10, 725	2, 552	222, 765	98, 962	392, 458
Fumigants	7, 704	14	48	84	1, 621	7, 890	17, 361
Herbicides	37, 767	934	887	784	16, 832	62, 644	119, 848
Rodenticides	202	*n*	2	8	2, 569	--------	2, 781
Other pesticides and dips	798	3, 038	830	2, 656	2, 434	--------	9, 756
Area totals	129, 644	32, 980	21, 173	6, 924	283, 912	275, 748	750, 381

n=negligible quantity (500 kg or less).

In India, for example, during the 3-year period 1962/63 to 1964/65 improved technology was applied in the production of rice, sugarcane, and cassava. These three select food crops were grown on 23.5 percent of India's total arable area and yielded an average of 1,510 kg/ha. All other significant food crops were grown on 60.5 percent of the total arable area and yields averaged 580 kg/ha. The aggregate average for all food crops was 840 kg/ha on 84 percent of the arable area. However, India grew non-food crops—cotton, fiber crops, tea, coffee, citrus, tobacco, and rubber—on an estimated 8 percent of the remaining area. From Equation I, pesticide usage rates of 388 and 31.3 g/ha can be calculated for the select and other food crops, respectively. If these rates are assumed applicable for corresponding non-food crops, the averaged pesticide usage rate for India, weighted for respective areas of crop types is 144 g/ha. This rate compares very favorably with the observed rate of 149 g/ha. and corresponds to an average yield of 1,050 kg/ha, reported in Table 3, as the adjusted yield (Y_{adj}). The value Y_{adj} provides a better base value than the observed Y for projecting requirements since it accounts for usage disproportionalities.

For countries and areas other than India (Table 3), an approximation of Y_{adj} was obtained by substituting observed values for P and F in Equations I and III, respectively, and averaging the separate determinations of log Y. Differences in Y and Y_{adj} reflect the magnitude of disproportionate usages. For Latin America, Africa, and Brazil, the Y_{adj} values are considerably lower than observed yields because of disproportionate inputs into a single high-yielding food crop, sugarcane. For Asia and India, Y_{adj} is greater than Y, primarily because of disproportionate inputs into export non-food crops.

TABLE 3.—*Estimated pesticides requirements for food production increases of 10, 25, 50, and 100 percent in major developing areas and selected countries*

	Major Developing Areas			Total pesticides m. tons	Selected Countries	
	Asia [1]	Africa	Latin America [2]		India	Brazil
Basic statistics—1962/63:						
Total arable area (10^3 ha)	342,000	260 000	96,000	----------	162,883	19,095
Fertilizer usage (10^3 m. tons)	1,631	790	1,086	----------	458	192
Pesticide usage (m. tons)	64,463	32,980	21,173	118,616	24,223	Not reported
Average usage—						
(F) Fertilizers (kg/ha)	4.8	3.0	11.3	----------	2.8	10.1
(P) Pesticides (g/ha)	188	127	221	----------	149	[3] (574)
(Y) Average yield-major crops	1,175	1,210	1,970	----------	820	2,040
(Yadj) Adjusted yield [4] (kg/ha)	1,143	970	1,380	----------	[5] 1,050	1,630
Usage rate—g/hectare:						
Calculated pesticide usage for yield increases in percentages of—						
10	229	150	372	----------	184	565
25	319	209	519	----------	256	791
50	511	335	828	----------	409	1,265
100	1,069	703	1,742	----------	859	2,649
Total quantity—m. tons—						
10	78,300	39,000	35,700	153,000	30,000	10,800
25	109,000	54,300	49,800	213,100	41,700	15,100
50	175,000	87,100	79,500	341,600	66,600	24,200
100	366,000	182,800	167,200	716,000	139,900	50,600
Increased quantity—m. tons (Projected total quantity less 1962/63 usage)—						
10	13,800	6,000	14,500	34,300	5,800	2,300
25	44,500	21,300	28,600	94,400	17,500	6,600
50	110 500	54,100	58,300	222,900	42,400	15,700
100	301,500	149,800	146,000	597,300	115,700	42,100

[1] Includes India but excludes Japan, mainland China and U.S.S.R.
[2] Includes Brazil.
[3] Estimated from Y and F.
[4] Adjusted yields corrected for disproportionality in use of fertilizers and/or pesticides.
[5] Based on detailed estimates (see text).

Pesticides Requirements for Increasing Food Production by Geographical Area

The amounts of pesticides required to increase food production 10, 25, 50, and 100 percent were obtained by substituting the correspondingly increased values of Y_{adj} in Equation I and solving for the pesticide usage rate. This rate, multiplied by the total arable area of the geographical area (or country), gives the total pesticide requirement for the area (Table 3). Differences in projected usages, less 1962/63 usages (the increased requirement), are also tabulated. The total increases in metric tons of pesticides required to meet the needs of the major developing areas (Asia, Africa, and Latin America) for the designated increased production levels are:

Percent of Production increase	Pesticide increase	
	Metric tons	Percent
10	34,300	(29)
25	94,400	(80)
50	222,900	(188)
100	597,300	(504)

Pesticides usage by these developing areas during the base year 1962/63 was 118,616 m. tons. In other words, for the 100 percent increased production level, these areas must increase their usage of pesticides by approximately 5 times the 1962/63 amounts.

Pesticide usage is largly a function of the level of economic productivity of a given region. The types of pesticides used are also dependent on the state of technological development of the agriculture of the region. There seems little need for pesticides in an impoverished agriculture. Crop protection requirements, however, increase exponentially with each technological advance, such as increased use of fertilizers and improved cultural practices. In the developing countries, initial usage of pesticides appears to involve protection problems for which hand-labor is unsatisfactory or inadequate; namely, problems of insects and plant diseases. Herbicides and fumigants are introduced at a later stage of development and probably coincide closely with increased mechanization of crop production.

Initial attempts to project requirements by classes of pesticides involved a detailed analysis of the 1963 pesticide usage data for India, the United States, and Japan. These countries represent—respectively—low, intermediate, and high levels of technology in crop production, and at least some usage of each class of pesticides.

Several preliminary graphic analyses demonstrated that certain classes of pesticides were related exponentially to fertilizer usage or were similarly related to each other. The exponential functions reduced to linear relations in log-log plots, and regression equations were calculated which, within limits, were usable for predicting usages of several other countries. Since yield, fertilizers, and total pesticides are interrelated (Equations I, II, and III)—and since total pesticides (P) can be best estimated from the adjusted yield value (Y_{adj})—regression equations were redetermined to estimate the following separate classes: insecticides (I); fungicides (G); fumigants (M); herbicides (H); and rodenticides, dips and others (R). The equations and correlation coefficients (r) are as follows:

$$\log I = 0.739 \log P + 0.427;\ r = 0.999$$
$$\log G = 1.139 \log P - 0.930;\ r = 0.999$$
$$\log M = 1.676 \log P - 3.695;\ r = 0.999$$
$$\log R = \log P - 1.658;\ \text{or } R = 2.2 \text{ percent P (constant ratio)}$$
$$H = P - (I + G + M + R)$$

Correlation coefficients are significant at the 5 percent level of probability.

The quantities I, G, and M are found as logarithmic functions of P. Because of their small proportion of the total pesticides in world usage (Table 2) rodenticides and other pesticides (R) are estimated as a set percentage of the total pesticides requirement. By graphic calculations this was established at 2.2 percent. The requirement for herbicides (H) was determined by difference.

For Japan, India, and the United States, very close agreement is found between observed and calculated values for 1963 pesticide usage by classes (Table 4.). For other geographic areas, the majority of the calculated values are of the same order of magnitude as observed values; but some differ in relative proportion to the total. The theoretical class percentage of the total pesticide requirement is shown graphically in Figure 4 for each class at different total pesticide usage levels. The series of curves plotted show that insecticides constitute about 80 percent of the total when the requirement for pesticides is small (at low productivity levels). As pesticide requirements increase, the amounts of insecticides also increase; for example, from 80% × 100 g/ha (80 g/ha) to 24% × 10,000 g/ha (2,400 g/ha). However, the proportional requirement decreases. Herbicides increase rapidly to about 21 percent of the total at 1,000 g/ha, but level off at that usage level. Fumigant usage does not reach sizable proportions until total requirements are of the order of Japan's (10,000 g/ha).

The fungicide requirement is confounded by the unusual status of sulfur and its compounds. This group of fungicides makes up 98 percent of all fungicides used in Africa but only 9 percent in India. In other areas, sulfur usage varies from 20–30 percent in Oceania and Latin America, 50–60 percent in Europe and Asia (including Japan), and almost 80 percent in the United States (Table 2). Non-sulfur fungicides, however, are exponentially related to total pesticide usage (Figure 5). Except for the United States and Asia as a whole, the

TABLE 4.—*Observed and calculated usage of pesticides (g/ha) by pesticide classes for major geographical areas and selected countries, 1963*

	Insecticides		Fungicides		Fumigants		Herbicides		Rodenticides and others		Total	
	Obs.	Calc.	Obs.	Calc.	Obs.	Calc.	Obs.	Calc.	Obs.	Calc.	Obs.	Calc.[1]
Geographical areas:												
Asia (including Japan and India but not mainland China)	125	202	114	92	22	4	109	43	3	8	373	349
Africa	43	91	68	27	n	1	4	-----	12	3	127	[2] 118
Latin America (including Brazil)	90	117	112	76	1	3	9	30	9	6	221	292
Oceania	24	231	73	113	2	5	23	59	76	9	198	417
Europe	248	830	1,466	815	10	90	111	568	33	52	1,868	2,355
Selected countries:												
India	109	105	34	34	1	1	1	1	4	3	149	144
Japan	2,611	2,270	4,381	3,846	1,149	889	2,649	1,997	4	202	10,794	9,204
United States	574	592	534	483	43	42	338	343	-----	33	1,489	1,493
Brazil	-----	242	-----	122	-----	6	-----	67	-----	10	[3] (574)	447

[1] Calculations of total pesticides based on equation $\log P = 2.575 \log Y_{adj} - 5.620$.

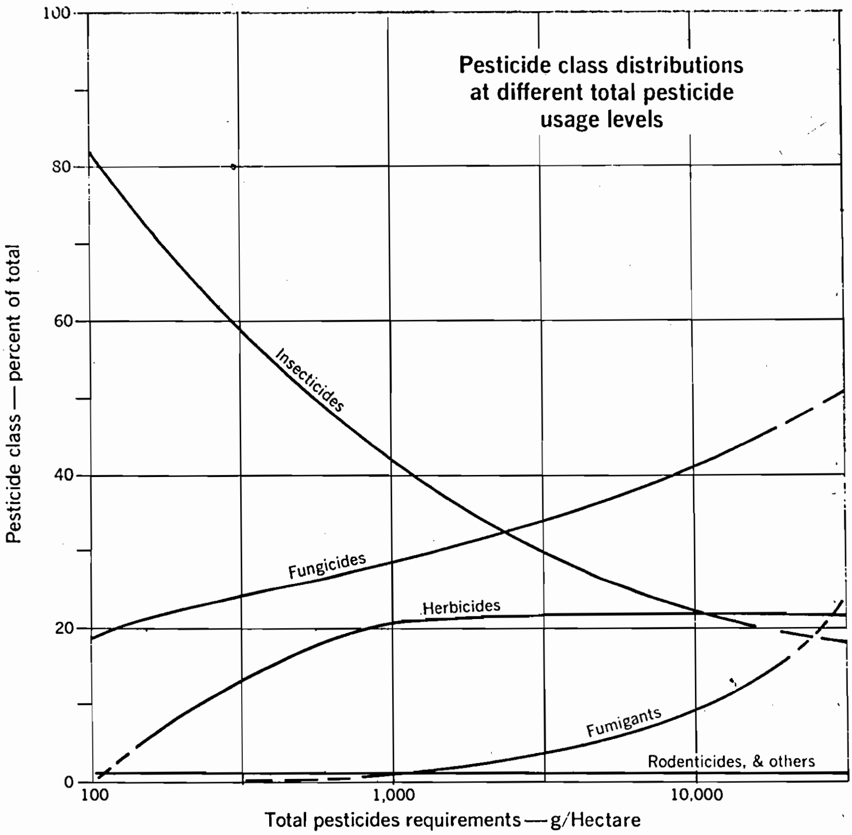
[2] Calculated total is less than calculated class sum. The discrepancy indicates that the estimation equations for classes have a lower limit of accuracy at some requirement level which is slightly larger than the requirement for Africa.

[3] Estimated from yield and fertilizer usage.

data plotted in Figure 5 fit the curve $\log X = 1.332 \log P - 1.836$; $r = 0.88$, significant at the 5 percent level of probability. Thus, X provides an estimate of fungicides other than sulfur and $G - X$ can be used to approximate the sulfur requirement.

The various equations derived in this analysis can be used to estimate future requirements for pesticides and breakdown requirements for various classes, provided that we make certain assumptions. First, only the estimate of total pesticide requirement is related to a time factor (an 11-year period); the equations for pesticide classes are based on data for a single year 1963. We must assume then, that the pesticide requirements for 1963 with respect to productivity can also be transferred to a time curve for growth, and that the rate of growth or production increase will be determined by the population growth and its demands. Second, all estimates are founded on the state of pesticide technology and the nature of its development in Japan, India, and the United States since 1952. Projections based on the prediction equations must, therefore, be predicated on the assumption that future advances in pesticide technology will not radically change the pattern of developments established from 1952 to 1963. No allowance can be made for new and improved pesticide usages which may markedly lower the overall requirement per unit of land area. We must also

Figure 4



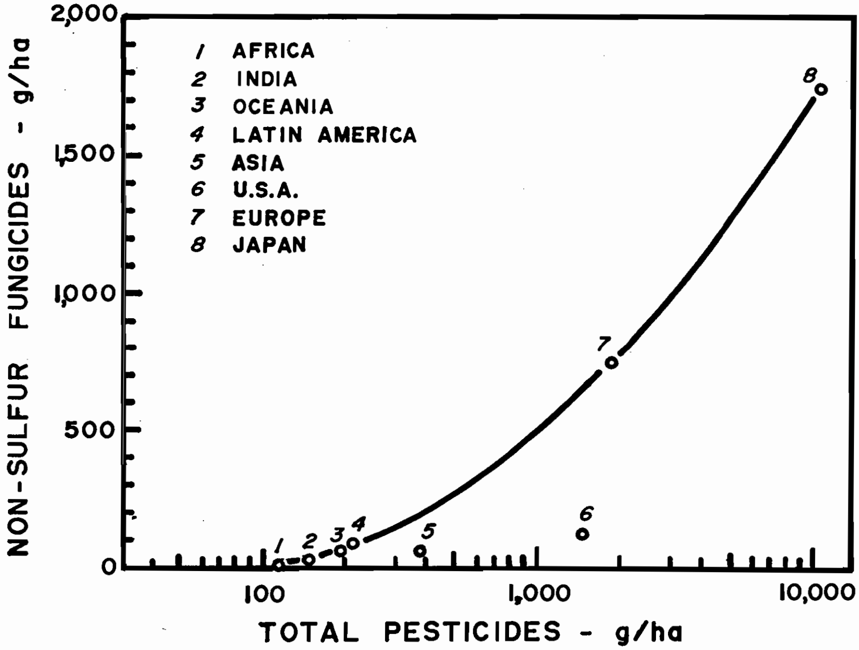
Approximate percentage contributions of different pesticide classes to the total pesticides requirement as the total requirement changes from approximately 100 to 10,000 g/hectare. Based on data for India, the United States, and Japan, 1963.

assume that future class usages in all areas will sooner or later parallel the proportionalities established for Japan, India, and the United States or that further study will result in modifications.

An estimation of India's pesticide requirements by classes, to achieve production increases of 10, 25, 50, and 100 percent, involves all phases of the estimation procedure (Table 5). First, an adjusted average yield (Y_{adj}) is calculated from observed pesticide and fertilizer usage in 1963 by using Equations I and III. Substitution of this value in Equation I provides an estimate of the total pesticide requirement (P). Similar values of P are derived for ($Y_{adj}+10\%\ Y_{adj}$) to ($Y_{adj}+100\%\ Y_{adj}$). Class estimates are calculated for each value of P. Table 5 does

Figure 5

1963 Usage of Non-Sulfur Fungicides — in Relation to Total Pesticides



not include a breakdown of fungicide requirements into sulfur compounds and other fungicides. In 1963 India used 3 g of sulfur per hectare and 31 g of non-sulfur fungicides. By calculation, the ratios of these groups for the 10, 25, 50, and 100 percent production increases should be 30 : 15, 41 : 24, 67 : 44, and 140 : 118 g/ha, respectively. Thus, India was using a sufficient quantity of non-sulfur fungicides in 1963 to meet the demands of a 25 percent production increase. The fungicide requirements for a time may be best met through increased usage of sulfur and sulfur compounds. India's requirements for sulfur fungicides at the respective increased production levels are estimated at 4,900, 6,700, 10,900, and 20,800 metric tons.

Costs of Pesticides Production, Formulation, and Storage Facilities

Substantial investments will have to be made to meet the requirements for pesticides, to help increase food production throughout the world. It is difficult to develop precise data on these costs, since the cost of construction of facilities to produce one type of pesticide may

TABLE 5.—*Estimated quantities of pesticides by classes to satisfy India's pesticide requirements for increased production levels*

Pesticide class	1963 usage	Estimated quantities for production increases of			
		10 percent	25 percent	50 percent	100 percent
Usage rate—g/ha:					
Insecticides	109	126	161	228	394
Fungicides	34	45	65	111	258
Fumigants	0.9	1.3	2.2	5	17
Herbicides	0.7	7.6	22.2	56	171
Rodenticides and others	4.4	4.1	5.6	9	19
Total	149	184	256	409	859
Quantity—metric tons:					
Insecticides	17,787	20,520	26,200	37,100	64,200
Fungicides	5,494	7,330	10,600	18,100	42,000
Fumigants	144	210	400	800	2,800
Herbicides	112	1,240	3,600	9,100	27,800
Rodenticides and others	686	700	900	1,500	3,100
Total	24,223	30,000	41,700	66,600	139,900

greatly differ from that of another. Also the rapidity with which new and improved pesticides replace old ones necessitates changes in production methods. To arrive at some generalizations for the cost of pesticide manufacture, some actual cost figures were assembled on four United States pesticide manufacturing plants that produce a rather wide range of pesticidal materials (Table 6). From these figures and the calculated pesticide requirements cost estimates were derived for manufacturing pesticides in different regions of the world.

For the next few years, the great bulk of technical grade pesticides probably can be produced best in developed countries having a successful history of capability in this field. For example, the manufacture of most pesticides in the United States starts with fairly complex "raw materials" which are readily available in all regions of the country. If a pesticides plant is located in a developing country, it may be necessary to begin the production with basic chemicals. This factor alone could greatly increase permanent investment costs. Again, because raw materials are generally available in the United States and other developed countries, plants are usually located near markets. However, production of a typical pesticide involves processing 5–20 pounds of raw materials to produce one pound of finished product. This consideration may favor a plant location in an industrialized area so that only the finished product need be shipped. The above view gives no weight to political or balance of payment considerations. These would have to be considered in each specific case.

TABLE 6.—*Cost, permanent investment, and working capital associated with four actual "typical" pesticides production plants in the United States* [1]

	Pesticide A	Pesticide B	Pesticide C	Pesticide D	Composite
Annual Production, lbs	7,020,000	1,400,000	4,650,000	890,000	3,500,000
Annual Production, metric tons	3,185	635	2,110	404	1,588
Cost of Production, $/year	2,850,000	440,000	4,740,000	1,970,000	2,500,000
Cost of Production, $/lb	.41	.32	1.02	2.20	.72
Cost of Production, $/metric ton	904	705	2,248	4,849	1,587
Permanent Investment (Plant and Equipment):					
Active Ingredient Manufacture, $/lb	.25	.21	.75	2.07	.53
Active Ingredient Manufacture, $/metric ton	551	463	1,653	4,562	1,168
Formulation of 72 percent Active Ingredient $/lb	.08	.31	.11	.38	.14
Formulation of 72 percent Active Ingredient $/metric ton	176	683	242	838	309
Working Capital:					
Raw Materials, Cash, etc., $/lb	.07	.13	.24	.50	.16
Raw Materials, Cash, etc., $/metric ton	154	286	529	1,102	353
Accounts Receivable, finished product inventory, $/lb	.18	.19	.31	1.01	.28
Accounts Receivable, finished product inventory, $/metric ton	397	419	683	2,226	617
Total Investment, $/lb	.58	.84	1.41	3.96	1.11
Total Investment, $/metric ton	1,278	1,851	3,108	8,728	2,446

[1] Pesticide is formulated to approximately 72 percent active ingredient.

Other advantages to the establishment of basic pesticide manufacturing plants in developed countries are:

1. *Lower investment.*—A chemical manufacturing plant could vary in installed cost from a minimum of perhaps $500 thousand up to $4 million or more, depending upon the scope and complexity of chemical reactions involved. The investment required and total productive capacity of the plant can best be utilized within the developing country.

2. *Simplicity of operation.*—Chemical manufacturing units are more complicated, and often involve hazardous processes or toxic raw materials. With the type of labor and supervision currently available in many developing countries it is definitely of interest to keep the operation on the simplest possible basis.

3. *Expenditure of hard currency.*—The cost of plant installation is substantially less for a formulation plant than for a basic manufacturing plant. This is an important factor in developing countries where hard currency is scarce. In most of the developing areas the basic raw materials necessary for manufacture of the pesticide will not be available, and will have to be imported from other areas and require the use of scarce funds.

4. *Reluctance to release information.*—Most American and other western pesticide manufacturers would be reluctant to release manufacturing information on pesticides (other than the classical products such as DDT) to developing countries. On the other hand, a solution which enables the basic manufacturer to supply a concentrate manufactured in his own plant should be quite acceptable to most chemical manufacturers.

Even so, some pesticides production plants should be constructed at strategic locations in certain of the developing countries, perhaps when their capability for increasing food production by 50 percent has been attained. These might be located near projected fertilizer plants. Such locations would permit joint use of technical personnel and provide opportunities for the training of chemists, engineers, mechanics, and others to construct and operate chemical production plants.

Facilities for Producing Technical Grade Pesticides

As the specific pesticides to be produced and used in a given geographical area cannot be predicted with accuracy, it is possible to develop only general estimates of investment costs for pesticides production plants. It is certain that an array of pesticides within the broad classes of fungicides, herbicides, insecticides, nematocides, and rodenticides will be required if food production is to be increased substantially.

The total permanent investment required to construct a "typical" pesticides production plant in the United States ranges from about $500 to $5,000 per metric ton of technical product (Table 7). For the purpose of the broad estimates made in this study we used an average permanent investment figure of $1,410 per metric ton of technical pesticide produced (Table 8). These costs will change as the general economy fluctuates. If the plants are to be built in developing countries, the costs will generally be higher. For example, it is estimated that the construction of a fertilizer plant in India would cost about 30 percent more than in the United States. The escalation in costs for a pesticides production plant would probably be about the same.

The number of pesticides manufacturing plants needed to produce the estimated requirements was determined by using the composite production capacity estimates given in Table 8. An average plant capacity of 3,200 metric tons annually was used to obtain the data given in Table 9.

The working capital requirement for a "typical" U.S. pesticides production plant ranges from $150 to $1,100 per metric ton for raw materials, cash, etc., and $200 to $1,100 for accounts receivable and product inventory (Table 7). For purposes of calculating working

TABLE 7.—*Cost, permanent investment and working capital associated with four actual "typical" technical grade pesticides production plants in the United States* [1]

	Pesticide A	Pesticide B	Pesticide C	Pesticide D	Composite
Annual Production, lbs. tech	7,020,000	1,400,000	4,650,000	890,000	3,500,000
Annual Production, metric tons	3,185	635	2,110	404	1,588
Cost of Production, $/year	2,738,000	322,000	5,115,000	2,020,000	2,520,000
Cost of Production, $/lb	.39	.23	1.10	2.27	.72
Cost of Production, $/metric ton	859	507	2,425	5,004	1,587
Permanent Investment:					
Active Ingredient Manufacture, $/lb	.25	.21	.75	2.07	.53
Active Ingredient Manufacture, $/metric ton	551	463	1,653	4,563	1,168
Working Capital:					
Raw Materials, Cash, etc., $/lb	.07	.13	.24	.50	.16
Raw Materials, Cash, etc., $/metric ton	154	287	529	1,102	353
Accounts Receivable, finished product inventory, $/lb	.09	.10	.15	.50	.14
Accounts Receivable, finished product inventory, $/metric ton	198	220	330	1,102	309
Total Investment, $/lb	.41	.44	1.14	3.07	.83
Total Investment, $/metric ton	903	970	2,513	6,768	1,830

[1] Table 7 is based on Table 6—cost was allocated on the basis of investment to exclude formulation costs.

NOTE.—A "typical" technical grade pesticides manufacture plant would have an annual capacity of about 4,500,000 lb and produce 3,500,000 lb (78 percent of capacity) at a cost of $2,520,000. The total permanent investment (book value) would be $1,855,000 and the total capital (including working capital) would be $2,905,000.

Permanent investment/metric ton	$1,168
Working capital/metric ton	662
Total	1,830

TABLE 8.—*Cost, permanent investment, and working capital associated with technical grade pesticide: composite actual data from Table 7 adjusted for replacement value and for doubling capacity*

	Actual Composite data [1]		Adjusted for present replacement value [2]		Adjusted for doubling capacity [3]	
	Pound	Metric ton	Pound	Metric ton	Pound	Metric ton
Annual Production	3,500,000	1,588	3,500,000	1,588	7,000,000	3,176
Cost of Production, $/year	2,520,000	2,520,000	2,620,000	2,620,000	5,020,000	5,020,000
Cost of Production, $/unit	.72	1,587	.75	1,653	.72	1,587
Permanent Investment, $/unit:						
Active Ingredient Manufacture	.53	1,168	.80	1,763	.64	1,410
Working Capital, $/unit:						
Raw Materials, Cash, etc	.16	353	.16	353	.16	353
Accts. Receivable, finished product inventory, etc	.14	309	.14	309	.14	309
	.30	662	.30	662	.30	662
Total Investment, $/unit	.83	1,830	1.10	2,425	.94	2,072

[1] Composite of four products including insecticides, fungicides and herbicides.
[2] Costs increased by 10 percent of additional permanent investment (7 percent for depreciation).
[3] Doubling capacity increases the permanent investment by approximately 60 percent.

TABLE 9.—*Number of plants for manufacturing technical pesticides to meet needs for increasing food production by 10, 25, 50, and 100 percent*[1]

Production Level Increase (Percent)	Developing Geographical Area				Selected Countries	
	Asia[2]	Africa	Latin America	Totals for developing areas	India	Brazil
10	4	2	4	10	2	1
25	14	7	9	30	5	2
50	35	17	18	70	13	5
100	94	47	46	187	36	13

[1] Based on an annual production of 3,200 metric tons technical pesticides; current usage of pesticides excluded.
[2] Excludes Japan, mainland China, and U.S.S.R.

capital requirements for pesticide production plants, a composite figure of $660 per metric ton was used.

The calculated total permanent investment costs and working capital requirements to provide the needed pesticides manufacturing plants are shown in Table 10. Even though the costs for these plants are shown under individual continents and countries they may best be located in developed countries where production can be achieved more economically.

Pesticides Formulation and Storage Facilities

Based on estimates of formulators and others in the United States, the permanent investment in equipment and physical plant for pesticides formulating plants ranges from about $27 to $269 per metric ton of technical product formulated (Table 11). The costs vary greatly among different pesticides. A plant designed to formulate liquid concentrates is much less costly than one built to formulate dusts or granular preparations.

Special equipment must frequently be provided to safeguard workmen's health, and to dispose of wastes so as to minimize the occurrence of harmful pesticides in streams, soil, or air. Such specialized facilities add considerably to investment costs, particularly in the formulation of pesticides which are highly toxic to man.

For purposes of this study, an average formulation cost of $55 per metric ton of technical pesticide was used to calculate the permanent investment costs of providing pesticides formulation plants in different areas of the world (Table 12).

The capacity of formulation plants varies considerably, depending on the type of pesticide being formulated and the nature of the finished product; i.e., liquid, dust, or granular. Estimates of selected for-

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TABLE 10.—*Permanent investment costs and working capital requirements for pesticides (technical) manufacturing plants to meet needs for increasing food production by 10, 25, 50 and 100 percent* [1]

Production Level Increase (Percent)	Developing Geographical Area				Selected Countries	
	Asia [2]	Africa	Latin America	Totals for developing areas	India	Brazil
Permanent Investment Costs @$1410/M.T. ($1,000,000)						
10	19.5	8.5	20.4	48.4	8.2	3.2
25	62.7	30.0	40.3	133.0	24.7	9.3
50	155.8	76.3	82.2	314.3	59.8	22.1
100	425.1	211.2	205.9	842.2	163.1	59.4
Working Capital Requirements @$660/M.T. ($1,000,000)						
10	9.1	4.0	9.6	22.7	3.8	1.5
25	29.4	14.1	18.9	62.4	11.6	4.4
50	72.9	35.7	38.5	147.1	28.0	10.4
100	199.0	98.9	96.4	394.3	76.4	27.8
Total Costs ($1,000,000):						
10	28.6	12.5	30.0	71.1	12.0	4.7
25	92.1	44.1	59.2	195.4	36.3	13.7
50	228.7	112.0	120.7	461.4	87.8	32.5
100	624.1	310.1	302.3	1,236.5	239.5	87.2

[1] Estimates based on United States costs and will require adjustment to fit situation in particular coun tries. Costs of plants do not include tonnages of pesticides currently used in different areas.
[2] Excludes Japan, mainland China, and U.S.S.R.

TABLE 11.—*Estimated permanent investment cost in physical facilities for pesticides formulation plants*

Type of product:	Plant A: Dusts	Plant A: Granules	Plant A: Liquids	Plant A: Total	Plant B: Liquids	Plant C: Liquids
Processing Building:						
Open Construction	----------	----------	$5,000	$5,000	$7,500	[3] $5,000
Closed Construction	$15,000	(1)	20,000	35,000	----------	[2] 2,500
Plant & Laboratory Equipment	70,000	[1] 16,000	50,000	136,000	45,000	[3] 35,000
Office, Showers, Utility Storage	24,500	(1)	(1)	24,500	8,500	----------
Warehouse & Storage	22,500	7,500	20,000	50,000	12,500	[2] 37,500
Engineering, Contingency & Misc	----------	----------	----------	----------	----------	20,000
Total	$132,000	$23,500	$95,000	$245,000	$73,500	$100,000
Annual Prod.-Active Ingred. (M.T.)	300	240	3,240	3,780	2,760	725–2175
Permanent Invest. Cost ($/M.T.)		269	29	65	27	138–46 (69)

[1] Equipment and facilities shown for dusts also used for granules and/or liquids.
[2] Open construction calculated at $5/sq. ft., closed construction at $10/sq. ft., and warehouse at $5/sq. ft.
[3] 1,000 gal. stainless steel kettle with coils, pump, ventilation, auxiliaries. etc. Completely preassembled on common base ready for electricity and steam. Delivered foreign port duty free. Availability of steam and electricity assumed.

TABLE 12.—*Permanent investment costs (thousands of dollars) in physical plant and equipment for formulation of pesticides to meet needs for increasing food production by 10, 25, 50, and 100 percent—developing geographical areas and selected countries* [1]

Production Level Increase (Percent)	Developing Geographical Area				Selected Countries	
	Asia [2]	Africa	Latin America	Totals for developing areas	India	Brazil
10	759	330	798	1,887	319	126
25	2,448	1,172	1,573	5,193	962	363
50	6,078	2,976	3,206	12,260	2,332	864
100	16,582	8,239	8,030	32,851	6,364	2,316

[1] Tonnages of pesticides currently used are excluded from calculations; calculations based on $55 per metric ton.
[2] Excludes Japan, mainland China, and U.S.S.R.

mulators in the United States indicates that the capacity of an economical unit ranges from about 800 to 4,000 metric tons of technical pesticide. A production capacity of 1,800 metric tons was used to calculate the number of pesticide formulation plants needed in the different geographical areas (Table 13).

The cost of operating a pesticides formulation facility varies greatly, depending on the kind of pesticide being formulated, its basic cost, the prevailing labor and wage costs in the country, import duties, interest rates, and other considerations.

A United States chemical company with wide experience in the international pesticides field, helped to prepare a general hypothetical study, covering the cost of installing and operating a plant abroad for the formulation of a pesticide emulsion concentrate ready for use by growers. The results of this study should be applicable to any pesticide which can be shipped from the United States to a foreign country for formulation into a finished emulsion concentrate (Table 14).

TABLE 13.—*Number of plants for formulating pesticides to meet needs for increasing food production by 10, 25, 50, and 100 percent—developing geographical areas and selected countries* [1]

Production Level Increase (Percent)	Developing Geographical Area				Selected Countries	
	Asia [2]	Africa	Latin America	Totals for developing areas	India	Brazil
10	8	3	8	19	3	1
25	25	12	16	53	10	4
50	61	30	32	123	24	9
100	168	83	81	332	64	23

[1] Based on a unit plant production of 1800 metric tons of active ingredients annually. Tonnages of pesticides currently used are excluded from calculations.
[2] Excludes Japan, mainland China, and U.S.S.R.

TABLE 14.—*Basic data on operating costs, working capital, pesticide pricing and profit for pesticides formulating plants in developing countries*

I. PROCESSING COST

	Salary	50 percent sal. O.H.	8 hrs/day	16 hrs	24 hrs
A. Capacity in gallons:					
Operating 300 days/yr—6 hrs/batch			400,000	800,000	1,200,000
Tons/yr @8.5 #/gal.—(2000 lb. ton)			1,700	3,400	5,100
Tons/yr @8.5 #/gal.—(2204 lb. ton)			1,543	3,086	4,629
Metric tons/yr active ingredient (Calc. 4.25 lb/gal)			772	1,543	2,315
B. Labor:					
Chemist/Manager per year	$4,200	2,100	6,300	3,150	2,100
Clerk	1,200	600	1,800	900	600
Shift Foreman	1,500	750	2,250	4,500	6,750
Shift Labor 3 @$2/day	1,800	900	2,700	5,400	8,100
8 hr/day operation			13,050		
16 hr/day				13,950	
24 hr/day					17,550
C. Operations:					
Electricity & Steam			1,000	2,000	3,000
Supplies			600	1,200	1,800
Repairs @ 5 percent			5,000	5,000	5,000
Plant O.H. @ 2 percent			2,000	2,000	2,000
Depreciation @ 10 percent			10,000	10,000	10,000
D. Production Costs—Total			31,650	34,150	39,350
Processing/Gallon (cents)			7.9	4.3	3.3
Assumed: Processing costs to double due to seasonal nature of operation.	Per gal		$.16	$.09	$.07
	Per lb		.038	.021	.016
	Per M.T		83.75	46.72	36.15

TABLE 14.—*Basic data on operating costs, working capital, pesticide pricing and profit for pesticides formulating plants in developing countries*—Continued

II. PESTICIDE MANUFACTURING COSTS

(Technical materials @ 25¢/lb Freight Aboard Ship—30¢/lb Cost Insurance, Freight)

Ingredients	*Usage lbs/gal*	*RM cost/ 100 lbs*	*$/gal*	*$/lb a.i.*	*$/M.T. a.i.*
Technical Pesticide	4.25	30.00	1.28	.30	661.20
Solvent	4.25	12.00	.51	.12	264.48
Raw Material Cost	----------	----------	1.79	.42	925.68
(Technical material @ 50¢/lb Freight Aboard Ship—55¢/lb Cost Insurance, Freight)					
Technical Pesticide	4.25	55.00	2.34	.55	1212.28
Solvent	4.25	12.00	.51	.12	264.48
Raw Material Cost	----------	----------	2.85	.67	1476.60

25¢/lb. Technical	*400,000 gal/yr*			*800,000 gal/yr*			*1,200,000 gal/yr*		
	$/gal	*$/lb*	*$/M.T.*	*$/gal*	*$/lb*	*$/M.T.*	*$/gal*	*$/lb*	*$/M.T.*
Raw Materials	1.79	.42	926	1.79	.42	926	1.79	.42	926
Processing Cost	.16	.04	84	.09	.02	47	.07	.02	36
Cost FOB plant	1.95	.46	1010	1.88	.44	973	1.86	.44	962
50¢/lb. Technical									
Raw Materials	2.85	.67	1477	2.85	.67	1477	2.85	.67	1477
Processing Cost	.16	.04	84	.09	.02	47	.07	.02	36
Cost FOB plant	3.01	.71	1561	2.94	.69	1524	2.92	.69	1513

Assumed: (1) Technical pesticide—93 percent active ingredient; (2) Finished product—47 percent active ingredient; (3) Formulation of finished product requires dissolving technical pesticide or dilution to handling viscosity and concentration; (4) Finished pesticide—8.50 lbs/gal; (5) Technical pesticide and solvent 1.00 SG; (6) Shipping containers for technical pesticide and solvent are reusable for E.C.; (7) Technical material imported duty free.

TABLE 14.—*Basic data on operating costs, working capital, pesticide pricing and profit for pesticides formulating plants in developing countries*—Continued

III. WORKING CAPITAL

	400,000 gal/yr	*800,000 gal/yr*	*1,200,000 gal/yr*
A. Working Capital—25¢/lb Technical Pesticide (30¢ CIF):			
RM inventory—2 months	$119,000	$238,000	$357,000
Finished prod—2 months	130,000	250,000	372,000
Accts. Rec.—3 months	230,000	440,000	645,000
Total	479,000	928,000	1,374,000
Less Accts. Pay.—3 mos	179,000	358,000	537,000
Total working capital	$300,000	$570,000	$837,000
Interest @ 15 percent per yr	$45,000	$85,500	$125,000
B. Working Capital—50¢/lb Technical Pesticide (55¢ CIF):			
RM inventory—2 months	$190,000	$380,000	$570,000
Finished prod.—2 months	201,000	392,000	585,000
Accts. Rec.—3 months	350,000	674,000	1,000,000
Total	741,000	1,446,000	2,155,000
Less Accts. Pay.—3 mos	285,000	570,000	855,000
Total working capital	$456,000	$876,000	$1,300,000
Interest @ 15 percent per yr	$68,500	$131,500	$195,000

IV. PESTICIDE PRICING—F.O.B. PLANT

	400,000 gal/yr			*800,000 gal/yr*			*1,200,000 gal/yr*		
	$/gal	*$/lb*	*$/M.T.*	*$/gal*	*$/lb*	*$/M.T.*	*$/gal*	*$/lb*	*$/M.T.*
A. 25¢/lb FAS for Technical Pesticide (30¢/lb CIF) (15 percent money):									
Mfg. cost of Pesticide	1.95	.46	1010	1.88	.44	973	1.86	.44	962
Interest charges 15 percent	.11	.026	57	.10	.024	53	.10	.024	53
S&A—10 percent	.24	.056	123	.23	.054	119	.22	.052	115
Total	2.30	.542	1190	2.21	.518	1145	2.18	.516	1130
Gross Profit before 50 percent tax	.08	.019	42	.04	.009	20	.03	.007	15
Prices fob plant	2.38	.56	1232	2.25	.53	1165	2.21	.52	1145
Gross Sales		$952,000			$1,800,000			$2,652,000	
B. 50¢/lb FAS for Technical Pesticide (55¢/lb CIF) (15 percent money):									
Mfg. cost of Pesticide	3.01	.71	1561	2.94	.69	1524	2.92	.69	1513
Interest charges 15 percent	.17	.040	88	.17	.040	88	.16	.038	84
S&A—10 percent	.36	.085	187	.35	.082	181	.34	.080	176
Total	3.54	.835	1836	3.46	.812	1793	3.42	.808	1773
Gross Profit before 50 percent tax	.08	.019	42	.04	.009	20	.03	.007	15
Prices fob plant	3.62	.85	1878	3.50	.82	1813	3.45	.81	1788
Gross Sales		$1,448,000			$2,800,000			$4,140,000	

TABLE 14.—*Basic data on operating costs, working capital, pesticide pricing and profit for pesticides formulating plants in developing countries*—Continued

V. PROFIT

(Based on plant investment only. Working capital borrowed and interest charged as selling expense)

	400,000 gal/yr	*800,000 gal/yr*	*1,200,000 gal/yr*
Annual Sales:			
Gross profit/gallon	$.08	$.04	$.03
Gross profit/metric ton	41.88	19.84	15.43
Gross profit—dollars	32,000	32,000	36,000
Less taxes @ 50 percent	16,000	16,000	18,000
Net Profit	$16,000	$16,000	$18,000
Return on investment on $100,000 inv. (percent)	16	16	18

This study involved a number of assumptions. Labor costs were chosen to approximate those that prevail in a developing country, such as India, on the assumption that principal consideration is being given to developing countries. On this basis, and with certain other assumptions, we have listed the following:

1. Estimated cost for installation of a basic formulation plant involving a 1,000 gallon capacity stainless steel kettle and necessary auxiliaries, in or adjacent to an existing factory.

2. Processing costs on the basis of one, two, and three shifts per day.

3. Raw material costs, assuming that the technical product is imported duty free and the necessary solvents would be at the same price, whether imported or produced locally.

4. Working capital is to be borrowed at an interest rate of 15 percent annually. In many developing countries, borrowing locally would involve such an interest rate. This is higher than interest rates in the United States, but if hard currency is to be used as working capital, a premium should be added, to cover devaluation risk. This should bring the total consideration of interest on working capital up to, at least, the indicated figure of 15 percent.

5. Pricing. A 15 percent return on direct investment is assumed as a *minimum* return necessary to make such a project of interest to an American business.

6. Since the study was based on two cases, 25¢/lb and 50¢/lb cost for the technical pesticide, this study could be extrapolated to cover any cost for a pesticide, merely by substituting for these values the appropriate raw material cost to be studied.

We chose a plant for the formulation of an emulsifiable concentrate (EC) because this is the simplest form in which to apply a pesticide from the standpoint of equipment. The application of wettable powders on a large scale normally involves equipment which is not readily available in many developing countries. Admittedly, knapsack sprayers are used for small areas, and they are effective for wettable powders as well as emulsion concentrates. However, formulation of wettable powders in many cases is more costly in terms of equipment than formulation of emulsion concentrates. We have felt it desirable to consider, initially, the case with minimum investment.

Estimates from several United States companies of processing costs and working capital requirements for formulation plants are in fairly good agreement. For example, the working capital requirement ranges between 30 and 50 percent of the gross sales of the product. A breakdown of the costs for processing and raw materials and working capital is shown in Table 14.

As costs for operating a formulation plant depend greatly on the cost of the technical pesticide, the data in Table 14 were used to calculate investment for processing, raw material, working capital, and pricing for pesticides ranging in cost from $0.25 to $3.00 per pound (Table 15).

The costs for processing pesticides, including costs for the pesticides and solvents, increase from about $1,000 to $7,000 per metric ton of active ingredient as the cost of the pesticide increases from $0.25 to $3.00 per pound. Similarly, the working capital requirement ranges from about $0.6 million to $4.7 million. Gross sales are estimated to range from $2 million to $15 million (Table 15) in plants which formulate 1,500 to 2,500 metric tons of technical pesticide. The working capital requirement is about 30 to 35 percent of gross sales.

The building of pesticide formulation plants in developing countries will require provisions for some type of credit or financing for both their construction and operation. The precise arrangement which is applicable to a particular country can best be determined after a careful socio-politico-economic study of the individual country.

Storage facilities for formulated pesticides are needed in each major geographical area. The number will vary, depending on the availability of adequate transport to move such products to small villages and farms.

Assuming 9 cu. ft. of usable storage per sq. ft. of floor space and 30 percent allowance for aisles and service, 50 sq. ft. is the estimated space (floor) requirement for storing one metric ton of technical pesticides as formulated products (15 percent active ingredient). Estimates of costs for metal storage buildings on a concrete slab (but without

TABLE 15.—*Estimated operating and working capital requirements, pricing, and profits for pesticides formulation plants*

	Basic Cost of Technical Pesticide															
	$0.25		$0.50		$0.75		$1.00		$1.50		$2.00		$2.50		$3.00	
	lb.	M.T.	lb.	M.T.	lb.	M.T.	lb.	M.T.	lb.	M.T.	lb.	M.T.	lb.	M.T.	lb.	M.T.
Processing costs (labor, utilities, repairs, supply, depreciation, etc.) [1]	.021	47	.021	47	.021	47	.021	47	.021	47	.021	47	.021	47	.021	47
Tech. pesticide and solvent	.42	926	.67	1,477	.92	2,028	1.17	2,579	1.67	3,681	2.17	4,783	2.67	5,885	3.17	6,987
Cost f.o.b. plant	.441	973	.691	1,524	.941	2,075	1.191	2,626	1.691	3,728	2.191	4,830	2.691	5,932	3.191	7,034
Working Capital ($1,000) [2]	656		1,024		1,392		1,760		2,496		3,231		3,967		4,702	
Interest @ 15 percent ($1,000/yr)	98		154		209		264		374		485		595		705	
Pesticide Pricing:																
Mfg. cost of pesticides	.441	973	.691	1,524	.941	2,075	1.191	2,626	1.691	3,728	2.191	4,830	2.691	5,932	3.191	7,034
Interest @ 15 percent	.025	54	.039	86	.053	116	.067	147	.094	208	.123	270	.150	331	.178	392
Selling & Admin.—10 percent	.052	114	.081	179	.111	244	.140	308	.198	438	.257	567	.316	696	.374	826
	.518	1,141	.811	1,789	1.105	2,435	1.398	3,081	1.983	4,374	2.571	5,667	3.157	6,959	3.739	8,252
Gross profit before 50 percent tax	.008	18	.008	18	.008	18	.008	18	.008	18	.008	18	.008	18	.008	18
Prices f.o.b. plant	.53	1,159	.82	1,807	1.11	2,453	1.41	3,099	1.99	4,392	2.58	5,685	3.16	6,977	3.75	8,270
Profit and Sales:																
Gross sales ($1,000,000)	2.1		3.3		4.4		5.6		7.9		10.2		12.6		14.9	
Gross profit @ $18/M.T.	32,400		32,400		32,400		32,400		32,400		32,400		32,400		32,400	
Less taxes @50 percent	16,200		16,200		16,200		16,200		16,200		16,200		16,200		16,200	
Net Profit	16,200		16,200		16,200		16,200		16,200		16,200		16,200		16,200	

[1] Based on formulation of 1,500–2,500 metric tons technical pesticide annually and the data in Table 14.

[2] Based on annual formulation of 1,800 metric tons of technical pesticides.

utilities) are about $4 to $5 per sq. ft. in the United States. Storage facilities in India are calculated at a cost of $1.50 to $1.87 per sq. ft. Assuming a cost of $4 per sq. ft. for a metal building on a concrete slab and that space is required on a 12-month basis, each ton of technical pesticides would require an investment cost in storage facilities of about $200. In fact, however, it is estimated that no more than 40 percent of the pesticides for a given agricultural area would require storage at any one time due to seasonal usage. Thus, the cost of storage would be 40 percent of $200 or $80 per ton.

Calculated total costs of pesticides storage facilities in different geographical areas, to meet requirements for various food production increases, are shown in Table 16.

Some provision should be made for extending credit, loans, or other types of financing to fulfill the needs for the storage facilities shown in Table 16.

TABLE 16.—*Total space and estimated costs of storage facilities to meet pesticide requirements of geographical areas* [1]

Area	Total Pesticides Required (metric tons)	Total Storage Space (thousands of sq. ft.)	Estimated Costs (thousands of dollars)
10-percent increase in food production:			
Asia [2]	13,800	276	1,140
Africa	6,000	120	480
Latin America	14,500	290	1,160
Total	34,300	686	2,744
25-percent increase in food production:			
Asia	44,500	890	3,560
Africa	21,300	426	1,740
Latin America	28,600	572	2,288
Total	94,400	1,888	7,552
50-percent increase in food production:			
Asia	110,500	2,210	8,840
Africa	54,100	1,082	4,328
Latin America	58,300	1,166	4,664
Total	222,900	4,458	17,832
100-percent increase in food production:			
Asia	301,500	6,030	24,120
Africa	149,800	2,996	11,984
Latin America	146,000	2,920	11,680
Total	597,300	11,946	47,784

[1] Present consumption of pesticides excluded; space requirements based on 20 sq. ft. per metric ton and costs on $80 per metric ton.

[2] Excludes Japan, mainland China, and U.S.S.R.

Technological Aspects and Problems

Although many of the basic principles of advanced pest control technology can be exported to developing countries for direct use, maximum efficiency in the use of pesticides to control pests will result only when adequate research, regulatory and education programs are implemented in these countries. However, it should be possible to obtain short-term gains in food production by the direct use of pesticides in the developing countries based on current pest control technology in North America and Western Europe.

Pest Control Research Needs

Research is needed to determine the best method to use to control the pests which limit food production in developing areas. If pesticides offer the best potential for control, adaptive research will be needed to determine the pesticide to use, the amount to apply, the time of application, and efficacy of performance under the local soil, climatic, cropping, and cultural conditions. The proper and effective use of pesticides will also require a knowledge of the life cycle of the pest and its ecological relationships. Adaptive research should have a two-fold purpose: (1) efficacy of pesticide performance, and (2) safety in use.

Adaptive research will be required to develop suitable application equipment and operator know-how to assure the efficient and safe application of pesticides, to minimize harmful residues, and to avoid health hazards. Research will also be required to predict and assess ecological shifts in populations of birds, disease organisms, insects, nematodes, weeds, and other pests. Basic and applied information will be necessary on soil, water, crop varieties, climate and other climatic and edaphic characteristics essential to the efficient and safe use of pesticides. Pest populations must be monitored to detect ecological shifts and the development of resistence to pesticides. The estimated requirement for technical and other manpower for research is shown in Table 17.

Suitable methods are not available to cope with some pests and these will require both basic and applied research to develop efficient and effective control measures.

Regulatory Program Needs

Pesticides, or other effective pest control measures, will be required on a markedly increased basis in the developing countries if food production is to be increased by 10 to 100 percent. For the most part the training and experience of the farmers are wholly inadequate to use many

TABLE 17.—*Estimated requirements for technical manpower to implement expanded pesticides programs*

Production Increase Level (Percent)	Developing Geographical Areas								Selected Countries			
	Asia [1]		Africa		Latin America		Totals for developing areas		India		Brazil	
	R&D	Other	R&D	Other	R&D	Other	R&D	Other	R&D	Other	R&D	Other
Manpower for Production of Pesticides: [2]												
10	44	48	22	24	44	48	110	120	22	24	11	12
25	154	168	77	84	99	108	330	360	55	60	22	24
50	385	420	187	204	198	216	770	840	143	156	55	60
100	1,034	1,128	517	564	506	552	2,057	2,244	396	432	143	156
Manpower for Formulation of Pesticides: [3]												
10	16	48	6	18	16	48	38	114	6	18	2	6
25	50	150	24	72	32	96	106	318	20	60	8	24
50	121	366	60	180	64	192	245	738	48	144	18	54
100	336	1,008	166	498	162	486	664	1,992	128	384	46	138
Adaptive Pesticides Research Program: [4]												
10	238	476	203	406	167	334	608	1,216	112	224	56	112
25	476	952	406	812	334	668	1,216	2,432	224	448	113	226
50	952	1,904	609	1,218	504	1,008	2,065	4,130	336	672	169	338
100	1,190	2,380	812	1,624	672	1,344	2,674	5,348	448	896	226	452

Pesticides and Pest Control Regulatory Program: [5]												
10	180	220	90	110	90	110	360	440	72	88	26	36
25	252	308	130	158	135	165	517	631	108	132	40	55
50	324	396	195	240	215	246	734	882	144	176	60	81
100	504	616	261	319	270	330	1,035	1,265	216	264	80	110
Pesticides and Pest Control Educational Program: [6]												
10	170	--------	145	--------	120	--------	435	--------	80	--------	40	--------
25	340	--------	290	--------	240	--------	870	--------	160	--------	80	--------
50	510	--------	435	--------	360	--------	1,305	--------	240	--------	120	--------
100	680	--------	580	--------	480	--------	1,740	--------	320	--------	160	--------

[1] Excludes Japan, mainland China, and U.S.S.R.

[2] R&D personnel are about 50:50 chemical engineers and mechanics; other personnel are about 20 percent technicians and the remainder operators, both with training equivalent to high school education plus experience.

[3] R&D personnel are chemical engineers and maintenance mechanics; other personnel as in footnote 2.

[4] Typical adaptive research units for major political and agricultural areas consist of at least 7 scientists representing the disciplines of agricultural engineering, biologist (rodents & birds), entomology, nematology, plant pathology and weed science. Areas of concentration for these teams are grain crops, pulses, oilseeds and other crops.

[5] Typical unit for major political area or country consists of the following: Registration—1 registrar, 1 safety officer (pharmacologist), 5 pesticide performance officers (entomologist, nematologist, plant pathologist, weed scientist, wildlife specialist), 1 chemist, and 7 other; Enforcement—2 chemists, 2 inspectors and 2 technicians.

[6] No estimates are given for equivalent of the United States county agricultural agent but these will be required in all developing countries. The estimates are for extension pest control specialist teams in major political areas or countries consisting of the disciplines of biology (rodents), entomology, nematology, plant pathology, and weed science. Areas of specialization for each team are grain crops, pulses, oilseeds and other crops.

of the potent pesticides safely. It is likely that the residues, tolerances, and registration of most pesticides to be used in developing countries will have been carefully studied in developed countries. Nevertheless, it is imperative that some regulatory control be exercised in the developing countries. Pesticides should be registered in the country where they are to be used and provision should be made for enforcement to insure against adulteration, mislabeling, misuse, etc. Typical regulatory units are described in Table 17, note 5.

In addition to simple and practical systems for the registration of pesticides, programs for the eradication of certain pests may be desirable. Pests such as field rats and desert locusts may be so serious that individual control efforts would not effectively increase food production.

The regulatory programs needed in the developing countries, to insure the efficient and safe use of pesticides, should not duplicate programs in other countries, but rather they should be developed to meet national needs. For example, it would be foolish to repeat the toxicological studies conducted for the registration of pesticides in the United States and the other developed countries.

Education and Manpower Needs

The safe and effective use of pesticides in the developing countries will require extensive research and educational programs. Technical manpower is largely lacking in these countries, and educational programs are needed to train a large number of specialists.

Scientists and engineers will be required to run pesticide formulation plants in developing countries. We believe the manufacture of technical grade pesticides should be undertaken in developed countries with demonstrated capability in this field. As experience in operating pesticide formulation plants in the developing countries is gained, some plants can be built for the manufacture of technical pesticides. Eventually there will be a need for management skills in the manufacture, formulation, distribution and sale of pesticide products. Discipline areas include chemical engineers, formulation chemists, organic chemists, mechanics, economists, and marketing specialists, among others.

There are not enough scientists available to conduct the adaptive research required on pesticides in each of the major agricultural areas. Educational programs must be devised to train additional crop protection specialists. Disciplines include entomology, plant pathology, nematology, weed science, agricultural engineering and biology (to deal with rodents and bird pests).

As a part of the overall program in pest control, extension specialists will be needed to work with village agricultural agents to assure that pesticides are used by farmers in the proper way to control pests, yet safeguard human health and other values. Educational programs should provide for the training of technicians to do the needed regulatory work in the developing countries. Until such a time as farmers can be trained to use pesticides safely, custom and other specially trained technicians should be trained to apply pesticides on a fee basis.

The estimated minimum technical and other manpower requirements for pest control research, education, and regulatory programs and for the formulation of pesticides, are shown in Table 17. While manpower needs are shown for the basic manufacture of pesticides, much of it may best be obtained from the developed countries where the pesticides will probably be produced.

Pesticide information centers should be established in the developing countries to obtain, synthesize, evaluate, and utilize the voluminous literature on pesticides, and their use, which is already available in the developed countries. The published literature on pesticides and pest control is tremendous.' It should constitute one of the most valuable resources for establishing effective pest control programs in the developing countries.

There is a general tendency to overestimate the amount of advanced pest control technology that can be directly exported to, and used in, countries where research, regulatory, and education programs on pesticides do not exist, or where they have only been intiated recently. A realistic appraisal of the opportunities for direct exportation of the pest control technology will quickly reveal that well-balanced research, regulatory, and education programs will be needed in the developing country if any long-term gains in food production are to result from improved pest control. Another vitally important consideration is that pesticides use must be properly integrated and balanced with other production inputs, such as fertilization, irrigation, mechanization, and the use of improved crop varieties.

Safety Problems

The rate of increase in use of pesticides by the devolping countries is likely to be rapid if food production requirements are to be met. Along with rapid acceptance of pesticides will go certain potential hazards associated with their use. In the developed countries where the effective pesticides have been introduced over a period of time, sufficient experience and background knowledge have been built up to provide a base upon which to establish safe practices of handling potent pesticides at all stages from the manufacturing process to the farmer who uses them. Even with the relatively sophisticated knowledge of developed countries, there are hazards associated with the handling and using of those pesticides which are highly toxic to man, animals, wildlife. Thus, intense educational safety programs are necessary. Constant attention to safety is required to avoid unfortunate and careless occurences.

In the developing countries, where the backlog of experience with pesticides is limited, or lacking, where trained personnel, skilled in pesticide safety procedures are rare, the problem of avoiding accidental, careless, or unknowing contacts with hazardous pesticides must be given particular attention. In many developing countries it is recommended that the handling and application of certain pesticides which have high oral or dermal toxicity (e.g., parathion) be limited to specially trained or licensed personnel until such time as 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.

Findings and Summary

1. Plant pests, such as diseases, insects, nematodes, rodents, and weeds, must be controlled if world food production needs are to be met.

2. The use of pesticides provides the best current approach to the control of most of the serious pests that impede efficient food production. A certain degree of dynamic stability of pesticidal and biological pest control will probably be achieved in the future. For the foreseeable future, however, it is expected that pesticide usage will increase in proportion to the needs for food production in the developing countries.

3. Linear relations among levels of pesticides and fertilizer usages and yields of food crops were shown to occur in those areas of the world where adequate data were available. These relations can be expressed mathematically in terms of past and current food productivity.

4. Estimates of future pesticides inputs, to increase the food production of developing countries were mathematically determined. The projections for future pesticides requirements of developing countries approximate present pesticide usage of developed countries which currently have the desired levels of food production.

5. Increased usage of pesticides in developing countries may produce genetic and ecological alterations in the control susceptibility of pest populations. These changes caused by pesticide usage will necessitate continued development of new pesticidal chemicals that will, in turn, require new manufacturing and formulation plants and adequate research, education, and regulation programs.

6. The requirements for technical pesticides to increase food production in developing countries can be met best by expanding manufacturing facilities in developed countries. Technical grade pesticides can be formulated, in most cases, in developing countries.

7. Manufacturing, formulation, and storage facilities for pesticides must be expanded in the developing countries to provide the pesticides needed to increase food production. Arrangements for financing the construction of formulation plants and storage facilities and extending credit to farmers should be provided. Private industry, rather than governments, should be encouraged to manufacture, formulate, distribute, and sell pesticides in developing countries.

8. Adaptive research, education, and regulatory programs should be established to insure that pesticides are used effectively, economically, and safely.

9. A summary of pesticides requirements and associated financing, and technical manpower requirements, to increase the food production of the developing countries is shown in Table 18. Rounded figures covering the principal requirements for progressive, 10 percent increase levels of production are shown in Table 19.

10. To obtain maximum increases of food production by developing countries increased usage of pesticides must be properly integrated and balanced with other production inputs such as fertilization, irrigation, mechanization; and the use of improved crop varieties (Figure 6).

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TABLE 18.—*Summary of increases in pesticides requirements, pesticides manufacturing, formulating and storing facilities and costs, and technical manpower needs to increase the food production of developing countries* [1]

Input Requirements for Developing Countries	Increased Food Production Levels							
	Cumulative Totals				Net Increments			
	10 percent	25 percent	50 percent	100 percent	10 percent	25 percent	50 percent	100 percent
Pesticides Increase, m. tons tech.	34,300	94,400	222,900	597,300	34,300	60,100	128,500	374,400
Manufacturing Facilities, tech.:								
Number, 3200 m. ton capacity	10	30	70	187	10	20	40	117
Permanent Investment ($1,000,000)	48.4	133.0	314.3	842.2	48.4	84.6	181.3	527.9
Working Capital ($1,000,000)	22.7	62.4	147.1	394.3	22.7	39.7	84.7	247.2
Total Manufacturing Investments ($1,000,000)	71.1	195.4	461.4	1,236.5	71.1	124.3	266.0	775.1
Formulation Plants:								
Number, 1800 m. ton capacity	19	53	123	332	19	34	70	209
Permanent Investment ($1,000,000)	1.9	5.2	12.3	32.9	1.9	3.3	7.1	20.6
Working Capital ($1,000,000)[2]	33.4	93.3	216.5	584.3	33.4	59.9	123.2	367.8
Total Formulation Investments	35.3	98.5	228.8	617.2	35.3	63.2	130.3	388.4
Storage Facilities:								
Space (1,000 sq. ft.)	686	1,888	4,458	11,946	686	1,202	2,570	7,48
Construction Costs ($1,000,000)	2.7	7.5	17.8	47.8	2.7	4.8	10.3	30.0
Total Costs for Manufacture, Formulation & Storage	109.1	301.4	708.0	1,901.5	109.1	192.3	406.6	1,193.5
Price of annual product [3] ($1,000,000)	106.3	292.5	690.8	1,851.0	106.3	186.2	398.3	1,160.2
Increased cost to farmer [4] ($1,000,000)	170	460	1,080	2,900	170	290	620	1,820
Technical Manpower for Pesticides:								
Manufacture	110	330	770	2,057	110	220	440	1,287
Formulation	38	106	245	664	38	68	139	419
Research	608	1,216	2,065	2,674	608	608	849	609
Education	435	870	1,305	1,740	435	435	435	435
Regulation	360	517	734	1,035	360	157	217	301
Total	1,551	3,039	5,119	8,170	1,551	1,488	2,080	3,051

[1] Asia (except mainland China, Japan, and USSR), Africa, and Latin America.

[2] Based on formulation of a $1.00-per-lb technical pesticide.

[3] Does not include added costs for local storage and handling: based on f.o.b. (plant) pricing of $3099/m. ton for $1.00-per-lb technical pesticide.

[4] Assumes 56.5 percent total mark-up in competitive marketing; farmer cost $4850/m. ton (=$2.20/lb).

TABLE 19.—*Pesticides needed to increase food production on areas now under cultivation in Asia,[1] Africa, and Latin America by the percentages indicated*

[Millions of U.S. Dollars]

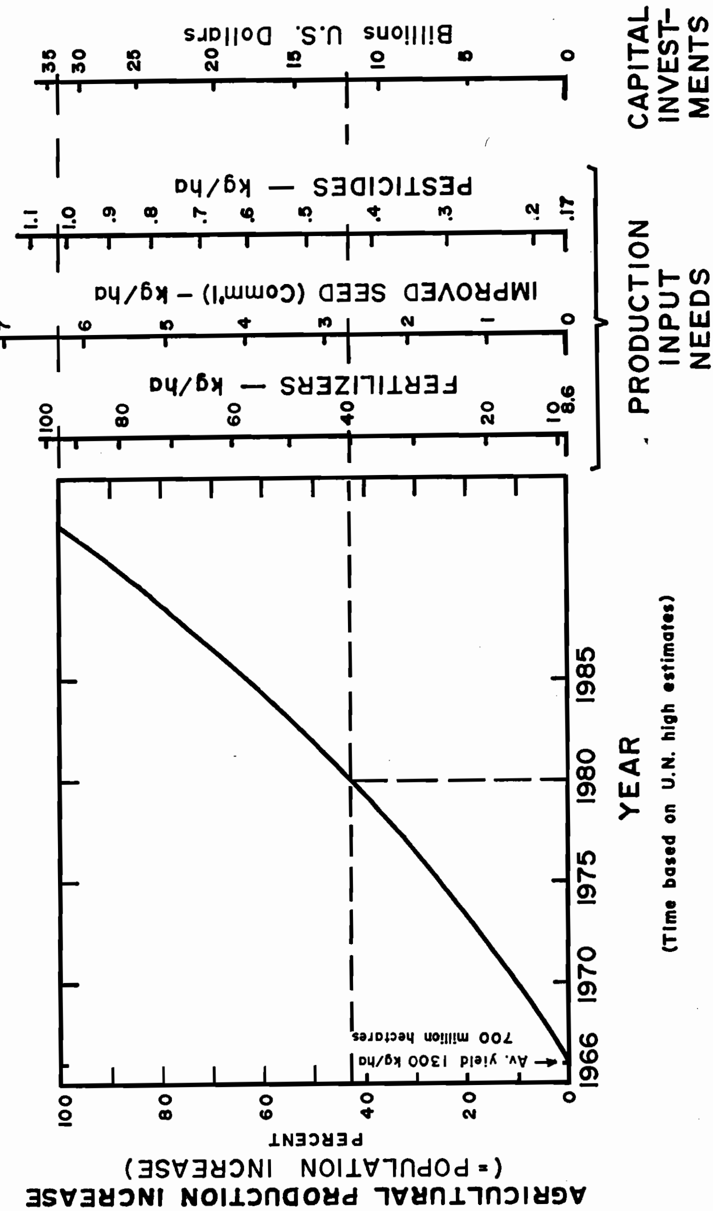
Percent Increase Agricultural Production	Tonnage Needed (Metric Tons)	Capital		Total Annual Cost to Farmers [4]
		Manufacturing [2]	Formulation & Distribution [3]	
------------------------------	120,000	----------------	----------------	$580
10 ------------------------------	155,000	$70	$40	750
20 ------------------------------	190,000	145	80	920
30 ------------------------------	235,000	240	130	1,140
40 ------------------------------	285,000	340	185	1,380
50 ------------------------------	340,000	455	245	1,650
60 ------------------------------	405,000	590	320	1,965
63 ------------------------------	420,000	630	335	2,035
70 ------------------------------	470,000	725	390	2,280
80 ------------------------------	545,000	880	475	2,645
90 ------------------------------	630,000	1,055	570	3,055
100 ------------------------------	715,000	1,230	660	3,470

[1] Except mainland China, Japan, and U.S.S.R.
[2] Calculated at $2070/m. ton.
[3] Formulation, $1033/m. ton; storage facilities, $80/m. ton; total, $1113/m. ton.
[4] Calculated at $4850/m. ton (=$2.20/lb.) for product containing $1.00/lb. tech. pesticide.

Figure 6

Interrelations of 3 Production Inputs and Investments in Food Production

ASIA (except mainland CHINA and JAPAN), AFRICA, and LATIN AMERICA



Estimates of the integrated requirements for fertilizers, seeds, pesticides, and increased total capital investments to meet the agricultural production needs of three developing areas.

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AGRICULTURAL POWER AND EQUIPMENT

By G. W. Giles, Raleigh, N.C.

Introduction

This report defines the problems in power and equipment associated with increasing yields in the developing countries, identifies the kinds of power and equipment needed for field production, estimates the quantities needed for specified time periods, estimates the cost of this added input to farmers, estimates the capital costs and manpower requirements for manufacturing plants, and lastly, makes recommendations pertaining to implementation. Estimates of the requirements for tractor fuel and local repair and service facilities are planned as a subsequent study.

The estimates, of course, will be general and therefore much detail will need to be worked out for implementation at the national level. Perspective and planning on a broad scale are of necessity in the first instance. A framework is provided later for more informed detailing of specific local requirements.

Importance, Status, and Problems

The power for an operational farming system including the type of equipment is planned around one of the following sources of power:

1. Human.
2. Human + Animal.
3. Human + Animal + Mechanical.
4. Human + Mechanical.

These four are arranged in the order in which agriculture progresses from a low standard of living, labor productivity, and energy input per unit area to a higher level. The relative proportion of human energy input in number one is greatest and decreases to a minimum in number four. The next step beyond number four is automation, but it is of little concern in this study.

The developing countries are utilizing all four of these power sources in varying proportions depending upon the pecularities of their situation and environment.

Since the problem of the developing countries is one of increasing the production of food, the highest priority for power and equipment should be for kinds that will contribute to increased yields. Power and equipment accomplish this through more *timely* and *effective* operations. Examples are better seedbed, placing fertilizer properly, and uniform timely distribution of chemicals. Of secondary importance is the matter of increasing labor efficiency and reducing drudgery.

It is important to note that power and equipment do not consume food sources of energy as do work animals. According to Johnson (5) "power (mechanical) and equipment are the products of non-food energy and they are converters of non-food energy in performing the agricultural operations normally performed by men and animals. It is appropriate, then, to consider mechanization as a means of substituting non-food energy for food energy in order to make additional food available for the growing urban population."

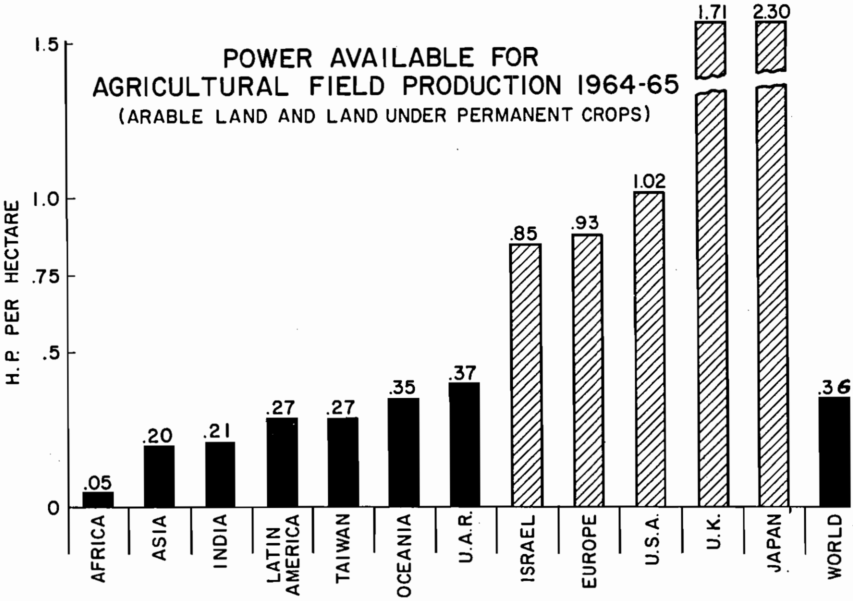
Power Analysis and Goal

A tentative assessment of the existing horsepower availability for agricultural field production in various countries, regions, and continents by kinds of power is presented in Table 1. Data used in calculating the horsepower per hectare are given in Table 11 in the Appendix. Figure 1 shows the totals in bar form arranged for easy comparisons in order of available power.

Stationary power units for irrigation and other uses are not included in the power analysis. The intention here is to assess approximately the power now available for field work. It is recognized that a refined and complete study should include all power units that contribute to increased production.

The data for making the power calculations are generally for the year 1964 and are taken from the 1965 FAO Production Yearbook, volume 19. In some instances, however, adjustments have been made

Figure 1



on the basis of more recent information supplied by experts. For example, the 2.18 million garden tractors reported for Japan are for 1963. According to A. D. Faunce of FAO, the number is increasing at the rate of 350 thousand per year, so, a value of 2½ million was taken for 1964.

Arable land and land under permanent crops, which includes land for temporary fallow, temporary meadows for mowing or pasture, fruit trees, vines, shrubs, and rubber plantations as well as crops, are defined as the agricultural area. It is reasoned that all of these require varying degrees of power and therefore, should be used to calculate the power rate. Further, FAO states that reports from Asia, Africa, and South America frequently provide only the area under major crops, even though the request is for land area under the broader classification.

An estimate of the persons actually engaged in performing field and related work was not available. Therefore, FAO's figures on the number of both sexes engaged in agricultural operations were used. These figures include all economically active persons engaged prin-

TABLE 1.—*Available horsepower per hectare of arable land and land under permanent crops* [1]

	Africa	Asia	India	Latin America	Taiwan	Oceania	U.A.R.	Israel	Europe	U.S.A.	U.K.	Japan	World
Tractor [2]	.03	.02	.008	.18	.080	.33	.181	.815	.81	1.0	1.57	.004	.266
Garden Tractor [3]	--------	.03	--------	--------	.063	.006	--------	.007	.02	.014	.03	2.06	.024
Animal	.01	.10	.145	.07	.063	.011	.065	.010	.08	--------	.02	.088	.044
Human	.01	.05	.056	.02	.113	.001	.12	.016	.02	.002	.09	.148	.024
Total	.05	.20	.21	.27	.27	.35	.37	.85	.93	1.02	1.71	2.30	.36

[1] Calculations based largely on values taken from FAO's 1965 Production Yearbook (See Table XI in Appendix).

[2] Defined by FAO as wheel and crawler tractors developing over 8 H.P. and used in agriculture.

[3] Defined by FAO as tractors developing under 8 H.P. and/or weighing under 850 kgs and used in agriculture.

cipally in agriculture, forestry, and fishing. Obviously this will not be very accurate but it is the closest meaningful figure available.

The proportion of people engaged in agricultural operations in Europe is unusually high, causing skepticism about the validity of this figure. However, since Europe uses large amounts of mechanical power, the contribution of human power to the total, even though inflated, would be insignificant.

The initial and most important question is: What is the minimum amount of power per hectare needed to optimize yields? An attempt to arrive at an answer objectively, is presented in Figure 2. Horsepower per hectare is plotted against the yield per hectare of all cereals; pulses; oilseeds, sugar crops (raw sugar), potatoes, cassava, onions, and tomatoes for the countries, regions, or continents used in Table 1. The results in Figure 2 indicate that the minimal power per hectare for developing countries should fall within a range of 0.5 to 0.8 horsepower. The logarithmic scale for yields helps to emphasize the 0.5 H.P./Ha as a marked inflection point in the slope of the curve. For calculating the estimates required in this study, 0.5 H.P./Ha should be a reasonable goal. United States, Europe, United Kingdom, and Japan are probably over powered for the optimum where production commands the main attention. These high production, high standard of living countries are also concerned with labor efficiency and convenience as dominating criteria.

To make a more detailed and informative analysis, one should include all of the nations used in "Changes in Agriculture in 26 Developing Nations" [1] and "Crop Production Levels and Fertilizer Use," by Williams and Couston, J. W. (10), particularly those that fall within the 0.4 to 1 H.P./Ha class. To assess the power more accurately, one should get more precise estimates of the horsepower capacities of human labor, animals and tractors used in agriculture than the author was able to secure in the time available. Power for irrigation and stationary machine usage directly related to food crop production and preservation should be included also. An index of yields/Ha that weighs the data according to crop areas, tonnage, and relative energy requirements for production should be used. Perhaps the yield-value index as developed and used by FAO and reported by Williams and Couston (10), will be satisfactory for this purpose. *It is recommended that such a study be undertaken.*

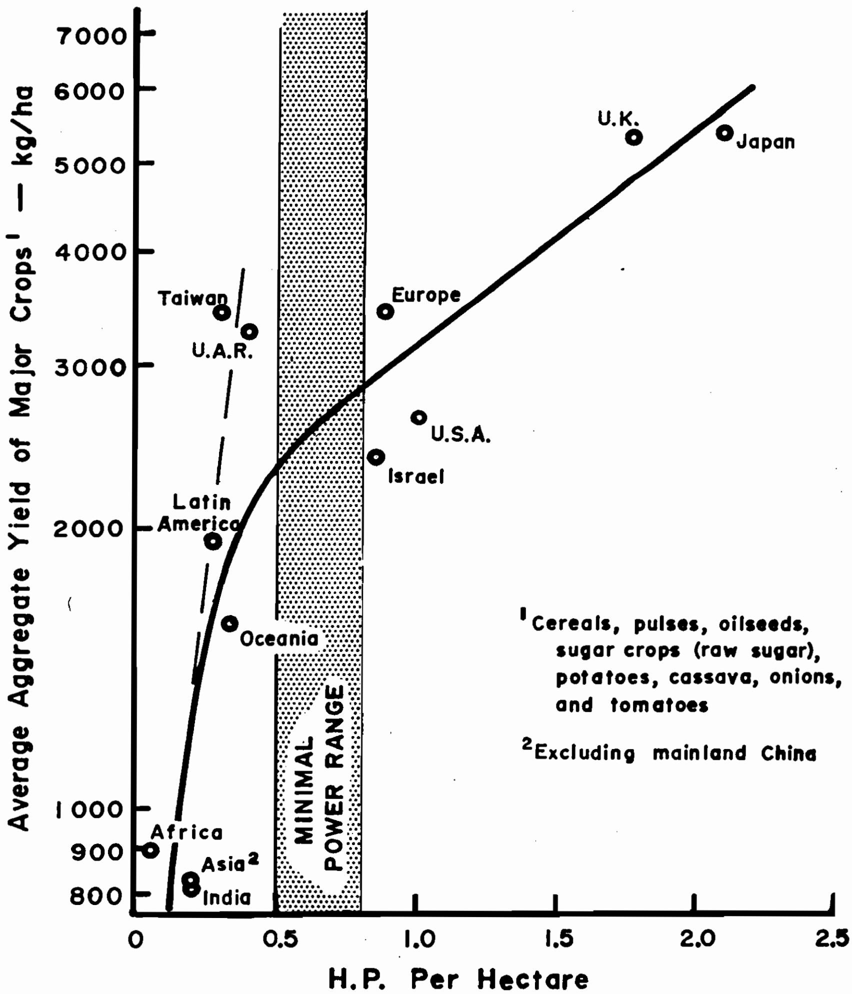
---

[1] "Changes in Agriculture in 26 Developing Nations, 1948 to 1963," Foreign Agricultural Economic Report, No. 27, Economic Research Service, USDA, November 1965.

Figure 2

RELATIONSHIP BETWEEN YIELDS IN KG/HECTARE AND POWER IN HORSE POWER PER HECTARE

Major Food Crops



[1] Cereals, pulses, oilseeds, sugar crops (raw sugar), potatoes, cassava, onions, and tomatoes

[2] Excluding mainland China

One must keep in mind that Figure 2 does not necessarily prove that greater power applications to agricultural operations in the developing countries will contribute to increased yields. It does give more to support the thesis, and it does provide a more scientific base for programming needs that would not be possible otherwise.

A question can be raised as to why Africa, Latin America, and Asia cannot do as well in increasing yields as Taiwan and U.A.R., both of whom have proportionally large inputs of human power. A partial answer may be found in Table 2 in comparing some of their characteristics with India. The data were taken from "Changes in Agriculture

TABLE 2.—*Characteristics of land and other factors in U.A.R., India, and Taiwan*

	Ratio of irrigated to cultivated land	Quality of potentially arable land	Health Rating	Calorie Level Percent	Educational Rating
Taiwan	61.8	1	1	102	2
India	19.9	2	3	84	3
U.A.R.	100.0	1	3	108	3

in 26 Developing Nations."[2] The most important difference is the ratio of irrigated to cultivated land. Where a dependable source of irrigation water is available, timeliness is not as important in seed or plant bed preparation, except in a three crop/year system, because one can extend the time to adequately prepare a good bed with little loss, if any, of yields. This is one of the reasons for puddling soil for paddy. Also, the energy requirement per unit area for tillage is less if the soil moisture can be maintained at the optimum. The tough "black cotton" soils of India cannot be tilled satisfactorily with bullocks except at a very critical moisture level. During the months preceding the onset of the monsoon, this land cannot be tilled with country equipment and animal power. Farmers and extension workers in this area say that additional power is one of their more critical needs.

High quality land as indicated in Table 2 should be more productive for a given set of inputs. Toughness to mechanical manipulation is not included in the quality rating; yet it affects power requirements more than any one other factor. Informative sources say the soils of Taiwan are easily worked.

[2] Ibid.

The general level of health and strength of the agricultural workers are also important factors.

Discussions of Studies and Recommendations

There has been little research and consequently there is limited information on the minimum amount of power to optimize yields. Swamy Rao's review of research findings in India indicated that generally good tilth and timely sowing resulted in higher yields (8). He concluded that in general there is a loss in yield for many crops to the extent of 1 percent per day of late sowing beyond an optimum period of 10–15 days. One reference reported that the yield increased with the frequency of tillage up to a limit of nine plowings.

David Hopper and Jai Krishman analyzed input-output data on wheat in 1963 from the Ludhiana package district of India.[3] Every extra plowing with the country plow in preparing the seedbed added about 35 pounds of grain per acre. This value was highly significant and was applicable for the entire district. The number of plowings usually varies from 4 to 9, depending upon the time and power available. The problem therefore is getting a good seedbed quickly, which can be achieved only by the application of more power per unit of time.

If all of the bullocks in Raipur district of India were put to work preparing the unirrigated paddy land with the country plow, it would take them about 50 days. If the mouldboard plow were substituted, it would take about 27 days. These unirrigated fields cannot be tilled until some rain falls at the start of the monsoon season and the time available from the beginning of the rains is about 15 days. The result is inadequate or delayed preparation on some fields with a probable loss in yields.

Pande and Bhan (7) of the Department of Agricultural Engineering of the Indian Institute of Technology at Kharagpur, India studied the effect of varying degrees of soil manipulation on yield of upland paddy. Greater manipulation in preparing the field for sowing gave significantly higher grain yields and was more effective in controlling weeds. A 40 percent increase was obtained for the best treatment (III G) over the kind of treatment (III F) commonly used in Raipur district because of their limited number of bullocks (see Figure 3).

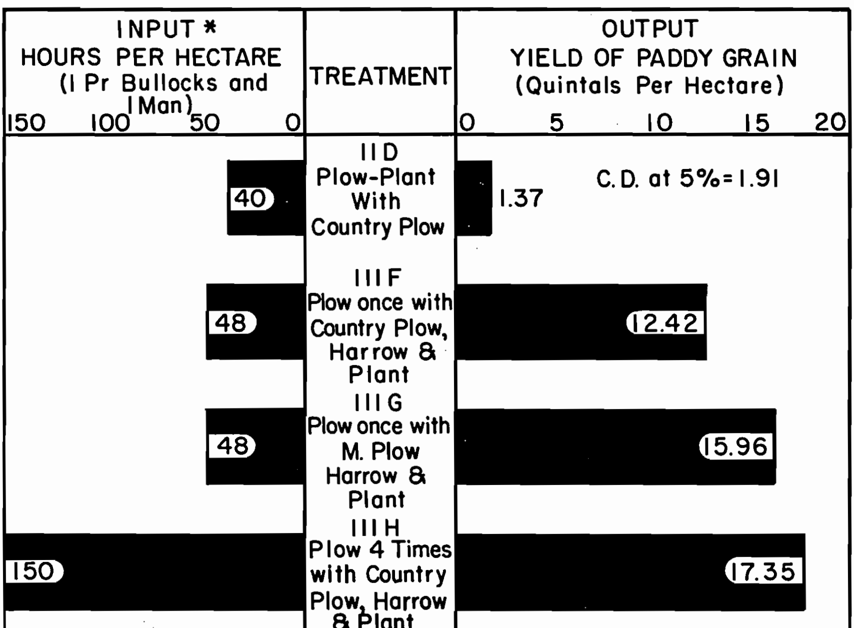
[3] Unpublished data from records furnished by Ludhiana District, IADP, 4 Tolstoy Marg, New Delhi, 1963.

More humans could be put to work with hand tools but this is not likely to be done to any significant extent in India. These people are not motivated in this direction, even under the influence of a spirited extension program.

Punjab Agricultural University and Ohio State University staffs made estimates in 1963 of labor requirements for production, harvesting, and marketing of crops in Punjab, India. From these estimates, Figure 4 was constructed for a two crop per year rotation of maize and wheat. The critical peak labor demand is in November when the maize is harvested and wheat put in. It is in this period, particularly,

Figure 3

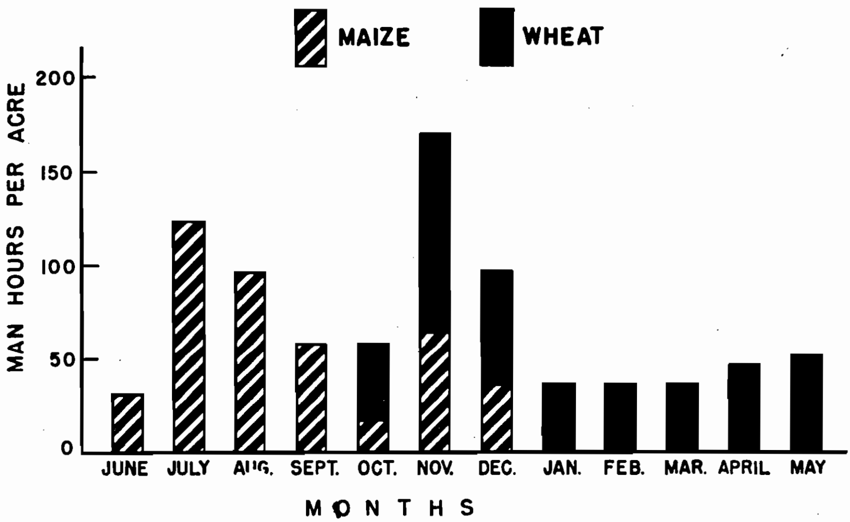
EFFECT OF VARYING DEGREES OF SOIL MANIPULATION ON YIELD OF UPLAND PADDY



*ESTIMATED. DOES NOT INCLUDE TIME FOR PLANTING.

Figure 4

LABOR REQUIREMENTS



that power would contribute to *timely* operations. Labor wage rates are about double during this period.

Loyd Johnson (5) of the International Rice Research Institute (IRRI) in the Philippines has studied mechanization from the standpoint of utilizing power to keep the land in production more days per year. He said the following about land preparation:

> The importance of mechanized land preparation and lesser operations are still questioned by some people who would prefer to continue the use of animal or manpower. However, animal or manpower is slow, consumes large quantities of food, and results in loss of productive land time.
>
> . . . If a man owns one hectare and has no work animal, he will require 200 to 333 man-hours for a single spading of the farm, or 20 to 30 days of hard labor. The weeds will be growing back during this period, and 20 and 30 days productive time will be lost, which could amount to a minimum of 200 to 300 kg of rice production. With one animal, the time will be reduced to 4 to 7 days and only 40 to 70 kg of lost production. As the size of the power unit increases, the lost production rapidly decreases. When the

rainy season is short, rapid land preparation insures good weed control and best use of the rainy season. Following the harvest of the rice crop, rapid land preparation and re-seeding also make use of the residual soil moisture to grow a crop of wheat, gain sorghum, or pulses.

Swastik Manufacturers, Limited, of Secunderabad, India, developed a modern 3-row grain drill capable of being pulled by a pair of bullocks. It included the side placement of fertilizer. Taneja and Giles (9) found that sixty trials in 1964–65 in the wheat growing areas of India gave a significant 12.5 percent increase in the yield of wheat and a 39.5 percent decrease in the hours per acre over the conventional practice. Everything, including seedbed preparation, seed, fertilizer, and pesticide applications was the same on both plots, except the drill. The farmers operated the drill for the first time under the direction of the extension workers. Some farmers obtained as high as 50 and 60 percent increases in wheat yields.

Cost-benefit analyses on the drill by Morse and Giles (6) indicated substantial economic gains for a wide range of farm conditions. Considering only a 10 percent increase in yields, the purchase of a drill would bring a 13 percent return to a farmer in Ludhiana District with 4 acres under wheat, a 28 percent return on 6 acres, and a 59 percent return on 10 acres. If the drill is used on 15 acres, it would pay off its initial cost in one year's time. The drill is capable of handling 50 acres a season.

More beneficial and exciting results have been achieved with a one row planter with metering and side placement of fertilizer. This particular machine was developed by the Agricultural Implements and Power Development Center, Allahabad Agricultural Institute, Allahabad, India. In 1965, 18 trials with maize gave a 40 percent increase in yields and a 36 percent decrease in hours per acre over the conventional practice according to Giles (4).

As in drilling and planting, more efficient utilization of fertilizer in paddy production will call for more power and new equipment. Finjrock and Donahue (3) found that up to 50 percent more rice is produced when the ammonium forms of nitrogen are placed two inches to four inches deep, in rows nine to twelve inches apart, as compared to broadcast applications. Working the fertilizer well into the puddle is the next more efficient practice.

The hand-placing of rice seedlings one at a time causes one period of peak labor demands. Seemingly, a fully automatic method of picking up and depositing single plants is very difficult to achieve economically. Attention has been given to such a development in India, United States, Japan, Italy, and elsewhere, with limited success. It is easy to meter and place seed accurately but not transplants. The best opportunity therefore may be in direct field seeding with conventional drills. Tanjore District in India did this in 1964 and achieved 23 percent increase in yields on a limited number of trials.

There are few or no data on the effect on yields of using modern spraying and dusting equipment. The existing improved equipment in many of the developing nations is a pressure tank or hand pump with a single nozzle. It is generally agreed that the erratic waving of this nozzle, as commonly practiced, as the operator walks across the field does not give the uniformity of distribution required for good pest control. Perhaps the greatest gain in yields through power and equipment can be achieved through the use of power sprayers and dusters.

Timely harvesting and improved harvesting and threshing equipment will not increase the yield but will help to save what is produced. The following are excerpts from the "State of Food and Agriculture, 1966" by FAO:[4]

> The choice of optimum harvesting time is an important element. Where early harvesting (paddy rice) is carried out, wastage will be high because of the presence of chalky and immature grains. Where the harvest is late, the greater number of sun-cracked grains results in a high percentage of brokens and wastage in the milled product. . . . The Agricultural Research Institute of Gyogen near Rangoon, Burma, has shown that for long grain paddy a loss of 2 percent in head rice is suffered for every day the harvest is postponed, once the grain is ripe. For the medium and short grain varieties, the figures are around 0.8 percent.

Johnson (5) made the following statement regarding the harvesting of rice:

> Harvesting is the last major operation in the crop cycle. As the grain or other crops mature, losses begin and become serious when the crop is left in the field past maturity.
>
> Studies should be made on grain losses or losses of other crops due to shattering, rat damage, etc. when left in the field past the

[4] "Rice in the World Food Economy: Situation and Outlook in the International Rice Year 1966," Processing and Storage, The State of Food and Agriculture, p. 166, FAO, Rome, 1966.

Earliest period at which harvest could occur. Once the crop is mature, the plot is no longer efficient in absorbing sunlight, and losses when occur detract from the already mature crop. When we add these losses to the losses of land production, we exceed 10 kg of palay per ha per day cost of the idle land.

The development of combines and threshers to speed up the harvesting is important both to prevent losses of the crop which is already grown and also to facilitate rapid harvesting, plowing, and re-planting to make use of the residual soil moisture. This aspect is of major importance to agricultural engineers in improving the agriculture of developing countries, and it is one in which mechanization can be most effectve where multiple crops are possible.

A team of experts developing a program for the Government of India to increase the outturn or yield of edible rice from paddy made the following statement in a report by Faulkner, et al. (2) with regard to harvesting:

Concentrate agricultural engineering research resources on the problems of developing mechanical paddy harvesters, threshers, and dryers to work under improved conditions of production and handling with modern storage facilities.

While it may be possible to teach farmers to harvest, thresh, dry and store paddy by modest improvements of currently used techniques it is doubtful if the level of adoption obtained would improve milling quality of paddy very much. Mechanical threshing, at the optimum moisture content, bulk handling, off-farm mechanical dryers, and off-farm fully protected scientific storage are essential to increase rice outturn to the 68 to 72 percent level but are less important at lower levels of rice outturn. Mechanical harvesting, threshing at 20 to 24 percent moisture followed by immediate delivery to a mechanical dryer, and modern storage facility would permit farmers to plant a second crop 10 to 30 days quicker. These are very important gains both to the farmer and to the nation's supply.

It is recommended that applied research be encouraged in the developing countries to get more data for drawing valid conclusions regarding the power-yield and implement-yield relationships. Applied research should also be carried out on improved "equipment-methods." There are three critical areas: (1) tillage machines and methods to re-

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duce the power and the time to prepare an adequate seed bed; methods and equipment to maintain the quality of grain crops and decrease the time required for harvesting and (3) methods and equipment to increase the milling outturn of edible rice from paddy.

Questions have been raised about the high cost of mechanical power. A rough estimate of the purchase price per horsepower of the larger tractor (30 horsepower) in India is lower than a small (10 horsepower) tractor and a pair of good bullocks. John Balis (1) of the Allahabad Agricultural Institute estimates that the cost of operating the larger tractor is lower. These data appear in Table 3 below:

TABLE 3.—*Estimate of horse power costs by source*

	Rough Estimate of Initial Cost per H.P.	Operating Cost per H.P. Hr.
Bullocks	$500	$0.15–$0.22
10 H.P. Tractor	$200	$0.08–$0.19
25–30 H.P. Tractor	$120	$0.06–$0.16

Questions have also been raised ranging from the inhibiting aspects of the small fields and holdings and the inadequacy or lack of access roads, to the practicality of mechanization in the developing countries. By and large, these obstacles will be removed by the people concerned in a normal course of events, when tractors and equipment are more readily available. The immediate problem is one of producing, servicing, and demonstrating machines as one of the "yield-increasing" inputs.

A systems analysis approach, which is effectively used in the United States, for the economic selection of alternate machine systems and for added guidance in applied research, should be used to establish the optimum in the developing countries. Such factors as implement performance, power and labor availability, timeliness and costs are considered in this approach. The applied research, as mentioned above, will supply some of the data for the analysis. This approach is particularly important in the final selection and implementation of the power and equipment inputs on a nation and state wide basis. The World Food Study must of necessity be more broad and general. *Therefore, a systems analysis approach is recommended for final implementation of the program at the local level.*

Identification of High Priority Equipment

The machine operations that are most critical for increasing yields through timeliness and effectiveness are identified below. Local selections and/or substitution of machines for those listed is recommended. However, such alterations and substitutions should not affect the total cost estimates substantially. A study encompassing the world needs must of necessity be very general. A priority rating of 1, 2, or 3 is assigned to each machine and appears in the left hand column.

Priority rating (1, 2, or 3) — *Operations, Definitions of Need and Equipment*

Seed and Plant Bed Preparation

These operations require more energy input than any one other. Rapid preparation is most important in multicropping systems. As a generalization, the dry land preparation consists of mouldboard or disc plowing with secondary tillage of discing and harrowing and are used in this study to compile estimates of equipment needs. It is recognized, however, that there are other tools such as the tined tiller that are more effective under some situations.

The power tiller (one axle garden type tractor with an attached roto-tiller driven from the engine) which has been so successful in Japan is equally good for puddling soil for paddy production in India and probably elsewhere. While the power-tiller principle has not gained wide acceptance for dry land farming, it is ideally suited for wet land puddling. A 6 to 7 H.P. unit can be satisfactorily operated by and multiplies the efforts of the typical Indian farmer; and most importantly does an effective job in a short time.

A ridger is an important and necessary machine for crops such as sugarcane but generally not for the cereals, pulses, and oilseeds. It is important for crops such as maize that are affected by water logging on some soils during the monsoon. For these latter areas, the ridge can be included as one of the primary tilage tools.

Priority rating	Equipment	
1	1. Mouldboard or Disc plow or Tined Tiller and/or Ridger.	Principally for dry land, but the mouldboard plow and a disc harrow designed specifically for operation in the puddle are satisfactory for wet land also. (items 1–3)
1	2. Disc Harrow	
3	3. Peg Harrow	
1	4. Power Tiller	Primarily for wet land.

Seeding and Fertilizing

The precision drilling of small grain and the planting of large seeded crops in properly spaced rows along with simultaneously placed fertilizer as a basal application has given an average of 12.5 percent increase in wheat [Giles (4);

Priority rating (1, 2, or 3)	*Operations, Definitions of Need and Equipment*—Continued

Seeding and Fertilizing—Continued

Taneja and Giles (9)] and 40 percent increase in maize [Giles (4)] over the coventional tools in India. Those farmers who managed their machines well obtained greater percentage increases.

1 or 2 .... 5. Seed drill with fertilizer distributor

1 or 2 .... 6. Row planter with fertilizer distributor

There are some situations and crops where the broadcast of the basal application of fertilizer is advantageous. An example is the application just prior to the last puddling operations for paddy. The uniformity of distribution desired cannot be obtained with existing methods of hand application. Therefore, either tractor or animal drawn or hand rotary units are recommended. As indicated previously, the fertilizer should be mixed well into the puddle. The tillage tools under A can be used for this purpose.

3 .... 7. Broadcast fertilizer distributor

Pest Control

Intercultivation with an increase in the use of chemicals, as these become available, are sure ways to increase yields. The uniform distribution of the chemicals for disease, insects, and other uses is equally if not more important. A laborer operating a single nozzle unit which is fed by air pressure or a foot operated pump cannot distribute the chemicals uniformly. Power application is a must. Here is a case where a relatively low cost 2 H.P. engine will take care of 20 hectares with increased effectiveness of pest control.

The use of airplanes for wide scale spraying and/or dusting, particularly, for outbreaks of diseases and pests over a large area is now practiced to a limited extent in some countries. It surmounts the problem of small fields, non-uniformity of compliance and of teaching technology of chemical pest control to overwhelming numbers of farmers. India's fourth plan calls for aerial spraying of nearly 2 million hectares using over 100 planes or 20,000 hectares per plane. They estimate the potential for aerial spraying to be 12.8 million hectares or about 8 percent of their arable land.

2 .... 8. Row cultivator

1 .... 9. Knapsack power duster-sprayer

3 .... 10. Tractor mounted duster-sprayer

3 .... 11. Airplane sprayer-duster

Harvesting and Threshing

The case here is for timeliness and better quality of harvested products, as discussed in the previous section. The data from the Agricultural Research Institute, Gyogen, Burma, on effect of timeliness of harvest on loss of rice is pertinent.

Priority rating (1, 2, or 3)	*Operations, Definitions of Need and Equipment*—Continued

Harvesting and Threshing—Continued

In a report to the Government of India, Faulkner et al. (2) recommended modern rice mills and called for mechanical harvesting with slow drying, preferably mechanical to obtain the highest outturn of rice. They stated that "paddy be harvested and threshed at a moisture content of about 24 percent and mechanically dried, starting within 2 to 10 hours after harvesting, to a moisture content to below 14 percent without exposure to contined wetting and drying and sunlight". This can be achieved only with mechanical harvesters and threshers.

Timeliness is also essential for multi-cropping as discussed in the earlier section, on *Importance, Status and Problems.*

There are two approaches, both of which should be carried out simultaneously. These are self-propelled combines for the larger farms operated by progressive farmers, and reapers and stationary threshers for the animal powered farms. There is less opportunity for the tractor pulled and powered combine.

2................ 12. Self-propelled combines

1................ 13. Reaper and stationary thresher

Ground nut cultivation can be handled with the previously listed equipment but harvesting and picking require special machines. The mechanization of harvesting and picking should be advantageous because of the large number of pods that must be handled individually; in contrast maize in which many kernels attached to a cob can be handled collectively.

2................ 14. Ground nut digger-shaker

2................ 15. Ground nut combine

Minor items of farming equipment such as the Burmese setturn for puddling, hand sickles, seed treaters and smoothing planks which are rather simple and made locally are not included in this study. Local interests can and will undoubtedly satisfy these needs. The emphasis in this study has been on the more sophisticated less-known machines incorporating modern principles that will increase yields substantially and that will be accepted readily by the progressive farmers.

Estimate of Needs

Tractors

The additional power per hectare needed in the next 32 years for Latin America, Asia, Africa, and Oceania is presented in Table 4. It is assumed that a minimal level of 0.5 H.P./Ha. will be required and that the labor force will double in the next 32 years.

It is assumed also that the power to be added, other than the labor increase, to reach the minimum will have to be met by mechanical power. The amount that labor can add is insignificant, even with a doubling of the labor force, as was shown in Table 4. The only other alternative is animal power. Increasing animal power would be a slow

TABLE 4.—*Existing power (H.P./Ha.) and amount needed by 1998 to meet minimum goal of 0.5 H.P./Ha.*

	H.P. per Ha.			
	Latin America	Asia	Africa	Oceania
Existing:				
Human	.02	.05	.01	.001
Animal	.07	.10	.01	.011
Tractor-including garden types	.18	.05	.03	.336
Additional Needs:				
Human (Assume labor force will double)	.02	.05	.01	----
Tractor	.21	.25	.44	.15
Total Available in 1998	.5	.5	.5	.5

frustrating process, very expensive in capital costs and maintenance, and doubtful as to its ultimate success. The capital cost per horsepower for work animals is higher than mechanical. Furthermore, this direction is not exciting and is opposite to what the progressive farmer wants and will do. Today he is tractor minded.

Latin America and Oceania can probably fill their needs at a reasonable tractor growth rate. However, the number of mechanical power units for service and educational activities required for Asia and Africa to meet the 0.5 H.P./Ha minimum are overwhelming. For a 32-year period for these two areas it would be advisable, in the initial phases at least, to project an achievable tractor production growth rate of 6 percent compounded with a depreciation rate of 7 percent. In other words, determine the quantities of tractors needed by using a 6 percent compounded growth rate rather than by using the 0.5 H.P./Ha goal. The latter approach can be used if and when a valid equation has been developed for a yields vs power curve and, if and when these continents demonstrate their capability to move forward in the area of power and equipment at a rate greater than 6 percent. The 6 percent rate will be modest in comparison. Further, it is hazardous to project an ambitious program without additional data for establishing the minimum power goal.

Also, one should investigate the availability of tractor fuel and one should see that the repair and maintenance services are available and adequate. Provision for these services should parallel the expansion of tractors.

Table 5 gives the quantities of tractors required by the end of successive 4, 6, 10, and 12 year periods, using the 6 percent compound tractor production growth and 7 percent on-the-farm depreciation rate. The starting point is the present tractor population and the rate of change is the average for the past 10 years. The net growth on farms over the past 10 years of tractors averaging 30 horsepower in size is 12,000/yr. for Asia, 9,500/yr. for Africa, and 27,800/yr. for Latin America. The growth of tractors on farms for the past 10 years in these three regions is plotted in Figure 5. The data are from FAO Yearbooks.

TABLE 5.—*Number of tractors, averaging 30 H.P., to be manufactured during the periods indicated* [1]

[6 percent compound factory production growth rate]

Period	Number of Tractors (30 H.P.)			
	Latin America	Asia	Africa	Oceania
1. 4 year period ending 1970	145,000	123,000	119,000	
2. 6 year period ending 1976	291,000	248,000	239,000	300,000 (Est) Minimal power achieved in 1976
3. 10 year period ending 1986	761,000 Minimal power achieved in 1986	665,000	641,000	
4. 12 year period ending 1998	----------------	1,523,000	1,468,000	
Summary and Analysis				
1. Total number of tractors to be manufactured	1,200,000 (in 20 years)	2,560,000 (in 32 years)	2,467,000 (in 32 years)	300,000 (Est) (in 10 years)
2. Net on Farms (Existing population + new tractors − depreciation losses)	828,000 (in 1986)	1,318,000 (in 1998)	1,274,000 (in 1998)	175,000 (in 1976)
3. Net H.P./Ha	.26	.113	.15	.15
4. Percentage of the total additional H.P./Ha tractor power needed (table IV)	124	45	34	100

[1] Includes all sizes and types, from the small garden type to the largest crawler and wheel. Does not include power tillers recommended for wet land operations. Estimates for power tillers appear later and are in addition to the above tractors.

A program has been set up for computer analysis in the Department of Biological and Agricultural Engineering at North Carolina State University with the following input parameters:

d = depreciation rate

g = growth rate of production

Yi = inventory at start of year i

Pi = production in year i

Ni = net increase in year i

If one selects d and g and has the inventory at start (0 years) or 1966 in our case and has the net increase for that year (No) then

$$Po = Yod + No$$

Then for each i_o

$$Yi+1 = Yi + Pi - Yid$$
$$Pi+1 = Pi(1+g)$$

The tractor production in numbers appearing in Table 5 is computed for the 30 horsepower size. It is expected that a country would manufacture a range of sizes, perhaps from the 10 horsepower small type to the greater than 50 horsepower and over, wheel and crawler types. The product mix will need to be determined at the national level

In Figure 6, the number of tractors (averaging 30 horsepower) on farm in Latin America, Asia, and Africa have been plotted for the past 10 years and to the year 1998. These curves for the future assume the 6 percent compound factory production growth rate and the 7 percent depreciation rate as mentioned previously. Latin America is plotted only to the year 1986, the date it will meet its minimal total need of 0.5 H.P./Ha. Again, these growth rates are considered realistic and achieveable.

Power Equipment

One plow, disc harrow, and peg harrow for seedbed preparation should accompany each tractor. The remainder of the tractor equipment for seeding and fertilizing, controlling pests, and harvesting and threshing are calculated according to the following:

$$\frac{\text{Crop area (Ha)} \times \text{Percentage of area to be served by tractor farming} \times \text{Percentage that the added tractor power meets minimum needs}}{\text{Capacity of machine in Ha/season}}$$

The percentage of the area to be served by tractors at the end of the 20 year period for Latin America and the 32 year period for Asia and Africa and the percentage tractor power meets the 0.5 H.P./Ha minimum is shown in Table 12 of the Appendix. Data on the hectares to be handled by each type of equipment appears in Table 13 of the Appendix. General specifications of equipment, capacity and unit cost used in this study appear in Table 14 of the Appendix.

In the case of Oceania, the following is used:

$$\frac{\text{Crop area (Ha)} \times \text{Percentage of new tractor power to total}}{\text{Capacity of machine in Ha/season}}$$

Figure 5

NUMBER OF TRACTORS USED IN AGRICULTURE
(WHEEL AND CRAWLER)

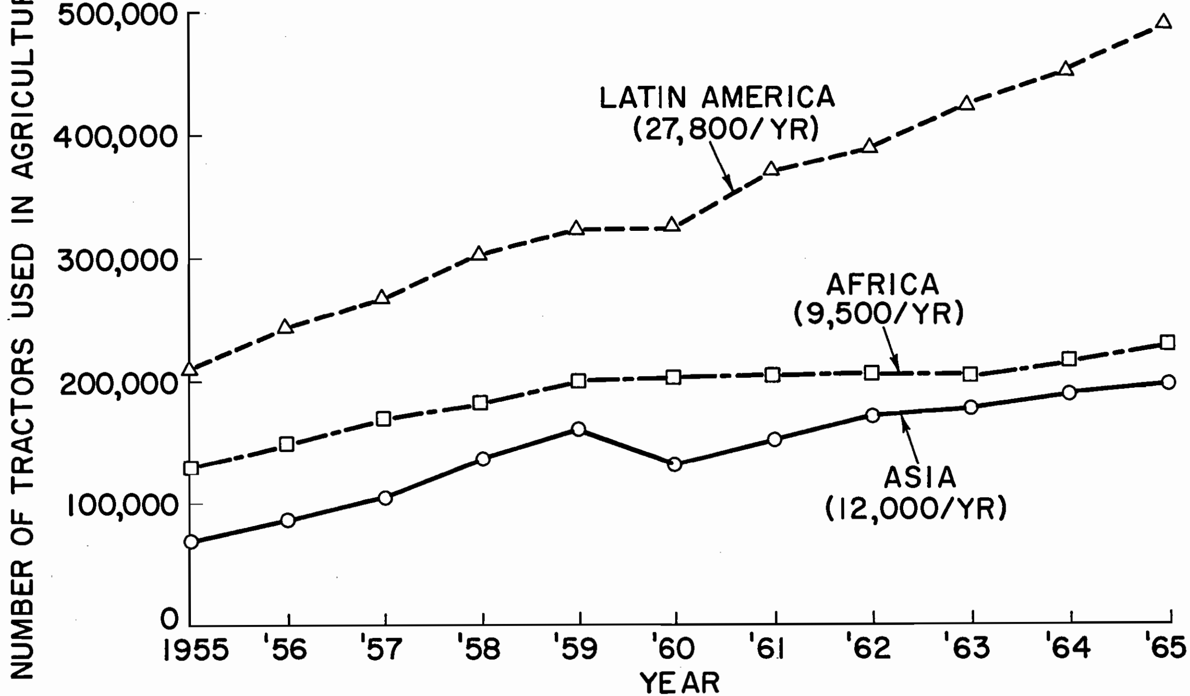
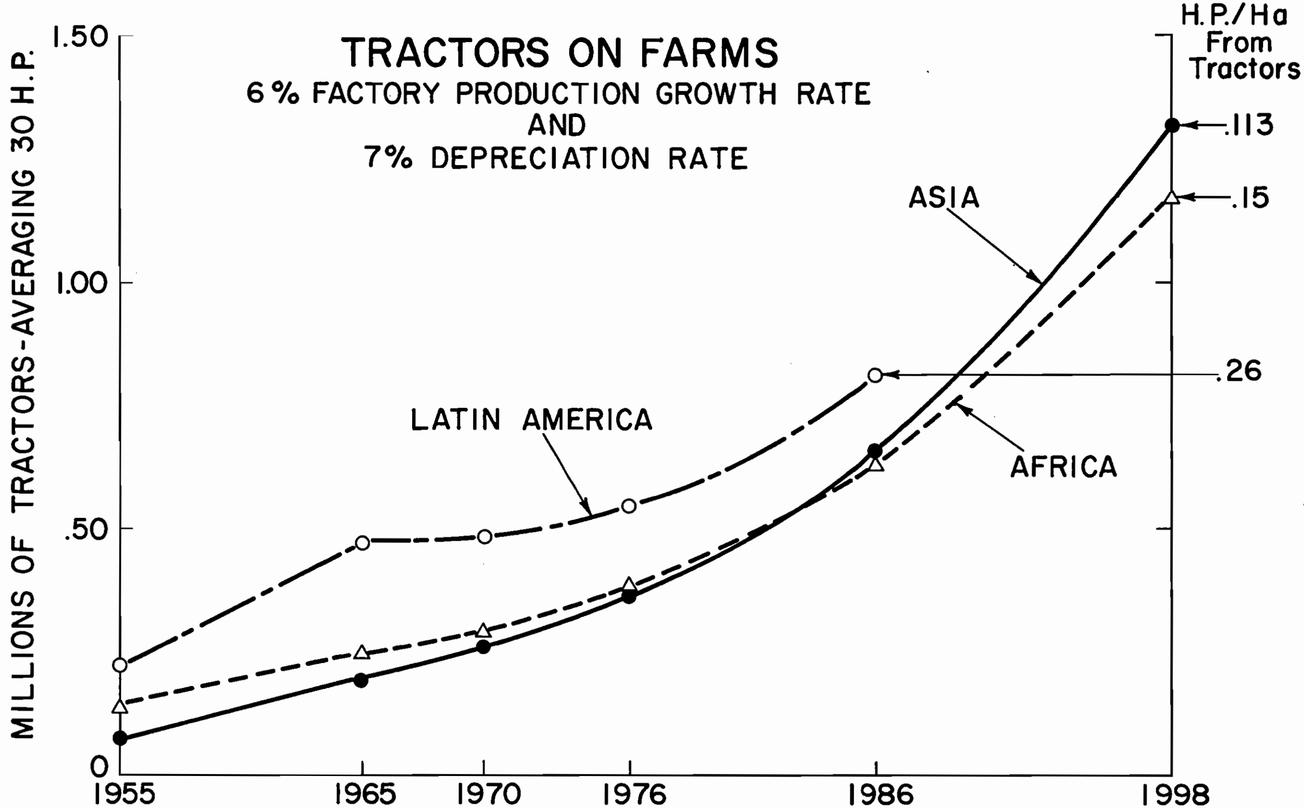


Figure 6


TRACTORS ON FARMS
6% FACTORY PRODUCTION GROWTH RATE
AND
7% DEPRECIATION RATE
MILLIONS OF TRACTORS-AVERAGING 30 H.P.
H.P./Ha
From
Tractors
1.50
1.00
.50
0
1955
1965
1970
1976
1986
1998
LATIN AMERICA
ASIA
AFRICA
.113
.15
.26

The number of power and equipment units and their costs are summarized in Table 6. The estimates for power-tillers are programmed on the basis of their use for only one-half of the land area in paddy. The remainder of the area in paddy is left for tillage by the tractor and animal power and other appropriate equipment.

TABLE 6.—*Total number of units and cost of mechanical power and equipment to be added in the period of time indicated*

[Depreciation losses accounted for in the case of tractors and seedbed preparation equipment but not for the remaining equipment]

	Priority Rating	Latin America (20 yr. period) Millions		Asia (32 yr. period) Millions		Africa (32 yr. period) Millions		Oceania (1 yr. period) Millions	
		No.	$	No.	$	No.	$	No.	$
Tractors	1	1.20	4,560.00	2.56	9,728.00	2.47	9,366.00	.30	1.140.00
Seedbed Preparation:									
Plow	1	1.2	300.00	2.56	640.00	2.47	617.00	.30	75.00
Disc Harrow	1	.60	156.00	1.28	460.00	1.23	443.00	.15	54.00
Peg Harrow	3	.30	60.00	.64	128.00	.62	124.00	.075	15.00
Seeding and Fertilizing:									
Drill	2	.25	150.00	.52	312.00	.21	126.00	.20	120.00
Planter	2	.72	324.00	.3	180.00	.170	76.00	[1](1,200)	.54
Distributor	3	.16	43.00	.16	43.00	.062	17.00	.50	135.00
Pest Control:									
Cultivator	2	.56	168.00	.30	90.00	.134	40.00	(1,200)	.36
Sprayer	3	.32	96.00	.30	90.00	.123	37.00	.062	18.60
Harvesting and Threshing:									
Grain Combine	2	.27	2,700.00	.48	4,800.00	.177	1,770.00	.15	1,500.00
Groundnut Combine	2	.026	78.00	.05	150.00	.047	141.00		
Groundnut Digger	2	.013	13.00	.025	25.00	.023	23.00		
Integrated Powe and Equipment:									
Knapsack power sprayer	1	1.70	510.00	2.8	840.00	.57	171.00	.25	75.00
Power Tiller	1	.27	243.00	1.9	1,710.00	.047	42.00	(1,700)	1.50
Airplane Sprayer-Duster	3	(400)	1.00	(1,400)	28.00	(1,000)	10.00	(150)	1.50
Total Cost of Power and Equipment			9,615.00		19,224.00		13,003.00		3,136.50

[1] Estimated values given in parentheses.

Equipment for Animal Power

Much can be done to increase the effectiveness of the existing animal power in the developing countries. For example, a mouldboard plow in place of the country plow for bullocks will provide a better seedbed in probably half the time; a modern seed drill with fertilizer placement will increase yields at least 12.5 percent and reduce the hours per acre for seeding by 40 percent; a planter with fertilizer placement will increase yields at least 40 percent and reduce the time by 36 percent; small stationary engine driven threshers will accomplish a more timely operation and preserve the quality of the grain.

In computing the number of units required, one mouldboard plow is provided for each pair of draft animals. Because of greater working capacity, one disc harrow is provided for every two plows and one peg harrow for every two disc harrows. The number of existing mouldboard plows, discs and harrows is insignificant and need not be considered. All other animal drawn equipment is calculated according to the following:

$$\frac{\text{Crop area (Ha)} \times \text{Percentage of area to be covered by animal power}}{\textit{Capacity of machine in Ha/season}}$$

The percentage of area to be farmed by animal power at the end of the 20 year period for Latin America and the 32 year period for Asia and Africa is given in Table 12 in the Appendix.

The number of units required and their retail cost are summarized in Table 7.

Estimate of Retail Costs

A summarization of the retail costs for the added inputs of tractors, power tillers, power equipment (including knapsack power duster, self-propelled combines), and animal powered equipment (including stationary power threshers) for each region for each of the four periods is given in Table 8.

Although the total retail cost of these inputs seems large, the amount per hectare of land is reasonable. The last two lines in Table 8 give the total investment over a period of 32 years (20 years for Latin America and 10 years for Oceania) per hectare and per acre. This averages to be about $31 per acre or about $1 per acre per year. The average for Latin America is $2.15 per acre per year, for Asia is $1.06, and for Africa is $0.69. The average may be misleading, however, since they are computed on the basis of the total arable land and land under permanent crops. Each acre would not necessarily receive

TABLE 7.—*Total number of units and cost of animal powered equipment to be added in the period of time indicated*

[Depreciation losses not included]

	Priority Rating	Latin America (20 yr Period) Millions		Asia (32 yr Period) Millions		Africa (32 yr Period) Millions		Oceania (10 yr Period) Millions	
		No.	$	No.	$	No.	$	No.	$
Seedbed Preparation:									
Plow	1	7.0	70.0	60.00	600.0	1.50	15.0	.125	1.25
Disc Harrow	1	3.5	350.0	30.00	3000.0	.75	75.0	.062	6.20
Peg Harrow	3	3.5	280.0	30.00	2400.0	.75	60.0	.062	5.00
Seeding and Fertilizing:									
Drill	1	.165	20.0	3.00	360.0	.23	27.6	.010	1.20
Planter	1	.466	37.0	1.90	152.0	.19	15.2	[1] (300)	.024
Distributor, Hand	3	.170	5.0	1.60	48.0	.11	3.3	.010	.30
Pest Control:									
Cultivator	2	.466	37.3	1.90	152.0	.19	15.2	[1] (300)	.024
Harvesting and Threshing:									
Reaper	3	.225	45.0	3.80	760.0	.25	50.0	.015	3.00
Thresher with Engine	2	.15	150.0	2.50	2500.0	.16	160.0	.010	10.00
Total Cost	-------	-------	994.3	-------	9972.0	-------	421.3	-------	27.00

[1] Total numbers given in parenthesis.

a proportional share because the types of power and equipment and crops would influence the investment on a farm level.

As a basis for comparison, the United States (48 states) during the 20 year period from 1940 to 1960 increased its assets in machinery and motor vehicles (includes 40 percent of the value of automobiles) by $15.4 billion.[5] This amounts to about $33 per acre of arable land and land under permanent crops or, $1.65 per acre per year.

Estimated Capital and Manpower Requirements for Manufacturing Plants

The plants for manufacturing tractors, self-contained power machines, and tractor and animal drawn equipment of the types important to increasing production are so varied and complex that it is impossible to plan precisely for the international needs without a detailed time consuming study. An approximation is only possible at

[5] "The Balance Sheet of Agriculture 1966," Bul. No. 314, Economic Research Service, USDA.

TABLE 8.—*A summarization of retail costs by type of equipment, area, and period*

	Millions of U.S. Dollars [1]				
	Latin America	Asia	Africa	Oceania	Weighted Averages
4 Year Period Ending 1970:					
Tractors	550	470	450	460	------
Power Tillers	50	220	10	00	------
Power Equipment	960	980	450	800	------
Animal Equipment	170	1,250	50	10	------
Total	1,730	2,920	960	1,270	------
6 Year Period Ending 1976:					
Tractors	1,110	940	910	680	------
Power Tillers	70	320	10	00	------
Power Equipment	1,440	1,470	670	1,200	------
Animal Equipment	250	1,870	80	20	------
Total	2,870	4,600	1,670	1,900	------
10 Year Period Ending 1986:					
Tractors	2,900	2,530	2,440	------	------
Power Tillers	120	530	10	------	------
Power Equipment	2,400	2,440	1,120	------	------
Animal Equipment	420	3,120	130	------	------
Total	5,840	8,620	3,700	------	------
12 Year Period Ending 1998:					
Tractors	------	5,790	5,580	------	------
Power Tillers	------	640	20	------	------
Power Equipment	------	2,930	1,350	------	------
Animal Equipment	------	3,740	160	------	------
Total	------	13,100	7,110	------	------
Total for the Period	10,440	29,240	13,440	3,170	------
Grand Total=56,290.					
Investment/Ha	$109	$84	$54	$99	$77
/Acre	43	34	22	36	31

[1] Figures are rounded to the nearest ten million.

this time. Two approaches were considered. The first involved gathering data from manufacturing companies on the cost to build and equip a plant abroad. The second was to estimate capital cost on the basis of the annual value of sales that are summarized in Table 8. The latter approach was determined to be more realistic under the prevailing time conditions and was adopted for this report.

The data collected to date and the calculations for the first approach are recorded below for information only. For this first approach, five general types of manufacturing plants were adopted. These are itemized and defined as follows:

1. *Tractors and equipment.*—While the tractor is the main item, related tractor powered equipment such as plows, discs, drills, planters, and cultivators can also be manufactured in the same plant. This, of course, does not rule out other plants for producing such items. These latter plants can be economical, serve a useful purpose, and should be encouraged. As a generalization, the tractor engine, wheels, and tires may be produced in specialized plants.

2. *Power tillers.*—This plant includes the facilities for producing the complete unit including the engine and roto-tiller attachments.

3. *Power sprayer-dusters.*—Sprayers and dusters, including nozzles, pumps, and other features are specialized equipment that can best be manufactured in specially designed plants. Two main items are required: (*a*) Knapsack with engine. The average size is about 2 horsepower but smaller and larger sizes will undoubtedly be required and (*b*) tractor and engine powered.

4. *Combines and threshers.*—These are specialized items that can best be produced in a plant uniquely designed for this purpose. Included are self-propelled and pulled combines, stationary threshers, and peanut harvesting equipment. Engines for these units can best be produced outside this type of plant.

5. *Animal drawn equipment.*—Plows, harrows, drills, planters, cultivators, and reapers are included. The plow, as the primary tillage tool and largest in terms of numbers required, may be the main manufacturing item. Some or all of the remaining items can be so scheduled as to form an efficient yearly product mix. The optimum might be 100 thousand per year. One plant might include discs, harrows, and cultivators in addition to the plows. Another might include drills, planters, and reapers. In any event, the plow shares, cultivator shovels, discs, and harrow spikes can best be produced in large numbers in speciality plants equipped with modern production tools. For example, 300 thousand to 500 thousand plow shares per year could be produced in one plant equipped with a drop forge and related equipment.

A limited amount of data on the cost of constructing and equipping (complete, ready for operation) manufacturing plants and the manpower requirements for operation for various regions have been compiled. The data collected to date and the author's estimations for an average plant made therefrom are presented below. One should keep in mind that these data do not include ancillary plants for the production of such specialized items as tires, wheels, batteries, springs, and, in some cases, engines. Neither do they include costs for obsolescence of production tools. Plants, and the resulting costs, vary from simple assembly types to nearly 100 percent manufacture.

Tractor Plant—Capital and manpower requirements of a manufacturing plant producing 12,000 tractors/year plus related equipment

	Latin America	Asia	Africa
Cost:			
(a) Land	$400,000	$200,000	$250,000
(b) Buildings	2,000,000	850,000	1,200,000
(c) Machinery and Equipment	10,000,000	8,500,000	8,500,000
Manpower:			
(a) Technical	400	450	400
(b) Non-Technical	1,000	700	1,000

Power Tiller Plant—Capital and manpower requirements of a power tiller manufacturing plant producing 10,000 units/year plus related equipment

Cost:	
(a) Land	$28,000
(b) Buildings	130,000
(c) Machinery and Equipment	1,100,000
Manpower:	
(a) Technical	500
(b) Non-Technical	720

Animal Drawn Equipment Plant—Capital and manpower requirements of a plant producing 100,000 animal drawn mouldboard plows per year plus other animal drawn equipment

Cost:	
(a) Land	$80,000
(b) Buildings	350,000
(c) Machinery and Equipment	1,000,000
Manpower:	
(a) Technical	250
(b) Non-Technical	500

Power Sprayer-Duster Plant—Capital and manpower requirements of a plant producing 30,000 knapsack power sprayer (with engine) and 4,000 tractor mounted sprayers per year

Cost:	
(a) Land	$100,000
(b) Buildings	200,000
(c) Machinery and Equipment	300,000
Manpower:	
(a) Technical	70
(b) Non-Technical	150

On the basis of the above estimates, the capital and manpower requirements for manufacturing plants to serve Latin America, Asia, and Africa are presented in Table 9. No data have been collected for the factories to produce combines and threshers so this column has been left blank.

The second approach was suggested by Ira T. Ellis, Economist, of E. I. duPont de Nemours and member of the Subpanel concerned with Manufactured Physical and Biological Inputs. It consists of computing the capital costs at 100 percent of the total annual machinery sales.

TABLE 9.—*Capital and manpower requirements for manufacturing plants*

	Tractors & Related Equipment	Power Tiller	Power Sprayer-Duster (Knapsack [1] and Tractor)	Animal Equipment	Combines & Threshers
LATIN AMERICA					
Number of Plants	8	1	3	3	
Capacity per Plant units/year	[2] 12,000	13,500	30,000 & 5,000	100,000 plows	
Costs (for no. plants indicated):					
Land	$3,200,000	$28,000	$300,000	$240,000	
Buildings	16,000,000	130,000	60,000	1,050,000	
Machinery	80,000,000	1,100,000	90,000	3,000,000	
Total	$99,200,000	$1,258,000	$1,800,000	$4,290,000	
Manpower (Total):					
Technical	3,200	500	210	750	
Non-Technical	8,000	720	450	1,500	
ASIA					
Number of Plants	14	6	3	20	
Capacity per Plant units/year	[2] 12,000	10,000	30,000 & 3,000	100,000 plows	
Costs (for no. plants indicated):					
Land	$2,800,000	$168,000	$300,000	$1,600.000	
Buildings	11,900.000	780,000	600 000	7,000 000	
Machinery and Equipment	119,000,000	6,600,000	900,000	20,000,000	
Total	$133,700,000	$7,548,000	$1,800,000	$28,600,000	
Manpower (Total):					
Technical	6,300	3,000	210	5,000	
Non-Technical	9,800	4,320	450	10,000	
AFRICA					
Number of Plants	14	1	1	1	
Capacity per Plant units/year	[2] 12,000	15,000	18,000 & 4,000	50,000 plows	
Costs (for no. plants indicated):					
Land	$3,500,000	(3)	$100,000	$80,000	
Buildings	16,800,000	(3)	200,000	350,000	
Machinery	119,000,000	(3)	300,000	1,000,000	
Total	$139,300,000	(3)	$600,000	$1,430,000	
Manpower (Total):					
Technical	5,600	(3)	70	250	
Non-Technical	14,000	(3)	150	500	

[1] Does not include manufacture of engine (Approximately 2 horsepower).
[2] Tractors—Av. 30 horsepower.
[3] Suggest importation.

In other words there is, in all likelihood, a direct relationship of plant costs to sales. Mr. Ellis stated that this was a reasonable approximation for other types of plants such as fertilizer and that it probably

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would be more realistic for the manufacture of farm equipment than the figures used in the first approach. The costs computed by the percentage of sales would include warehousing, services such as electricity, and replacement of production tools as they become obsolete, and ancillary plants. It would also include the plants for combines and harvesters. Using this method, the capital costs for Latin America, Asia, and Africa and for the four categories—tractors, power tillers, power operated equipment, and animal drawn equipment—are shown in Table 10. These costs amount to approximately four times those calculated previously by the first approach. They include all costs and equipment, however, and as such as considered to be more realistic.

TABLE 10.—*Capital requirements for manufacturing plants (calculated at 100% of annual average sales over the 32 year period for Asia and Africa and 20 year period for Latin America)*

[Millions of U.S. dollars]

	Latin America	Asia	Africa	Total
Tractors	228	304	293	825
Power Tillers	12	54	2	68
Power Equipment (tractor operated and self-contained power units)	240	244	112	596
Animal Drawn Equipment	42	312	13	367
Total	522	914	420	1,856

The capital costs of manufacturing plants in the table in the ***Summary*** of this report have been taken from Table 10 and have been prorated for each region among the periods as indicated in the table. This represents a reasonable distribution of the total capital investment that will be required during the 32 years ending in 1998 for Asia and Africa and the 20 years ending in 1986 for Latin America.

The manpower requirements in the ***Summary*** are based on the data collected from the manufacturers.

Existing factories for the production of agricultural power and equipment in some of the developing nations are handicapped in achieving a high productive efficiency and the rated capacity of the plant because of inadequate imports of critical components or materials. These components are not manufactured currently in a developing country for various reasons such as the inadequacy of specialized materials, tooling, or skills. In the case of tractors, the value of the required imports is usually about 10 to 20 percent of the cost of the tractor. A case in point is the high speed, lightweight, 2 horsepower gasoline engine used for the knapsack power sprayer-duster now being manufactured in India. India has not been able to set up a factory for producing this highly specialized engine to date. However as production and demand for sprayer-dusters increase, engine plants will undoubtedly come into being.

It is recommended, therefore, that in the initial stages of building up plant capacities in the developing nations, increased imports of critical components should command the highest priority. Plants to produce these critical components can follow later. In other words, give first attention to increasing the capacity and efficiency of plants already in existence.

Summary

There is growing evidence that adequate power and adapted equipment incorporating modern principles will contribute substantially to higher yields in the developing countries. Valid data on probable yield increases from the use of a drill and a planter over conventional country methods are noteworthy in this regard.

Also, preliminary analysis indicates a positive relationship between yields per hectare and horsepower availability per hectare. This should be investigated more fully. The equation for this relationship, when developed, will subsequently form a base for programming the addition of mechanical power and equipment to the "input-mix."

Data on mechanization in developing countries given in FAO Yearbooks and other publications are incomplete and inadequate; much more so than for the other inputs such has fertilizer. Modifications and additions to the data used in this study can be made by studying AID reports, agricultural statistics, manufacturer's production, and other data, in the countries concerned. But, this will take more time than is now available.

Modest preliminary targets for the numbers and kinds of yield-increasing equipment and for the plants to manufacture the equipment have been established for each area and for specified time periods. These estimates along with adequate educational and service programs are considered *minimal* and *achieveable.* For example, the total additional investment required at the farm level averages about $31 per acre for the developing countries over the 20 or 30 years; or about $1 per acre per year.

The techniques employed and resulting estimates are considered sufficient at this time for a general overall analysis such as this study of the World Food Problem. Upgrading and increasing the estimates safely can best be carried out as more information is available from the studies indicated above, and as the implementation of the program progresses.

Specific details such as machine types and specifications must be done at the national level.

A summarization of the costs and manpower requirements to achieve the preliminary estimates is given in the table.

Summary Table

Period of Time	Latin America	Asia	Africa	Oceania	Total
RETAIL COST OF POWER AND EQUIPMENT					
(Millions of U.S. dollars)					
4-year period ending 1970 (10-percent yield increase)	1,730	2,920	960	1,270	6,880
6-year period ending 1976 (25-percent yield increase)	2,870	4,600	1,670	1,900	11,040
10-year period ending 1986 (50-percent yield increase)	5,840	8,620	3,700	(1)	18,160
12-year period ending 1998 (100-percent yield increase)	(2)	13,100	7,110	(1)	20,210
Total	10,440	29,240	13,440	3,170	56,290
Investment in dollars/Ha. of Arable Land	109.00	84.00	54.00	90.00	--------------
CAPITAL COST OF MANUFACTURING PLANTS (PRORATED BY PERIODS)					
(Millions of U.S. dollars)					
4-year period ending 1970	104	114	53	--------------	271
6-year period ending 1976	157	171	79	--------------	407
10-year period ending 1986	261	286	131	--------------	678
12-year period ending 1998	--------------	343	157	--------------	500
Total (for 20 yr. period)	522	914	420	--------------	1,856

MANPOWER REQUIREMENTS FOR MANUFACTURING PLANTS

(Accumulative numbers)

	Technical	Non-Technical	Technical	Non-Technical	Technical	Non-Technical	Technical	Non-Technical	Technical	Non-Technical
4-year period ending 1970	920	2,120	1,800	2,950	740	1,800	------	------	3,460	6,870
6-year period ending 1976	2,300	5,300	4,500	7,530	1,840	4,600	------	------	8,640	17,300
10-year period ending 1986	4,610	10,600	9,000	15,160	3,700	9,200	------	------	17,300	34,960
12-year period ending 1998	------	------	14,000	24,420	5,920	14,700	------	------	------	------

[1] Minimum reached at 1976.
[2] Minimum reached at 1986.

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APPENDIX

TABLE 11.—*Horsepower available for agricultural production in selected countries, regions, and continents*

	Africa	Asia (Exc. Red China)	India	Latin America	Taiwan	Oceania	U.A.R.	Israel	Europe	U.S.A.	U.K.	Japan	World
I. Agricultural Area (Arable land and land under permanent crops)—Millions of Hectares	248.0	348.0	162.9	96.0	.882	35.0	2.5	.405	152.0	185.2	7.4	6.04	1,457.0
II. Agricultural Population (1960) (Millions)	192.0	639.0	249.0	103.0	-------	2.0	-------	.224	99.0	14.3	-------	23.7	----------
III. Human Labor—Number (Both Sexes) Engaged in Agricultural Occupations and Total Horsepower—Millions:													
No. Engaged in Agricultural Operations	28.3	245.0	137.5	33.0	1.5	0.73	4.4	.11	51.4	5.1	1.1	13.1	----------
H.P. at 1/15 H.P. per worker	1.9	16.3	9.16	2.2	.1	.048	.3	.007	3.42	.34	.07	.9	[2] 35.0
IV. Livestock Numbers—Millions:													
Horses	3.5	6.1	1.35	22.9	-------	.7	.054	.02	9.9	3.09	.16	.322	62.8
Mules and Asses	12.6	9.6	1.15	16.2	-------	-------	1.13	.02	4.3	.96	-------	---------	57.2
Buffalo	2.0	82.5	51.21	-------	.293	-------	1.59	-------	0.5	---------	-------	---------	106.0
Cattle	122.6	267.1	175.56	211.9	.102	26.1	1.59	.216	116.4	---------	11.63	2.20	992.3
Camels	8.0	3.3	.90	-------	-------	-------	.175	.010	---------	---------	-------	---------	11.60
V. Extent of Total Livestock (By Species) Utilized For Draft Purposes in Agricultural Field Production—Estimated Percentage:[1]													
Horses	8	0	0	10	-------	50	8	8	60	2	10	2	30
Mules and Asses	15	0	0	10	-------	-------	15	15	60	2	-------	---------	20
Buffalo	.76	16	16	-------	40	-------	16	-------	60	---------	-------	---------	16
Cattle	1	40	40	6	50	0	1	1	5	---------	2	60	10
Camels	20	20	20	-------	-------	-------	30	20	---------	---------	-------	---------	20

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TABLE 11.—*Horsepower available for agricultural production in selected countries, regions, and continents*—Continued

	Africa	Asia (Exc. Red China)	India	Latin America	Taiwan	Oceania	U.A.R.	Israel	Europe	U.S.A.	U.K.	Japan	World
VI. Estimated H.P. (delivery capacity) of Workstock—Horsepower per Animal:[1]													
Horses	.6	--------	--------	.6	--------	1.0	.6	.6	1.0	1.0	1.0	1.0	.7
Mules and Asses	.3	--------	--------	.3	--------	--------	.3	.3	.7	.7	--------	--------	.4
Buffalo	.3	.3	.3	--------	.3	--------	.3	.3	.4	--------	--------	--------	.3
Cattle	.4	.3	.3	.4	.4	--------	.4	.4	.7	--------	.6	.4	.4
Camels	.5	.5	.5	--------	--------	--------	.5	.5	--------	--------	--------	--------	.5
VII. Total Power of Work Animals—Millions of Horsepower:													
Horses	.17	0	--------	1.38	--------	.4	.003	.0009	6.0	.062	.02	.006	13.2
Mules and Asses	.57	0	--------	.49	--------	--------	.051	.0009	1.8	.014	--------	--------	4.6
Buffalo	.09	3.96	2.46	5.08	.035	--------	.076	--------	.1	--------	--------	--------	5.0
Cattle	.49	32.0	21.06	--------	.020	--------	.006	.0009	4.0	--------	.139	.528	39.7
Camels	.80	.33	.09	--------	--------	--------	.026	.001	--------	--------	--------	--------	1.16
Total	2.12	36.29	23.61	6.95	.055	.4	.162	.0037	11.9	.076	.160	.534	63.66
VIII. Tractors (over 8 developed H.P.) (Wheel & Crawler) Used in Agriculture Number & Horsepower (Rated H.P. for continuous delivery):													
(a) Number	230,000	195,000	45,000	488,000	1,000	386,000	14,000	10,190	4,761,000	4,625,000	389,250	1,000	12,955,000
(b) Est. H.P./tractor[1]	32	30	30	35	26	30	32	32	26	40	30	26	30
(c) Total H.P.—Millions	7.4	5.85	1.35	17.08	.026	11.6	.458	.33	123.8	185.0	11.68	.026	388.6

IX. Garden Tractors (under 8 H.P. and/or under 850 kgs.) Used in Agriculture Number and Horsepower (rated H.P. for continuous delivery):													
(a) Number	1,402	2,550,000	1,000	386	11,000	46,381	-------	580	592,154	525,000	45,510	2,500,000	----------
(b) Est. H.P./tractor	5	5	5	5	5	5	5	5	5	5	5	5	5
(c) Total H.P.—Million	.007	12.75	.005	.002	.055	.231	-------	.003	2.96	2.63	.23	12.5	[2] 35.0
X. Summary of Power Available for Agricultural Production—Millions of H.P.:													
Tractor	7.4	5.85	1.35	17.08	.026	11.6	.458	.33	123.8	185.0	11.68	.026	388.6
G. Tractor	.007	12.75	.005	.002	.055	.23	-------	.003	2.96	2.63	.23	12.50	35.0
Animal	2.12	36.29	23.61	6.95	.055	.40	.162	.004	11.9	.076	.16	.554	63.6
Human	1.9	16.30	9.16	2.20	.100	.048	.300	.007	3.42	.34	.07	.900	[2] 35.0
Total	11.43	71.19	34.13	26.23	.240	12.28	.920	.340	142.10	188.05	12.14	13.96	522.2
XI. Available H.P. per Hectare of Arable Land and Land under Permanent Crops:													
Tractor	.03	.02	.008	.18	.030	.33	.181	.815	.81	1.0	1.57	.004	.266
G. Tractor	-------	.03	-------	-------	.063	.006	-------	.007	.02	.014	.03	2.06	.024
Animal	.01	.10	.145	.07	.063	.011	.065	.010	.08	----------	.02	.088	.044
Human	.01	.05	.056	.02	.113	.001	.12	.016	.02	.002	.09	.148	.024
Total	.05	.20	.21	.27	.27	.35	.37	.85	.93	1.02	1.71	2.30	.36

[1] Estimates in V, VI, and VIII(b) above were arrived at from estimates voiced by several knowledgeable individuals with experience in the foreign country concerned. Asia estimates of extent livestock utilized for draft are based upon calculations made from "Eighth All-India Livestock Census—1956." Average H.P./tractor estimated in part from data presented in "Progress in Mechanization, Bulletin of Agricultural Economics and Statistics, Vol. 15, No. 5, FAO, May, 1966," and from "Development of Farm Motorization, Bulletin OECD, Paris, 1960."

[2] Estimated.

NOTE: Number of tractors, garden tractors, animals, agricultural workers and hectares of agricultural area taken from 1965 Production Yearbook, Volume 19, FAO and generally are for the year 1964. In some instances adjustments have been made on the basis of more recent information and accurate estimates for the year 1964.

TABLE 12.—*Contribution of each type of power source to total power available in 1998 for Asia and Africa, in 1986 for Latin America and in 1976 for Oceania*

	Latin America		Asia		Africa		Oceania	
	H.P./ Ha.	Percent total	H.P./ Ha.	Percent total	H.P./ Ha.	Percent total	H.P./ Ha.	Percent total
Human	0.04	-------	0.10	-------	0.02	-------	0.001	-------
Animal	.07	-------	.10	-------	.01	-------	.011	-------
Total Human and Animal	.11	20	.20	50	.03	13	.012	3
Existing Tractors	.18	-------	.05	-------	.03	-------	.336	67
New Tractors	.26	-------	.113	-------	.15	-------	.15	30
Total Tractors	.44	77	.163	42	.18	86	.486	97
New Power Tillers	.015	3	.03	8	.003	1	-------	-------
Total H.P./Ha	.57	-------	.39	-------	.21	-------	.50	-------
Percentage of minimal needs (0.5 H.P./Ha)	-------	114	-------	78	-------	42	-------	100

TABLE 13.—*Area in important crops grouped by type of equipment*

Crop	1,000,000 Ha.			
	Latin America	Asia	Africa	Oceania
(4) Drill:				
Wheat	8.9	37.0	7.0	7.3
Rye	.8	.7	----------	----------
Barley	1.4	11.0	4.1	.9
Oats	.9	.6	.4	1.4
Millets & Sorghum	1.8	39.5	23.5	0.2
Rice—½ Area	2.7	42.2	1.4	.02
Total	16.5	131.0	36.4	9.8
(5) Planter:				
Maize	24.0	14.4	13.1	0.1
Pulses	6.0	21.9	2.8	----------
Oilseeds	10.6	31.1	10.5	0.1
Cotton (Lint)	6.0	8.0	3.2	----------
Total	46.6	75.4	29.6	0.2
(6) Fertilizer Distributor (Broadcast):				
¼ Total Crop Area	17.0	62.0	17.0	2.5
(7) Cultivator:				
Same as planter	46.6	75.4	29.6	0.2
(8) Sprayer-Duster:				
½ Total Crop Area	34.0	124.0	34.0	5.0
(9) Combine, and Thresher and Reaper:				
Same as for Drill	16.5	131.0	36.4	9.8
Pulses	6.0	21.9	2.8	----------
Total	22.5	152.9	39.2	9.8
(10) Groundnut Digger and Combine:				
Groundnut	1.07	8.4	5.2	.02
(11) Knapsack Power Duster-Sprayer:				
½ Total Crop Area	34.0	124.0	34.0	5.0
(12) Power-Tiller:				
Rice—Total Area	5.5	84.4	2.8	.035
½ for tiller	2.7	42.2	1.4	.017
(Remainder for tractor and disc harrow)				

TABLE 14.—*Data on size, capacity and cost of power and equipment units, used in making computations*

Type	Size	Capacity Ha/Crop Season	Cost, U.S. Dollars
Tractor and Equipment:			
1. Tractor	30 H.P.	....	3,800
2. Plow-disc or Mouldboard	24" cut, 2 Bottom	....	250
3. Disc Harrow or Paddy Disc Harrow	6′ or 7′	....	360
4. Peg Harrow	8′ or 9′	....	200
5. Drill with Fertilizer Distributor	7′	50	600
6. Planter with Fertilizer Distributor	2 row	50	450
7. Fertilizer Distributor—Broadcast	8′	80	270
8. Cultivator	2 row	64	300
9. Sprayer-Duster	Boom type	80	300
10. Ground Nut Digger	2 row	64	1,000
11. Ground Nut Combine	One-windrow	32	3,000
Supplementary Power Equipment:			
1. Combine-self-prop	10′ (minimum for covering tracks).	64	10,000
2. Power Tiller	7 H.P., one axle	10	900
3. Knapsack power sprayer-duster	2 H.P.	20	300
4. Airplane sprayer-duster	....	20,000	20,000
Animal Drawn Equipment:			
1. Plow	8"	....	10
2. Disc Harrow	3′	....	100
3. Peg Harrow	4½′	....	80
4. Drill	3 row	20	120
5. Planter	1 row	20	80
6. Fertilizer Distributor	Hand rotary	20	30
7. Cultivator-shovel	1 row	20	80
8. Reaper	3½′ cut	20	200
9. Thresher-stationary	8 H.P. Engine	30	1,000

CHAPTER 5
EDUCATION FOR AGRICULTURE IN INDIA*

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Introduction

We are concerned with education for agriculture, i.e., with all those educational activities that are needed to help develop Indian agriculture (including forestry and fisheries). In formulating an educational strategy, we must be sure that priorities and emphasis are those that will best help to meet the nation's food and agricultural needs. To do so we first need a clear picture of the objectives of Indian agricultural development.

In order of urgency these objectives must be:

(1) To ensure at least a minimum diet for all citizens.

(2) To increase the amount of high quality protein in the diet of the mass of the people and particularly of the children.

(3) To double the production of food during the next 15 to 20 years and thereafter to continue increasing production of food and other products at a rate of 4 to 5 percent per year.

(4) To lessen and, if possible, to remove the dependence of the nation's food supplies on the vagaries of the monsoon and the winter rains.

(5) To improve the living conditions of the rural population.

(6) To diversify and improve the quality of the products of farms, forests, and fisheries with the aims of (*a*) increasing the proportion of "cash crops"; (*b*) improving the quality and variety of human diets; (*c*) raising export earnings; (*d*) providing a wide range of improved raw materials for industry including leather, wool, cotton, silk, rubber, and such forest products as timber, paper, and cellulose.

To accomplish these objectives, two things are needed: considerable capital investment, and a great deal of skilled human effort. Education for agriculture is concerned with the human resources needed for this effort. Its task is to select, recruit, and give the necessary skills to able men and women who will dedicate themselves to help solve India's problems of food and agriculture.

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* This is a slightly modified version of a paper originally prepared in 1966 for the Education Commission of the Government of India.

Magnitude of the Problem

From 1950–51 to 1964–65 the net values of India's agricultural production, including animal husbandry, fisheries, and forest products, increased (at constant prices) from around Rs. 5,000 crores to Rs. 7,500 crores,[1] or at an average rate of nearly 3 percent a year. But even before the present disastrous years of crop failure in 1966 and 1967, the rate of increase of production was steadily declining. From 1960–61 to 1964–65, the production of foodgrains, which provide about 85 percent of the calories in the average Indian's diet, increased by only 2.25 percent per year—less than the rate of human population growth. Because of the stagnation in agriculture and the increasingly rapid population growth, per capita incomes have been rising at an ever slower rate—probably less than 2 percent per year from 1960–61 to 1964–65. This is in spite of the fact that agriculture's share of the total national product decreased from around 53 percent in 1950–51 to less than 45 percent in 1964–65.

Estimates made by the Planning Commission in 1964 indicate that a net direct investment in the agricultural "sector" of around Rs. 8,500 crores (at 1964 prices) would be required to double present agricultural production. Of this amount, 45 percent would be used for irrigation and flood-control; 12 percent for reclamation, conservation in the industrial and other sectors, and other land improvements; 14 percent for farm equipment; and 5 percent for storage. In addition, a capital investment of several thousand crores will be needed for nitrogen and phosphate fertilizer plants, pesticide manufacturing and distribution facilities, rural electrification, rural road construction and vehicles for transportation, education and research facilities, and other requirements.[2]

Besides these expenditures to increase production, a considerable investment in food processing plants and other industries based on agricultural products will be necessary to use the increased agricultural production effectively.

To lessen the disastrous effects of monsoon failure and winter droughts, a much greater investment, either in irrigation development or in pest-proof grain-storage facilities, would be required than that contemplated above. Extensive storage facilities, distributed throughout the country are also necessary for adequate food

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[1] A crore is ten million rupees or about $2,100,000 at the exchange rate prevailing in the 1950s.

[2] In Vol. II of this report (p. 676) W. Holst has estimated capital requirements for agricultural development in India from 1964–86 at $30 billion, or about Rs. 14.5 crores at the 1964 exchange rate.

distribution to ensure that all Indians receive at least a minimum food supply. Full benefits from chemical fertilizers and high yielding seeds will be impossible to realize unless the area of irrigated and adequately drained land is increased rapidly. Moreover, because nearly all India's arable land is already cultivated, the prospects for increased agricultural production depend to a considerable extent on the ability to increase the intensity of cultivation, i.e., to raise two or three crops rather than one in each year. In many parts of the country this will be an unprofitable gamble for the farmers unless irrigation water can be made available when it is needed.

It is clear that the rate of capital investment for agriculture during the next three Plan periods should be at a much higher level than during the first three Plans. Correspondingly, larger numbers of trained personnel than are now involved in agriculture will be needed to design and carry out these investments. Some of these new people can be co-opted from other sectors; most of them must be produced through education for agriculture.

But the necessary rapid increase in agricultural production requires much more than an increase in the level of capital investments. These investments will be almost wasted unless the technology to use them can be acquired or developed, and the farmers can be given the economic conditions, the incentives, and the knowledge to apply this technology.

Indeed in some areas knowledge can be partially substituted for capital investment. This is true, for example, in the use and management of water supplies. In many parts of India, irrigation waters are spread too thin with the result that crop yields are low and the soil deteriorates from salt accumulation. Production could be increased by applying the same amount of water on a smaller acreage. At the same time, much irrigation water is wasted because canals and distributaries are operated without regard to the needs of the crops. Elsewhere, crop yields are lessened and land is wasted because excess water is not drained off the fields. In these cases, remedial measures could be taken with a minimum of financial investment.

To provide better economic conditions for the cultivators, a thorough-going and decisive reform of land-owning and land-tenancy systems is needed. At present, rent and interest payments averaging 50 percent to 70 percent of the harvest (and sometimes collected by the same individual) reduce many tenants to a hopeless economic condition.

Tenants, fearful of eviction, plant and harvest with no regard for the future conditions of the land. Landlords aware of the superficiality of their schemes to evade present ownership regulations fail to make needed improvements for fear that their evasions may be detected and their investments lost.

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Land reform alone will not provide the economic base for a progressive and more productive agriculture. New landowners must have credit at economically bearable interest rates and other supporting services, or the forces which create inequity will reassert themselves.

Land consolidation is as urgent as land reform. When one visualizes the crazy-quilt pattern of fragmented, dispersed, and intermingled holdings which make up the agricultural lands of an Indian village and realizes that this is the condition of most of the cropland of India, it becomes less difficult to understand the extraordinarily low productivity of Indian agriculture. Small and scattered tracts, intermingled with similarly dispersed tracts of other owners, make the introduction of new technology and of rational methods of land use extremely difficult.

Land consolidation measures need to be integrated with measures for land improvements such as soil and moisture programs, drainage, contour furrowing, and irrigation. This will require expert planning and informed persuasion of the farmers.

The physical factors needed to increase crop yields are well known: water, chemical fertilizers, high-yielding seeds, plant protection, and improved agricultural practices. But what is not generally realized is that these inputs must be applied in combination. Chemical fertilizers will be of little use unless timely and adequate water supplies can be made available to meet the evapotransporation requirements of the crops and to control soil salinity. Only minimum amounts of fertilizers can be applied effectively on present plant varieties. High-yielding non-lodging varieties must be developed and used to obtain the full benefits of chemical fertilizers. Increased yields will be an open invitation to pests of all kinds unless effective control measures can be employed. Finally, water, chemical fertilizers, better seeds, and pest control will all require marked changes in present farm practices even to justify the increased costs, let alone to reap their full benefits.

During the past 100 years, agriculture in many parts of the world has been revolutionized. This revolution has been made possible in part by the development of chemical engineering and mechanization, and in part by a more fundamental revolution—that in man's biological understanding. This new scientific understanding of the nature of living creatures, both plants and animals, has led to a marvelous improvement in agricultural technology in the advanced countries. Much of the fundamental understanding exists for similar improvements in Indian agriculture but the new biological technology must be modified to fit Indian conditions. Applied research is necessary, particularly in plant and animal nutrition, genetics, physiology, pathology, and in the various fields of microbiology.

A large part of the existing technology of chemical fertilizers and of soil and water development through mechanization can be directly applied. But this application will require the services of many thousands of highly educated agricultural scientists and engineers as well as an even larger number of trained technicians.

The new technology will be valueless unless farmers know how to use it and are willing to do so. They must be brought into the educational process in appropriate and realistic ways. At the same time, planners, administrators, bankers, lawyers, community leaders, politicians, and entrepreneurs must understand agricultural problems and the nature of rural life sufficiently to provide the credit, crop insurance, marketing facilities, price structure, consumer goods, and other conditions and incentives the farmers need to increase their production of cash crops.

Though nearly 70 percent of the nation's labor force is in agriculture, it has the smallest population of educated workers—only three in a thousand agricultural workers are matriculates and one in a thousand is a graduate. Of the 237 thousand holders of technical university degrees in 1961, less than 10,000 were in agriculture, including veterinary science and animal husbandry. This number needs to be increased to around 125 thousand during the next 15 years. Especially important are the needs to increase the number of research workers in agriculture on the one hand and the level of training of the frontline extension workers on the other.

Transmitting Information to the Farmers

Clearly the most immediate task for agricultural education is to transmit to the present farmers technical information which is already available and which they can use to increase their crop yields and their incomes. At first sight this task seems overwhelming. There are some 60 million cultivators in India and probably at least 85 percent of them are functionally illiterate. The number of extension workers who have enough practical agricultural knowledge to be able to give any useful information to the farmers is completely inadequate. However, there are two hopeful aspects:

(1) More than half of the agricultural land is held by less than a third of the cultivators and these can be expected to be the most forward-looking and teachable farmers. We can concentrate much of our effort on perhaps 15 million people.

(2) Much of the transmission of information can be done by the farmers themselves. If a rather small proportion of them are taught the new technology and are enabled to apply what

they have learned successfully to their own fields, they will have a powerful influence on their neighbors.

The main problem in teaching the farmers is to teach their teachers, and this must be given high priority in the strategy of education for agriculture.

The educational background and level of specialized training in agriculture of present VLW's[3] is wholly inadequate to enable them to teach the farmers, who after all have a large store of traditional knowledge which has been hardened by experience. It is no surprise that these over-worked, under-paid, and under-qualified VLW's have been submerged in paper work and miscellaneous duties by their superiors—it is difficult to see how they can do much else. Many VLW's with sufficient general education undoubtedly could be salvaged for agriculture by enrolling them in the agricultural polytechnics. But for the most part the attempt to use present VLW's as the front-line of agricultural extension should be abandoned as rapidly as they can be replaced with properly trained personnel.

With the existing severe shortage of qualified workers, methods of teaching the farmers must be used which will enable a small number of trained personnel to reach and influence a large number of farmers. For the time being, it will be impossible for a qualified extension worker to come into individual contact with every farmer. Stress must be laid on—

1. Demonstrations on one farm in each village.
2. Radio broadcasts, distribution of literature, posters, bulletin boards, and other means of communication.
3. Bringing a leading farmer in from each village to a Primary Extension Centre in each Development Block at regular intervals (say once a week) to give him information and advice which he can then carry back to his village. This is part of the famous "Comilla Academy" approach that has been so successfully used in East Pakistan.

Character of the Agricultural Universities

Uniqueness

Compared with other Indian universities, the agricultural universities should have several unique characteristics:

(1) Their concern with all aspects of increasing, disseminating, and applying knowledge related to agriculture, including basic and applied research, teaching of their own students, and transmitting needed information to the cultivators.

[3] A VLW is a Village Level Worker with a secondary level education assigned to extension type work in community development.

(2) Their primary emphasis on teaching and research that are directly and immediately related to the solution of the social and economic problems of the countryside.

(3) Their readiness to develop through research, and to teach, the wide range of applied sciences and technologies needed to build the rural economy.

(4) Their readiness not only to teach undergraduates, post-graduates, and research students, but also to give specialized technical training to young people who are not candidates for degrees.

(5) Their emphasis on adult and continuing education side by side with teaching regularly enrolled students.

Range of Academic and Professional Subjects

Keeping in mind these unique characteristics, it is clear that the agricultural universities will be able to do their tasks only if their teaching and research cover many academic and professional fields. These should include:

(1) *The classical agricultural specialties.*—Agronomy, plant genetics, animal breeding, animal husbandry, veterinary science, plant pathology, soil science, microbiology, horticulture, entomology and parasitology.

(2) *Engineering for agriculture.*—Irrigation engineering; ground-water hydrology; civil engineering for design, construction, operation, and maintenance of surface water supply systems; mechanical engineering concerned with farm machinery and equipment, including well pumps, motors, and strainers for ground water development.

One of the most destructive failures of engineering education in the sub-continent has been the lack of appreciation by the engineers in charge of water resource development of plant and soil requirements for irrigation water supplies and drainage. The agricultural universities must take responsibility for producing a new breed of engineers.

(3) *Specialists in human nutrition and food technology.*—Even with present inadequate food supplies, the diets of the poor could be improved considerably and the deaths of many young children could be prevented if inexpensive high-quality protein supplements could be prepared, distributed, and made acceptable to the people; if food wastage could be lowered by better methods of preservation; and if knowledge of nutritional needs and how to meet them could be widely disseminated among the rural people.

(4) *Agricultural economics.*—Specialists are needed in market research, agricultural data collection and analysis, farm management, rural credit, crop insurance, benefit-cost analysis and other techniques of project evaluation, and price structures for farm products.

(5) *Public administration.*—Specialists in organization of government agricultural services, management of co-operatives, local self-government, and relations between different governmental levels.

(6) *Mass communications.*—Specialists in adult education, audio-visual teaching, and preparation of instructional materials.

(7) *Sociology, anthropology, and law.*—Analysts of village traditions, social structures, and values; and social engineers who can develop methods for their constructive modification. Analysts of land tenure and tenacy systems; and specialists in development and application of principles of land reform and consolidation.

(8) *Resource conservation.*—Specialists in soil and water conservation, erosion control, range management, reclamation, and soil classification and surveys.

About 40 percent of India's 323 million acres of cropland and 177 million acres of forest land have deteriorated through misuse—these lands need remedial treatment urgently. Deterioration has reached a point where, under present management methods, it is progressive and self-generating. An over-all land management strategy will depend on a national land survey and inventory, using criteria which can be expressed in terms of crop yield enhancement, costs, and time periods.

(9) *Forestry.*—Specialists in forest management and in the technology of forest products such as fuel, timber, paper, and cellulose.

(10) *Fisheries.*—Specialists in agricultural pond fisheries; management of river and lake fisheries; development of marine fisheries; design, construction, maintenance, and operation of fishing vessels and fishing equipment; fish preservation and processing; and fisheries economics.

(11) *Earth sciences.*—It is of utmost importance for Indian agriculture to be able to forecast the onset of the monsoon, its intensity and continuity, particularly in the first six weeks of the rainy season. These forecasts should not be on a day-to-day basis but should be made for periods of several weeks or preferably several months. To make such forecasts, both better meteorological data from the Indian Ocean and better understanding of the atmospheric mechanisms that cause the monsoon are needed. The number of Indian meteorologists educated in modern meteorological theory, observational techniques, and forecasting methods is inadequate. There is an equal scarcity of oceanographers capable of making or interpreting oceanographic measurements at sea. To remedy this situation, Departments of Earth Sciences should be built up as rapidly as possible in several agricultural universities. Besides emphaizing meteorology and oceanography, these departments should also concentrate on ground water geology

(the technology of finding and appraising ground water resources) and on engineering geology (appraisal of dam sites and the location of materials for heavy construction).

(12) *Basic science.*—For all the applied sciences and engineering specialities listed above, the students will need a firm foundation of basic science. The agricultural universities should develop strong faculty groups in statistics, applied mathematics, operational analysis, physical chemistry, biochemistry, molecular biology and physiology. Faculty members in these fields should do more than "service" teaching. They must also have postgraduate and doctoral students in their specialities and should have freedom and support for their own research.

(13) *Humanities.*—Similarly the students in the social sciences will need a background of Indian history and literature to gain understanding of the traditions and values of rural society. The faculties of the agricultural universities should therefore contain scholars in the humanities, even though the faculty balance for the foreseeable future should remain strongly tilted toward practical and professional subjects.

Functions

The main tasks of the agricultural universities will be to select and recruit able young people for all the above listed subjects and to give them not only the necessary intellectual and practical skills, but also the desire and the will to work in rural environments. The success of these universities will depend on their ability to provide lifetime careers and a total environment for their staff members which will attract many able persons in competition with other professions. This will probably mean that for many of their staff members there should be a rotation of assignments between classroom teaching and laboratory research, experiment station research, and work in the field with rural people.

Attracting and Holding Able Faculty and Staff

To attract and hold able faculty and staff, salaries, allowances, and the prospect of salary increases should be raised at least to the top level of the UGC (University Grants Commission) scales for other universities. The salaries for faculty members in agriculture, engineering, nutrition, agricultural economics, resource conservation, forestry, fisheries, earth sciences, and basic sciences, should be on a par with those in the Indian Institutes of Technology and the National Research Laboratories.

Many other things besides salary are needed to attract and hold able faculty members and research staff. The agricultural universities must be a community of scientists and scholars in which the faculty members have collective responsibility and authority for academic affairs. In each university there should be groups of able scientists in each field who will work together in preparing curricula, taking responsibility for the progress of the students, setting standards of student performance, testing and evaluating the students, organizing, developing, and using laboratory, library, computer, and field facilities, and stimulating each other in research and teaching through seminars, collaborative research and informal relationships.

The structure of faculties in the agricultural universities should not resemble the typical Indian university hierarchy. They should aim, as soon as good men can be found, to appoint a number of professors in each field. In the long run, the number of professors should be greater than the number of readers and about equal to the number of lecturers.

Part of the undergraduate teaching should be done by the senior professors and part by teaching assistants drawn from the ranks of postgraduates and research students.

The paths to faculty promotion should be based on outstanding accomplishment, independent of the accidents of seniority. The criteria for promotion should be primarily accomplishment in research, but first-rate teaching should also be rewarded.

Faculty and research staff members should receive sabbatical leaves every few years to refresh and renew their understanding of their own fields. Good faculty housing at low rentals should be available on or near the campus. Excellent schools for faculty children should be made available.

The faculties should have a major voice in choosing their own members, but the selection of new faculty members should be on the basis of wide participation within the university faculties and not simply by the department concerned.

Within broad limits established by his fellow faculty members, each teacher in an agricultural university should be free to teach as and what he thinks best. Such freedom in teaching will require that the teacher has major responsibility for assessing his own students. External examinations should be reduced in importance and abolished as early as possible.

No faculty member in the university proper should have more than nine to ten weekly contact hours with undergraduate or postgraduate students. For example, he might give three lectures per week to undergraduates, three hours of tutorials or preceptorials, and three hours of seminars for postgraduate and research students; alternatively, he might give four hours in lectures and six hours in laboratory teaching. The remainder of his time should be available for research, working with individual students, and working with fellow faculty members to improve the quality of instruction, the library collections, the physical facilities, and other problems of common interest.

Character of Undergraduate Teaching

Agriculture, like all other scientific subjects, is rapidly changing. Hence the main educational tasks of the agricultural universities will be the same as for other higher educational institutions: to give their students a bone-deep knowledge of fundamental principles; an ability to solve new problems as they arise; and the will and ability to continue learning without a teacher throughout their careers. In the agricultural universities, as in other higher educational institutions, the students should spend a major fraction of their time in independent study and should be introduced to research as early as possible. The aim of formal teaching should be to give the students a knowledge of the specialized language of the subject being taught, an understanding of its basic principles, an ability to use the relevant literature, and a recognition of the frontiers of knowledge in the field.

During the first two or three years of their undergraduate courses, the students should spend not more than 10 hours per week on lectures and 3 hours in the laboratory. In addition they might have 1 to 2 hours per week of "tutorials" or "preceptorials" and 2 to 3 hours per week of review, "quizzing," and explanation of lecture materials. The majority of their time should be spent in independent study in the library, the laboratory, and on the university farm, and in solving technical problems assigned by the instructors. During their last two or three years, the students should spend less time in lectures, review sections, and formal laboratory work, and more time in independent studies.

The requirements for independent study cannot be fulfilled unless the university library has a large collection of modern books and periodicals which are well arranged and easily accessible to the students. The university library will need both an adequate budget for purchasing books and periodicals, and an adequate staff to order, catalog, sort, and file acquisitions, to help students and faculty members find what they need, to maintain proper procedures for taking books on loan out of the library, and perhaps most important, to weed out obsolescent and useless books.

Other essential aspects of the teaching program should be: (1) meaningful assessment of the students' performance at frequent intervals throughout the year; (2) a high degree of flexibility in the courses taken by the students and considerable freedom of choice by the students in selecting their courses. To attain flexibility and ensure more frequent assessment, it will be desirable to break the academic year into two or three terms. This will allow coverage of more fields, deeper penetration of narrow areas, and the introduction of new disciplines and interdisciplinary studies. Each student should be assigned a faculty advisor who will help him make the best choice of courses to meet his particular interests and aptitudes.

The teaching at all stages should de-emphasize cramming and memorization, and should be designed to stimulate curiosity, to develop problem solving ability, and to foster originality.

Extra-curricular activities should be stressed, including student competitions, journalism and creative writing, debates, individual and team sports, and formal and informal student discussion groups. Each of these activities should have a voluntary faculty advisor who enjoys this aspect of his work.

Training of Sub-professional (Non-degree) Students

The responsibility of the agricultural universities for agricultural extension means that they should also supervise the training of subprofessional (non-degree) agricultural personnel. We recommend that each agricultural university establish, staff, and operate a training institution for middle level personnel at the diploma level—assistants in the extension services and agricultural credit and insurance organizations, farm managers, field and laboratory assistants in the research stations, field representatives of fertilizer and pesticide manufacturers, seed distributors, and technicians for agro-industry.

Eventually such agricultural polytechnics may be needed in fairly large numbers throughout the country, but for the present we would limit them to one institution situated on the campus of each agricultural university. Our reason for this is the present severe shortage of sufficiently qualified agricultural graduates who could be enlisted to teach in such institutions. By 1981 some universities might be able to operate two to four separate polytechnic campuses.

Adult and Continuing Education

Besides the regularly enrolled degree and diploma students, each university would have an extensive program of refresher training and retraining for central and state government professional staff members, district officers and advisers, development block extension officers, and front-line workers including both graduates and diploma-holders. The adult education program would also be available for workers in all the other professional and technical fields mentioned earlier and listed in Table 1 on page 233. Much of the program would be for specialists in the form of short intensive courses on new developments in their field. There would also be a major effort devoted to upgrading the level of education of village level workers and other less educated personnel.

Relations With State Departments of Food and Agriculture

Each agricultural university should be autonomous, under the control of a specially appointed Governing Board. It should receive the State portion of its financial support through the State Department of Food and Agriculture, and its budget will need to be approved by that Department.

There should be a clear delineation of responsibility between the agricultural universities and the State Departments of Food and Agriculture. As soon as possible these universities should have full responsibility for research, teaching at the polytechnic and the university levels, and agricultural extension. This means *inter alia* that the agricultural universities should manage all state research stations and demonstration farms as soon as they are sufficiently established to be able to do so.

Assignment of these responsibilities to the agricultural universities will leave the State Departments of Food and Agriculture free to do many critically important tasks. Among these are:

(1) Designing and co-ordinating or supervising the government share of capital improvements for agriculture, including minor irrigation developments and storage and transport facilities.

(2) Developing and supervising institutional arrangements (private and public) to insure that the farmers receive a timely, adequate and certain supply of chemical fertilizers, high yielding seeds, pesticides, farm tools and equipment, and farm credit at economically bearable interest rates.

(3) Operating State-owned foundation-seed farms, and regulating private seed-multiplication farms and the seed distribution system.

(4) Providing well-drilling equipment and drill crews to help farmers construct private tube-wells.

(5) Carrying out large-scale plant and livestock protection measures.

(6) Establishing and managing marketing arrangements and price structures for farm crops and livestock.

(7) Obtaining and compiling statistics on agricultural pro-

duction, including crop-cutting experiments and livestock and poultry censuses.

(8) Arranging for the production and distribution of high quality protein supplements for human diets and encouraging their acceptance by the people.

(9) Developing and helping to enforce land consolidation measures.

(10) Conducting soil surveys and analyses to determine fertilizer and irrigation water requirements.

(11) Carrying out, either directly or through technical assistance to Panchayati Raj Organizations, erosion control, land reclamation, and drainage measures on farm and grazing lands.

(12) Surveying and appraising ground water resources, including chemical analyses of water quality.

(13) Developing and enforcing standards for commercial livestock and poultry feeds and livestock, dairy, and poultry products.

(14) Carrying out large-scale measures to improve the quality of livestock and poultry.

Number and Size of Agricultural Universities

In each of the smaller States including Assam, Gujarat, Kerala, Madhya Pradesh, Madras, Mysore, Orissa, Punjab, Rajasthan, there should be one agricultural university which will be responsible in its extension activities for 3 to 5 million farmers. If the ratio of one university to 5 million farmers is not to be exceeded, Andhra Pradesh, Bihar, Maharashtra, and West Bengal would need to establish two agricultural universities and three would be required in Uttar Pradesh. Thus there would be 20 agricultural universities in the country as a whole. On the average each university would have extension responsibilities for 16 districts, 275 development blocks, and 27,500 villages. Its extension staff would need to furnish technical assistance in the cultivation of 15 to 20 million net acres. By 1981 the number of agricultural graduates on the extension staff of the agricultural university would be from 4,000 to 5,000. Its total faculty and research staff would number about a thousand and it would have around 6,000 students. Its annual budget for instruction, research, and extension would be of the order of Rs. 10 crores.

These estimates for budget, staff, and students are based on the estimated manpower needs for agricultural development given in Table 1.[4]

The polytechnic or diploma students under the charge of each agricultural university would number from 5,000 to 8,000. It might be

[4] Although the numbers of specialties listed in Table 1 are needed today, it will be nearly impossible to train these numbers before 1981.

necessary to divide these students among two to four separate campuses, each with its own experimental farm, forests, fish ponds, pilot processing plants, or other practical teaching facilities, depending on the specialties being taught.

The number of faculty and research staff members, undergraduates, postgraduates, and research students in the average agricultural university would be sufficiently small so that all teaching at the university level could be concentrated in one central campus without the necessity for isolated affiliated colleges. Such concentration is highly desirable to maintain the quality of the combined program of instruction and research. However, some experiment stations away from the central campus should be operated by the university to test the effects of different soil, water, and climate conditions, and there would, of course, be many demonstration farms for extension purposes throughout the land area under the university's jurisdiction.

Costs of Educated Personnel in Agriculture

The total salaries and expenses of the 260 thousand persons having university degrees listed in Table 1 would be about Rs. 300 crores—approximately 2 percent of the projected agricultural production in 1981. Salaries and allowances for 300 thousand diploma-holders would be about Rs. 90 crores and expenses for other personnel would be about an equal amount. Thus the annual costs of educated personnel for agricultural development would be between 3 and 4 percent of the projected total agricultural production.

Problems of Faculty Recruitment

The chief problem in building up the agricultural universities to the levels contemplated in Table 1 is the present acute shortage of potential faculty members. Because of the low status of agriculture and past neglect of agricultural education, there are only a few thousand persons in India with the education, intellectual competence, and experience that are needed in the faculties of the kind of university we have been discussing. At the present time, it would be impossible to start 20 such universities and even the 7 existing ones will have great difficulty in recruiting the required number of highly qualified staff members.

The temptation will be strong to recruit second raters to fill empty faculty positions. This would be a tragic mistake from which it would be almost impossible to recover for decades to come.

In spite of the great urgency to expand higher education in agriculture, a compromise of quality would be self-defeating. What then can be done? Four actions are essential:

(1) The agricultural universities must give first priority to educating their own future faculty members, together with future faculty for the new agricultural universities that will be established. This means that they should not burden themselves at first with all the enormous administrative tasks of agricultural extension and the operation of existing state experiment stations. Extension responsibility should be taken over gradually, essentially on a block by block basis. Responsibility for managing the state research stations and experiment farms should be taken over, together with their staffs, only three or four years after the establishment of the university.

(2) Faculty members in some disciplines such as humanities, economics, public administration, sociology and law, basic science, and mass communications could be "converted" by recruiting carefully selected young persons with doctoral degrees or the equivalent in experience from other universities, government services, and the private sector. This will not be possible in the case of the agricultural specialties, including animal husbandry and veterinary science, or in agricultural engineering, forestry, fisheries, resources conservation, earth science, nutrition and food technology (it may be possible to recruit some nutritionists and food technologists from the national laboratories.)

In these fields recourse must be had either to:

(3) Overseas training of future faculty members; or

(4) Enlisting faculty members on a temporary basis from the developed countries.

Both these measures will require extensive foreign financial and technical assistance.

Leadership and Financing

The great difficulties in developing agricultural universities and the very large responsibilities contemplated for them mean that each of these universities will need, right from the start, forceful and determined leadership supported by a competent and flexible administrative staff. Careful planning will be essential, but even more necessary will be prompt and generous government financing and freedom for rapid (and often unforeseen) action.

The necessity for suitable large-scale financing can probably be met only if the major costs of developing the agricultural universities are borne by the Central Government. This support from the Centre might be provided through the Indian Council of Agricultural Research, but if so the Council should be transformed into an independent statutory body, similar in character to the University Grants Commission. A more desirable arrangement might be to establish a semi-autonomous agricultural committee under the University Grants Commission.

TABLE 1.—*Manpower needs for agricultural development*

I. University graduates, postgraduates, and doctoral level.		
1. Agriculture (including Animal Husbandry and Veterinary Science):		
University teachers and research workers	12,000	
Polytechnic teachers	10,000	
State and Central Government professional staff	4,000	
District officers and advisers	4,000	
Development Block Extension Officers	35,000	
Development Block Frontline Workers (Graduates)	52,500	
Industry	10,000	
		127,500
2. Engineering:		
University and polytechnic teachers and research workers	3,000	
Chemical Engineers	5,000	
Irrigation Engineers and Hydrologists	10,000	
Mechanical Engineers	10,000	
		28,000
3. Nutrition and Food Technology:		
University and government teachers and research workers	5,700	
Industry	5,000	
Distribution and Acceptance Workers	5,000	
		15,700
4. Agricultural Economics:		
University and Polytechnic teachers and research workers	1,400	
Farm Credit Specialists	3,500	
Marketing Analysts	1,500	
Price Analysts	1,500	
Operational Analysts	1,500	
Crop Insurance Specialists	800	
		10,200
5. Public Administration:		
University teachers	500	
Government officers	7,000	
		7,500
6. Mass Communications:		
University teachers	200	
Government officers	4,000	
		4,200
7. Sociology, Anthropology and Law:		
University and polytechnic teachers and research workers	500	
Land and Tenancy Reform Officers	3,500	
Village Sociologists and Anthropologists	3,500	
		7,500
8. Resource conservation:		
University and polytechnic teachers	1,200	
Soil Survey Officers	3,500	
Erosion Control Officers	3,500	
Land and Water Management Officers	3,500	
		11,700
9. Forestry:		
University and polytechnic teachers	1,500	
Forest Management Officers	10,000	
Forest Product Specialists	5,000	
		16,500

TABLE 1.—*Manpower needs for agricultural development*—Continued

I. University graduates, postgraduates, and doctoral level—Continued		
10. Fisheries:		
University and polytechnic teachers	1,000	
Fresh Water Pond Fisheries Specialists	3,500	
River and Lake Fisheries Specialists	1,000	
Marine Fisheries Specialist	1,000	
Fishing Boat and Equipment Specialists	1,000	
Fish Processing and Distribution Specialists	1,000	
		8,500
11. Earth Science:		
University and polytechnic teachers	200	
Groundwater and Engineering Geologists	1,000	
Meteorologists	1,000	
Physical Oceanographers	500	
		2,700
12. Basic Science:		
University and polytechnic teachers and research workers	3,000	
Statisticians for government and industry	5,000	
Biochemists for government and industry	1,000	
Physiologists for government and industry	1,000	
Chemists for government and industry	5,000	
		15,000
13. Humanities:		
University teachers	1,000	
		1,000
Grand total		256,000
II. Diploma level. We have not attempted a detailed breakdown but a very rough projection indicates 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. (300,000 to 600,000)		

CHAPTER 6

UNITED STATES DEPARTMENT OF AGRICULTURE PARTICIPATION IN INTERNATIONAL TECHNICAL ASSISTANCE [1]

By Matthew Drosdoff, formerly Administrator, International Agricultural Development Service, United States Department of Agriculture, presently Professor of Soil Science, Cornell University

The Department of Agriculture has a long record of international activities, dating back almost to its origin in 1862. Probably the first formal involvement was with Japan in 1871 when Horace Capron, United States Commissioner of Agriculture, went to Japan with a staff to provide technical assistance in agriculture to the Japanese Government. They established experimental farms and an agricultural college which opened in January 1872.

The Capron mission employed 75 non-Japanese, 45 of them Americans. They assisted in the development and implementation of plans for the colonization of Hokkaido. The American technicians had their Japanese counterparts at every level. Among the vegetables introduced by the Capron mission were onions, turnips, cabbage, lettuce, tomatoes, carrots, beets, celery, and spinach. The Japanese became famous as vegetable gardeners.

The Department of Agriculture had no statutory authority for foreign activities other than that contained in the Organic Act which created the Department in 1862. This included the general mandate to collect and disseminate information on agriculture and to collect, propagate, and distribute new and valuable seeds and plants. This authority enabled the Department to begin a program of plant exploration, collection, and classification of agricultural materials which reached into the remote corners of the earth. Congress supported these explorations because many of the plant introductions proved to be of economic benefit to American farmers: improved strains of hard red winter wheat from Turkey and Russia, long staple cotton from Egypt,

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[1] This article is based on an unpublished manuscript by Jane M. Porter, History Branch, Economic and Statistical Division, Economic Research Service. USDA. It is a revision of an earlier version which appeared in the November 1966 Newsletter of the International Agricultural Development Service.

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alfalfa from Siberia and Afghanistan, soybeans and tung oil from China, figs from Syria, and dates from North Africa.

The exchange of information and agricultural materials with other governments became an established function of the Department from its inception. Such exchanges in the early days were often arranged through American ministers and consuls in foreign countries. James Wilson, who became Secretary of Agriculture in 1897, supported United States membership in the International Institute of Agriculture. This was the first international agricultural organization with a permanent headquarters and staff. It was a clearing house for scientific, economic, and statistical information supplied by participating countries which in 1908 numbered 46.

At the turn of the century, the Department was a center for postgraduate training in the agricultural sciences. Foreign countries began to compete for services of USDA-trained scientists. Sometimes the requests came through diplomatic channels for loan of a man with certain specialized knowledge to analyze and suggest solutions for specific problems. On other occasions, men who had become known through their exploratory travels, publications, or attendance at scientific meetings were approached directly with offers of jobs. The Department usually regarded such overseas employment as an opportunity to enlarge its own knowledge and maintained close contacts with former employees.

Sixty years of continuous development had created by 1932, a Department of Agriculture in the United States which was without equal in any other country. It was world renowned for its research on plants and animals and on their diseases and pests. It was equally known for its crop reporting, development of standards for basic commodities, inspection of plant and animal products and agricultural statistics. By 1933 Americans had given technical assistance in agriculture to countries in five continents.

International work of the Department was carried on by the several bureaus in their separate subject matter fields. There was scarcely an agency in the Department whose work did not touch at some point in the international field, but most international work was concentrated in a few of the bureaus.

The Bureau of Plant Industry had plant exploration, seed and plant introduction, tropical agriculture, and rubber and hard-fiber investigations. The Bureau of Entomology and Plant Quarantine searched for insects and their parasites and conducted a nationwide inspection service. The Bureau of Animal Industry engaged in the study of animal diseases prevalent in foreign countries as well as those existing in the United States. The rationale for this was that this knowledge would better enable the veterinarians to prevent the introduction of foreign diseases here and, if introduced, facilitate their eradication. The Office of Experiment Stations was responsible for maintaining correspondence and exchange of publications with foreign schools and experiment stations.

Several lines of foreign economic work had, by successive steps, been combined into the Foreign Agriculture Service Division of the Bureau of Agricultural Economics. The Bureau of Statistics had been created by 1901 by combining the Section of Foreign Markets with the Division of Statistics. Research on foreign agriculture in the Office of Farm Management had also been undertaken by the Division of Agricultural History and Geography. When the Bureau of Statistics, the Office of Farm Management, and the Bureau of Markets were combined in 1923 to form the Bureau of Agricultural Economics, the new Bureau had a section of Foreign Competition and Demand. Strenuous efforts were made during the 1920's with the funds and facilities available to establish regularized reporting on foreign crops and markets around the globe. In this, the Department both helped and received help from the International Institute of Agriculture in Rome.

Following ratification of the Convention of Cultural Relations by the United States, President Franklin D. Roosevelt signed, on May 25, 1938 an Act of the 75th Congress authorizing the detail of United States employees possessing special qualifications to governments of American Republics, the Philippines, and Liberia. This Act provided that the President could accept reimbursement if the government receiving the services of a United States technician desired to pay for the services. Thus, for the first time, the Department of Agriculture was given legal authority for extending technical assistance.

OFAR Created

On July 1, 1939, the Office of Foreign Agricultural Relations was created within the Department of Agriculture. One of its functions was, "to plan, direct, and coordinate participation by the Department of Agriculture in the general program of cooperation between the Governments of the United States and of other American Republics under the terms of acts of Congress authorizing such cooperation."

In 1939 the 76th Congress passed several laws designed to improve relations with Latin America. Public Law 355 approved establishment of cooperative tropical experiment stations in Latin American countries for development of crops complementary to U.S. production. The functions of these stations included agricultural research centering around development, propagation, and distribution of superior planting materials of complementary tropical crops, and extension work to interest farmers in growing these crops, once feasibility of their production was established.

War Spurs International Efforts

With the outbreak of World War II in 1939, the United States became acutely aware of the need for promoting sources in the Western Hemisphere for rubber, manila hemp, the cinchona plant (for quinine), insecticidal crops, and several other products. At the same time it recognized that increased production in Latin America of other complementary crops—coffee, bananas, cocoa, and certain fibers—would improve buying power of cooperating countries and make them better customers for United States products.

The Second Deficiency Appropriation Act of 1940 provided for an appropriation of the State Department for scientific and cultural cooperation. This $250,000 appropriated to the State Department could be transferred to any government department or agency participating in the program of Inter-American cooperation. Thus was established the precedent for carrying out technical assistance in the Department of Agriculture through transfer of funds appropriated originally to another agency.

During the war years, 1941–45, the bulk of the funds used for Technical Assistance by the Department of Agriculture was channeled from the Office of the Coordinator of Inter-American Affairs. This office was established by the President by Executive Order 8840 on July 30, 1941. In November 1941 a Division of Agriculture was established in this office.

The Office of Inter-American Affairs had other agricultural programs not administered by the Department of Agriculture but drawing heavily on agricultural scientists from the Department through loan or recruiting. These programs were usually administered through *Servicios*, established in cooperation with individual countries. These *Servicios* carried on food supply programs as well as promotion of complementary crops and general agricultural development in Latin American countries. A major effort was directed toward increasing the production of rubber. Rubber surveys and establishment of propagating and multiplication stations got underway on a crash program basis in 1940. Cooperative arrangements were made with fifteen Latin American countries and by February 1941, fifteen sub-experiment stations and nurseries had been established in widely separated areas and rubber seed had been brought in from the Philippines.

Another war agency through which Technical Funds were allocated to the Department of Agriculture was the Board of Economic Warfare. It was a Cabinet level organization established on July 30, 1941 by Executive Order 3839 as the Economic Defense Board.

Crop Research in Latin America

In July 1941 Congress appropriated funds for cooperation with other American Republics to stimulate production of agricultural commodities which would be complementary to our own. The first cooperative agricultural experiment station in Latin America began with the signing of an agreement on April 21, 1942, between Peru and the United States. The station was located at Tingo Maria in a tropical forest area 260 miles northeast of Lima.

Studies to improve cultural practices of coffee began in Costa Rica, El Salvador, Guatemala, and Peru. These studies resulted in two innovations: the hedgerow planting system of coffee and discovery that minor elements played an important role in the utilization of fertilizer by the coffee plant. Research on tea was conducted in Peru. Timber surveys were made in Ecuador, El Salvador, Guatemala, and Nicaragua. Several thousand hectares of mahogany plantations were established in Nicaragua. Vegetable oil crops were tested as possible export commodities in Ecuador, El Salvador, Nicaragua, and Peru. Research was begun in Ecuador and Nicaragua to combat diseases which attack cacao, the source of cocoa and chocolate. Research got underway in Ecuador, Guatemala, and Nicaragua on such new crops as essential oil plants, medicinals, and insecticidal plants.

Agricultural experts from the United States were detailed for cooperative work and for consultation with national officials in the other republics. Most of these were regular experienced staff officers of the USDA. Some were men with long experience in the Extension Service in various states of the United States; others were prominent officials and teachers in agricultural schools and land-grant colleges.

First Training Participants

Promising young trainees in the cooperating nations began to learn about scientific agriculture from United States technicians stationed in their countries.

Some came to the United States to attend classes in the land-grant institutions. Others came to take on-the-job training courses in agricultural experiment stations and laboratories, and in agricultural extension work in rural communities, and in some cases, on farms. Specialists and farm leaders from the cooperating countries toured the United States in increasing numbers observing practices which could be applied in their homelands.

By 1946, fifteen countries were participating in technical assistance: In Central America—Costa Rica, El Salvador, Honduras, Guatemala, Mexico, Nicaragua, and Panama; in South America—Bolivia, Brazil, Colombia, Ecuador, and Peru; and in the West Indies—Cuba, Haiti, and the Dominican Republic.

Technical assistance continued in the forties under the Interdepartmental Committee on Scientific and Cultural Cooperation. During World War II, programs were operated by the Board of Economic Warfare through such agencies as the Defense Supplies Corporation and the Commodity Credit Corporation to stimulate production of strategic materials in the Western Hemisphere. Agricultural portions of the programs were coordinated in the Department of Agriculture.

Within the USDA, a Technical Collaboration Branch of the Office of Foreign Agricultural Relations was established in 1944, succeeding the Division of Latin American Agriculture, to carry out the Department's international responsibilities. It operated with funds allotted to it by the Interdepartmental Committee on Scientific and Cultural Cooperation. In general the cooperating countries spent three to four times as much on the various projects as the United States did.

In the summer of 1946 two agricultural missions, sponsored jointly by the Departments of State and Agriculture, went out; one to Mainland China, the other to the Philippines. Later, missions were sent to Syria, Lebanon, Iraq, Saudi Arabia, Siberia, Egypt, and Greece. These missions were requested by the respective governments to assist experts in specific technical phases of agriculture. The foreign countries selected and assigned their own technical experts to determine the potentiality of technical collaboration in agriculture between the two governments.

On January 27, 1948 President Truman signed the United States Information and Educational Exchange Act which provided for world-wide cooperation with other governments.

Marshall Plan Initiated

When Western Europe failed to recover quickly after the end of World War II and there appeared to be grave danger that communist groups would gain control of the governments in several countries, the Marshall Plan was inaugurated. On April 3, 1948, the Foreign Assistance Act creating the European Recovery Program was approved. It was a four-year program leading toward a goal of self-support by the countries of Western Europe by mid-1952. While the intial thrust in food and agriculture was directed toward importing enough food to enable industrial workers to function at a higher level of efficiency, restoration and expansion of food production was an ultimate goal.

The need for more fertilizer, higher yielding crop varieties, more effective disease and insect controls, better farm practices, and increased mechanization replaced concern over procurement and shipment of food and fiber from the United States after the first year of operation of the Economic Cooperation Administration.

Agricultural personnel of the Economic Cooperation Administration both in Washington and overseas were recruited largely from the Department of Agriculture and the land-grant colleges. Before the European Recovery Program was two years old, it was recognized that the greatest obstacle to increasing agricultural production was the backwardness of the peasantry. The cradle was commonly used for harvesting grain and the flail for threshing. The Persian wheel was used for lifting irrigation water.

Establishing agricultural educational and information services became the major emphasis in the later part of the European Recovery Program for Agriculture.

The Economic Cooperation Administration ran its own program in technical assistance but relied heavily on the Department of Agriculture for technical personnel and guidance. Economic data on agricultural production and consumption in Western Europe, as well as on requirements and availability of food from other areas, was also supplied by the Department of Agriculture.

USDA Trains Foreign Agriculturists

USDA has been continually involved in the education and training of foreign visitors. This has been an integral part of the long-range objective of transferring, by demonstration and teaching, technical knowledge to help them to improve their standard of living. These people are selected on the basis of their qualifications and remain in the United States an average of one year. Many re-enter government service when they return to their native lands, and have introduced American methods and standards of agricultural practice. Others have joined international organizations.

During the late 1940's, most trainees came from Latin America, sponsored by the Institute of Inter American Affairs and the Interdepartmental Committee on Scientific and Cultural Cooperation. The Department of the Army sent more than 100 from Germany, Austria, Japan, and Korea in 1949–50. The Economic Cooperation Administration delegated responsibility for conducting its training programs to the Department of Agriculture by an agreement approved August 8,

1950. From 1951 to 1954 most of the trainees came from Western Europe, Greece, Turkey, and Japan and were sponsored by the Economic Cooperation Administration and its successor, the Mutual Security Agency.

Point Four Program Started

The most significant step in the development of technical assistance came as a result of President Truman's inaugural address of January 20, 1949 whereby technical assistance became world-wide in scope. It was known as "Point Four," deriving from the fourth point which he emphasized. Several paragraphs from the address follow:

> Fourth, we must embark on a bold new program for making the benefits of our scientific advances and industrial progress available for the improvement and growth of underdeveloped areas.
>
> More than half the people of the world are living in conditions approaching misery. Their food is inadequate. They are the victims of disease. Their economic life is primitive and stagnant. Their poverty is a handicap and a threat both to them and to more prosperous areas.
>
> For the first time in history, humanity possesses the knowledge and the skill to relieve the suffering of these people.
>
> The United States is preeminent among nations in the development of industrial and scientific techniques. The material resources which we can afford to use for the assistance of other peoples are limited. But our imponderable resources in technical knowledge are constantly growing and are inexhaustible.
>
> I believe that we should make available to peace-loving peoples the benefits of our store of technical knowledge in order to help them realize their aspirations for a better life. And, in cooperation with other nations, we should foster capital investment in areas needing development.
>
> Our aim should be to help the free peoples of the world, through their own efforts, to produce more food, more clothing, more materials for housing, and more mechanical power to lighten their burdens.

On January 27, 1949 the Department of State was assigned the responsibility for planning Point Four programs. Meanwhile, while waiting for the Point Four program to clear through Congress and the executive department to establish machinery for its administration, the Department of Agriculture sent a team of three top technical experts on an 80-day trip through 12 Eastern Hemisphere countries which had requested the loan of United States technicians under the more limited technical cooperation authority of Public Law 402.

They returned with preliminary plans for cooperation with Iran in development of agricultural extension and research, cooperation with Ceylon in an agricultural extension program to increase the efficiency of rice production, and cooperation with Pakistan in improving agricultural extension work.

Department of Agriculture specialists went to Iran and Ceylon late in 1950 to inaugurate these programs. In 1950 five dates are noteworthy in the history of Point Four: On February 21 the Interim Office for Technical Cooperation and Development was established in the Department of State. On June 5 the Act for International Development, Public Law 535, was approved by the President (the enabling legislation for Point Four). On September 6 the President delegated authority for the administration of Point Four to the Secretary of State. On October 19 the first agreement, under Point Four with Iran, was signed; thus technical assistance became worldwide. On October 27, the Department of State announced the establishment of the Technical Cooperation Administration. It absorbed the work in Latin America of the Interdepartmental Committee on Scientific and Cultural Cooperation.

Under the Technical Cooperation Administration USDA continued to have operating responsibility for operation of agricultural assistance programs. This responsibility involved hiring, training, and assigning technical personnel overseas and providing all Washington support and backstopping. Funds were allocated from the Technical Cooperation Administration to USDA for this function.

Point Four Gets Continuing Legislation

Congress provided continuing authorization for Point Four in the Mutual Security Acts of 1951 and 1952. During these years the Department of Agriculture, through its Technical Collaboration Branch in the Office of Foreign Agricultural Relations, provided technical assistance. At the end of 1952 the United States was giving such help to 38 countries.

In 1952 the Secretary of Agriculture established a USDA Committee for Technical Cooperation with Foreign Areas, and by March 26, 1953, the Department of Agriculture had 313 employees serving outside the United States, paid from funds allocated or advanced by agencies outside the Department.

USDA had authorization to employ 504 technicians for foreign service as of April 1, 1953: Latin America, 120; Africa and the Near East, 108; Asia and the Pacific, 85. Funds for these research and technical assistance programs in fiscal 1953 came from the Department of the Army, Institute of Inter American Affairs, Reconstruction Finance

Corporation, Department of the Navy, and Mutual Security Act funds. In addition, these agencies provided about one seventh of the total budget of OFAR for salaries and expenses in Washington.

The Mutual Security Agency had 133 agricultural specialists serving overseas; 76 in Western Europe and Turkey and 57 in East Asia. Agricultural personnel in Point Four work employed directly by the Technical Cooperation Administration numbered 83.

USDA—Land-Grant Cooperation

The Department of Agriculture has cooperated closely with the land-grant colleges and universities, particularly in research and extension work. On February 3, 1950, a joint Department of Agriculture Land-Grant College Committee on Agricultural Services to Foreign Areas was established by the Association of State Universities and Land-Grant Colleges. The Economic Cooperation Administration, the Institute of Inter American Affairs of the State Department, and (after its establishment) the Technical Cooperation Administration were also represented. The committee was primarily concerned with two problems—recruitment and training of United States personnel for work in technical assistance overseas and handling of foreign trainees and observers who were arriving in large numbers.

Roster of Specialists

Both the land-grant colleges and universities and the Department of Agriculture feared that the need for technical personnel for international assistance programs would place a severe drain on their resources. The committee recommended establishment of a central roster of agricultural specialists available for assignment abroad. This was done by USDA's Office of Personnel and a recruiting drive was carried on in 1951 and 1952.

The USDA Office of Foreign Agricultral Relations, the Technical Cooperation Administration, the Economic Cooperation Administration, and the Mutual Security Administration all used this roster in their staffing. On October 1, 1951 it contained 1,452 names of specialists in such fields as soils, forestry, agronomy, biochemistry, genetics, horticulture, animal husbandry, veterinary medicine, entomology, agricultural and electrical engineering, economics, marketing, and rural sociology.

The committee also recommended that colleges concentrate on providing technical assistance to particular countries. This led to the establishment of agreements between United States institutions and institutions in foreign countries. It was the beginning of the University Contract Program.

The Department of Agriculture cooperated in the first contract with the University of Arkansas to send a mission to Panama to work with the Agricultural College on education, research, and extension. Another contract was with Oklahoma State to send a mission to Ethiopia. By mid-1951 the USDA assisted in contracts with Utah State, Texas A. & M., Purdue, Michigan State, North Carolina State, and Minnesota.

One of the most comprehensive projects was the agricultural development program undertaken by the New York College of Agriculture at Cornell University in cooperation with the College of Agriculture of the University of the Philippines at Los Banos. Over a period of eight years (1952–60) a total of 51 American professors, including 35 from Cornell, were assigned to the University of the Philippines for one to three years.

In regard to foreign training, the committee first surveyed the expected work load. It found that in agriculture alone the Economic Cooperation Administration was planning to bring in 600 trainees in 1951–52; the State Department (IIAA and TCA) planned for 472; and the Department of the Army, 365. The total approached 1500.

The committee recommended that the colleges and universities cooperate with the Department of Agriculture in working out special courses and programs for handling trainees of like interests in groups. Another recommendation was that the Department of Agriculture handle all correspondence on the assignment of foreign visitors to the colleges and universities and that this be done by a single office in the Department of Agriculture. Similarly, the colleges should have a single office assigned to coordinate all work in connection with foreign training.

The Association of State Universities and Land-Grant Colleges adopted this recommendation and has steadfastly adhered to it ever since. The Department's responsibility was assigned to the Division of Education and Training in the Office of Foreign Agricultural Relations.

On March 10 to 15, 1951, the first of a continuing series of conferences between Department of Agriculture officials and designated contact officials of the State universities and land-grant colleges was held in Washington. Administration of the training of foreign technicians in agricultural subjects has remained in the Department of Agriculture, and colleges and universities have fully cooperated in accepting groups of foreign students for training.

Between 1950 and 1953, this committee exerted an important influence on policy making and in promoting cooperation and coordination between the colleges and government agencies engaged in technical assistance. The Department of Agriculture withdrew its representatives from the committee after establishment of the Foreign Operations Administration and the transfer of technical assistance programs to that agency. The committee was continued as a committee of the Association of State Universities and Land-Grant Colleges and served during the late 1950's as a rallying point for resolving problems and policy issues with administration of the University Contract Program of the International Cooperation Administration.

USDA's Role Declines

Following establishment of the Foreign Operations Administration in 1953, all foreign economic and technical assistance programs were transferred to it, and the Department of Agriculture's participation in most phases of the assistance program decreased rapidly. The more than 300 overseas agricultural personnel were either transferred to the Foreign Operations Administration or brought home. Program planning and evaluation were discontinued except as specificially requested, and responsibility for all but three special regional projects was discontinued. The Department's responsibility with respect to technical assistance was made the subject of a Memorandum of Agreement in February 1954 between the USDA and the Foreign Operations Administration, and the Technical Collaboration Branch in the USDA was abolished the following month.

The memorandum provided that the Department would render services to FOA under the following categories: technical consultation and support; assignment of personnel for short periods on reimbursable detail; training of foreign nationals in agriculture in the United States; operation of a few special projects such as locust control, soil fertility and salinity, and plant material exchange; and administrative support for the above activities.

In July 1955 the International Cooperation Administration succeeded the Foreign Operations Administration.

Plant Pest Control Significant in 1950's

One of the significant contributions to technical assistance by the Department of Agriculture during the decade of the fifties was in plant pest control. Tremendous losses to crops and livestock throughout the world have been caused down the centuries by insects, rodents, and plant diseases. Ravages of locusts is an outstanding example of large-scale damage.

Sugarcane, wheat, cotton, rice, olives, citrus fruit, and other crops have all been attacked by various pests. The Plant Pest Control Division of the Agricultural Research Service sent entomologists to many countries of Latin America, the Near East, North Africa, and South Asia to wage war against these pests.

USDA's Forest Service was also active during the fifties in supplying technical assistance through FOA and ICA. It provided advisers in forestry, watershed research, and range management. About 40 specialists were usually attached to our missions in various foreign countries or to the Food and Agriculture Organization.

USDA assistance in establishing cooperative agricultural experiment stations and other agricultural institutions was an important contribution. This, together with extensive training programs both in the United States and other countries, helped immeasurably to lay the foundation for agricultural development in many less developed nations.

Many factors limited greater progress during this period. The war years and the post-war period were not conducive to the development of consistent policies and programs either in the United States or in the recipient countries. During the early war years emphasis was placed on production of strategic and critical materials such as rubber, quinine, and insecticides. Later, food supply programs became most important.

Political instability in the host countries seriously limited progress in agricultural programs. Land ownership patterns and land tenure systems were a severe handicap. Lack of overall country planning and neglect of the agricultural sector in public policies were problems. Agricultural education and technology did not offer challenging career opportunities for young people in most countries. Consequently, lack of trained personnel in the agricultural sciences was a serious problem.

In the United States, lack of coordinated direction and continuity of objectives in technical assistance programs handicapped progress. The prevailing concept of our foreign assistance programs as being only a temporary measure undoubtedly contributed greatly to this. Frequent reorganization and shifting of responsibilities from agency to agency and interagency bickering caused considerable confusion.

From 1954 to 1961 the Department of Agriculture had only limited participation and responsibilities in foreign assistance activities. The Foreign Operations Administration and subsequently the International Cooperation Administration assumed practically all programing and operating responsibilities for agricultural assistance programs. However, the Foreign Operations Administration requested the Department of Agriculture to continue to provide special services under the agreement signed in 1954 between the two agencies, such as:

(1) Continue to take responsibility for programing and supervising training for foreign agriculturists coming to the United States;

(2) Provide, upon request, technical consultation and backup support;

(3) Continue to staff the regional insect control project in the Near East and Africa and the two U.S.-based projects on soil fertility and salinity and plant materials exchange;

(4) Furnish, on request, qualified specialists for brief periods on a reimbursable basis.

During this 1954–61 period, an average of about 150 man-years per year of USDA employees were paid by transfer of funds of about $2 million a year from the Foreign Operation Administration and subsequently the International Cooperation Administration. About 70 percent of this was involved in training of foreign agriculturists coming to the United States. The remainder provided for requests for technical consultation and backup support, the regional insect control project, and reimbursable details.

USDA's Role Grows Again

Following passage of the Act for International Development in September, 1961 and establishment of the Agency for International Development, the Department gradually became more involved in international technical assistance programs. Section 621 of Public Law 87–195 states: "In providing technical assistance under this Act in the field of education, health, housing, or agriculture, or in other fields, the head of any such agency or such officer shall utilize, to the fullest extent practicable, the facilities and resources of the Federal agency or agencies with primary responsibilities for domestic programs in such fields."

This section of the Foreign Assistance Act was amended on December 16, 1963 to read: "In providing technical assistance under this Act, the head of any such agency or such officer shall utilize, to the fullest extent practicable, goods and professional and other services from private enterprise on a contract basis. In such fields as education, health, housing, or agriculture, the facilities and resources of other Federal agencies shall be utilized when such facilities are particularly or uniquely suitable for technical assistance, are not competitive with private enterprise, and can be made available without interfering unduly with domestic programs."

As a result of this legislation and the strong support given by the Secretary of Agriculture to international assistance programs, the Department's role in international agricultural development began to expand.

During fiscal 1962 the Department was active in eight projects as compared with three the previous year. Twenty-six technical personnel went abroad on short term detail in fiscal 1962 compared with fifteen in 1961. The next year agreements were signed and operations begun on five new regional and world-wide research programs. A publication resulting from one of these programs, an economic survey of "Factors Associated with Changes in Agriculture in 26 Developing Countries," is already being used in the development of programs to meet the world food crisis.

New Programs Begin

New programs were also started in three countries, El Salvador, Tunisia, and Algeria, during 1963. Four agencies of the Department are participating in a project to increase yields in El Salvador, the smallest western hemisphere republic but one of the most densely populated countries in the world.

The Soil Conservation Service undertook responsibility for projects in Tunisia and Algeria. In Tunisia work is concentrated on developing and implementing a detailed plan for a single watershed. As planning is completed, the Tunisian government is employing a force of men, as work relief, to build soil conservation structures and complete other conservation projects. Some 60,000 farm people will benefit, as floods are stopped and water is used properly for crops. Dams, tree planting, grass waterways and ponds have already doubled wheat yields for some farmers.

The Algerian project involved wide-spread application of basic conservation practices under a public works program supervised by Soil Conservation Service technicians. Algerian workers using hand tools were paid partly in food from the United States supplied under the Food for Peace program.

During 1963, the Department provided 245 man-years in technical assistance and training of foreign nationals, using almost $3 million transferred to the Department by the Agency for International Development. Further expansion of technical assistance took place during 1964 and 1965. In fiscal 1966 there were 300 professional people from 19 agencies working in 39 countries on 84 projects. Twenty-three USDA resident teams were working on individual country agricultural assistance programs.

The Department has been working intensively on the agricultural problems of India and South Vietnam during the past year. The crises in India arose from crop failures in 1965 and 1966 but the predicating conditions for food crises have existed in India for centuries.

USDA technicians are helping the Indian Government raise food production through a special soil and water research program and a nationwide price incentive program. The Government has allocated funds for a national researching of ways to get needed water to crops; USDA is helping to focus the project on the most critical needs. A Government price incentive program is being designed to assure farmers of prices for their crops to give them a reasonable profit if they use yield-raising production supplies such as better seeds and fertilizer. Last year, 67 Indian agriculturists participated in U.S. training in a variety of fields including fertilizer technology, seed improvement, irrigation, soil testing, and poultry production.

U.S. Opens Second Front in Vietnam

The problem in Vietnam is the result of 25 years of continuous war and civil disruption. Although this area is part of what was formerly the rice basket of Asia it has become a food-short area.

In the Declaration of Honolulu the rural reconstruction and agricultural development of South Vietnam was termed the "second front." President Johnson said, "The United States will wage war not only on the battlefield but also on the economic and political front as well." He has said that "our goal is to make at least one American agricultural adviser available in each of Vietnam's 43 provinces, as these areas are made secure."

USDA signed an agreement in November 1966 to conduct a major part of the AID technical agricultural assistance program in South Vietnam. The top USDA official in Vietnam will direct five USDA teams which eventually will include some 90 men. The five teams are agricultural credit and cooperatives, irrigation and rural engineering, plant and seed multiplication, forestry, and provincial agricultural advisers. The provincial agricultural advisory corps, 44 of the 90 men to be in Vietnam, are being picked mainly from the ranks of U.S. county agents.

IADS Established in 1963

The International Agricultural Development Service was established on August 2, 1963, to coordinate and administer the Department's programs in foreign technical assistance and training. This service is financed by the Agency for International Development. Requests for technical assistance come from many international and United States organizations. They range from highly detailed scientific requests to calls for assistance in broad agricultural program planning and execution. Assignments vary widely in scope and duration. Many Department technicians are detailed or loaned to AID, the Food and Agriculture Organization, and similar organizations for short periods on a reimbursable basis.

The Department is now participating actively in international assistance planning at all levels. For the first time since 1954 the Department and its various agencies are operating in foreign countries. Each project is undertaken under a Participating Agency Service Agreement (PASA), with the Agency for International Development. Departmental personnel remain on the employment rolls of their own agencies and receive administrative supervision and technical backstopping from these agencies. The agencies gain in having their technical employees acquire new experience, and the technician is assured of job continuity and frequently gains promotions through foreign service. The host countries gain in having programs that are fully backed by the resources of the USDA.

On February 15, 1966, a general agreement was signed by the Department of Agriculture and AID superseding the 1954 agreement. This new agreement formalized coordination and operating procedures which had been in effect by tacit agreement for some time. It recognizes the unique personnel resources, capabilities and experience of the Department and "seeks to enlist as fully and effectively as possible, on a partnership basis, the pertinent resources of the Department in planning, executing, and evaluating those portions of the internal assistance program in which it has special competence."

Aid Important to U.S. Foreign Policy

The U.S. Government considers aid for agricultural development an important arm of foreign policy. Since food shortages are important contributors to political instability, the United States wants to help developing countries increase their food production. Concrete evidence of this is the increased emphasis on agricultural development in the U.S. foreign assistance programs. The new Public Law 480 legislation requires that our food aid be utilized by recipient nations as an instrument for improving their own agriculture. It

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points up the urgent need for developing countries to allocate more resources and to provide more incentives to the agricultural sector. This strong emphasis on self-help places increased responsibilities on the Department of Agriculture and other agencies involved in this program.

CHAPTER 7

PRIVATE FOUNDATION PROGRAMS RELATING TO THE WORLD FOOD SUPPLY

Introduction

The President's Science Advisory Committee Panel on World Food Supply decided during the early period of the study to review the key elements of the international programs of certain private foundations who sponsor activities oriented toward the problems of food supplies of the developing nations. The Rockefeller Foundation, Ford Foundation, and Kellogg Foundation were selected to be included in this survey. Their records of successful operation of programs in foreign countries are well known to those who have had a first-hand involvement or have read their informative annual reports. The details of the programs may not be known by many who are interested in these operations.

The questions asked of the officials of these foundations were selected in order that answers might contribute to the topics that were under investigation by the Panels and Subpanels. Brief replies were requested and exhaustive treatment on any of the topics was discouraged. The information is reported as received from the foundations and follows the outline of topics on which replies were requested.

The importance of this information is in providing a brief synopsis of the kinds of operations and procedures used in what is generally considered among the most desirable and successful of all international programs. Specific references were made throughout volumes I and II of this report to the achievements of the Rockefeller Foundation programs in the agricultural sciences. Equally significant accomplishments could be cited for activities of the Ford and Kellogg Foundations.

THE FORD FOUNDATION

Countries in Which Aid Is Being Extended and Principal Areas of Program Emphasis

Countries in which the Overseas Development Program of the Ford Foundation has made grants in support of agricultural and rural development projects are shown in Table 1. The total amount of grants made in each country since the program was started early in the fiscal year 1952 is shown in the first column of Table 1. The amount of grants made during the last three fiscal years is shown in the second column. The Foundation's fiscal year begins October 1.

Grants made to United States organizations concerned with agriculture and rural development, including land grant colleges and universities, have been limited almost entirely to grants in support of overseas institutions and programs. Few grants have been made to United States institutions in support of their United States-based work in these fields.

Nature of the Program. The Ford Foundation began making grants in South and Southeast Asia and the Middle East late in 1951; in Africa south of the Sahara in 1958; and in Latin America and the Caribbean in 1959. In the 1950's a substantial volume of grants was made in South and Southeast Asia and the Middle East in support of rural community development programs. These programs were concerned not only with efforts to increase agricultural production but with rural housing, education, sanitation, and public works, particularly access roads and schools. Grants also were made to help strengthen

TABLE 1.—*Grants made by the overseas development program of the Ford Foundation during selected periods in support of agricultural, rural village development, and home economics projects*

Region and Country	Fiscal Years 1952–1966 [1] (thousands)	Fiscal Years 1964–1966 [1] (thousands)
South and Southeast Asia:		
Burma	$2,352	------------
India [2]	31,797	$4,702
Indonesia [2]	871	------------
Malaysia [2]	826	827
Nepal	1,594	------------
Pakistan [2]	10,557	3,633
Philippines [2]	4,493	2,820
Regional	1,892	800
Regional Total	54,382	12,782
Middle East and Africa:		
Central Africa [3]	310	------------
East Africa [2] [4]	235	235
Iran	991	------------
Iraq	255	------------
Israel	3,237	750
Jordan	1,591	438
Lebanon [2]	225	25
Syrian Arab Republic	2,211	450
United Arab Republic [2]	908	221
West Africa [2] [5]	1,848	1,603
Regional	2,113	550
Regional Total	13,924	4,272

TABLE 1.—*Grants made by the overseas development program of the Ford Foundation during selected periods in support of agricultural, rural village development, and home economics projects*—Continued

Region and County	Fiscal Years 1952–1966 [1] (thousands)	Fiscal Years 1964–1966 [1] (thousands)
Latin America and Caribbean:		
Argentina [2]	1,342	1,246
Brazil [2]	1,730	2,795
Caribbean [2] [6]	3,341	2,948
Chile [2]	576	518
Colombia [2]	1,215	1,210
Mexico [2]	3,971	3,057
Peru [2]	1,278	978
Venezuela	33	------------
Regional	84	60
Regional Total	13,570	12,812
Interregional Grants:		
Made by New York Office	13,610	5,880
Grand Total	95,486	35,749

[1] The Foundation's fiscal year begins October 1.

[2] Countries in which the Ford Foundation has offices and representatives. The Foundation also has offices and representatives in Thailand, Turkey, and Tunisia although no grants have been made so far in agriculture and related fields in these countries. Offices in Burma and Iran have been closed. The following offices serve more than one country:

Office:	*Countries Served*
India	India, Nepal.
Kenya	Kenya, Ethiopia, Sudan, Tanzania, Uganda, Nyasaland, So. Rhodesia, Zambia.
Nigeria	Nigeria, Cameroun, Ghana, Guinea, Ivory Coast, Liberia, Senegal, Congo.
Lebanon	Lebanon, Syria, Jordan, Iraq, Saudi Arabia.
Mexico	Mexico, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua.
Tunisia	Tunisia, Algeria, Morocco.
New York	Caribbean (Antigua, Barbados, Dominican Republic, Puerto Rico, Trinidad, Jamaica), Israel, Venezuela.

[3] Includes former Belgian Congo, Nyasaland, So. Rhodesia, Zambia.

[4] Includes Ethiopia, Kenya, Sudan, Tanzania, Uganda.

[5] Includes Cameroun, Ghana, Guinea, Ivory Coast, Liberia, Nigeria, Senegal.

[6] Includes Antigua, Barbados, Dominican Republic, Puerto Rico and Trinidad.

agricultural extension services, agricultural colleges, agricultural vocational education, and departments and agencies of government concerned with the administration of agricultural and community development programs. Work in home economics, in most cases with a strong rural orientation, also was supported. A few grants were made to help finance projects in agricultural credit and farmers' cooperatives.

Since the late 1950's the Foundation has increasingly emphasized production-oriented research designed to develop improved food crop production technology suitable for use in the tropics; the strengthening of higher education in agriculture at both the undergraduate and graduate levels; and agricultural extension and other types of programs designed to accelerate food production.

In 1960, for example, the Ford Foundation joined with the Rockefeller Foundation and the Government of the Philippines in establishing the International Rice Research Institute at Los Banos near Manila. The work of this Institute is currently financed by the two Foundations.

Plans by the Ford and Rockefeller Foundations for establishing an International Institute of Tropical Agriculture at Ibadan in Nigeria, in cooperation with the Government of Nigeria, were well along when the Government of Nigeria was overthrown for the second time last July. Planning work on this project is continuing although a decision by the two Foundations to proceed with it has not yet been made because of political uncertainties. If and when this Institute is organized, it will concentrate on developing improved production technology for the principal food crops grown or that can be grown in the humid tropics of Africa.

In 1963 the Government of Mexico and the Rockefeller Foundation joined in chartering the International Maize and Wheat Improvement Center located at Chapingo near Mexico City. This Center is an outgrowth of the Mexican-Rockefeller food crop improvement program which was started in 1943. The Ford Foundation has been invited to designate a person to serve on the Board of Trustees of the Center and to participate financially and otherwise in its program and is now doing so.

The two Foundations are currently discussing the possibility of establishing a fourth international agricultural research center to concentrate on the production of food crops, forage crops, and livestock—principally cattle—in the humid tropics of Latin America and the Caribbean.

A food production program in the arid and semi-arid areas of the Middle East and North Africa is also under discussion. If and when this program gets under way, it will concentrate on wheat, barley, sorghums, forage crops, and sheep production.

Increased support of agricultural research by the Ford Foundation in recent years is based on the belief (1) that greatly improved production technology must be made available to farmers in developing countries if food production is to be substantially increased in a reasonably short period of time and (2) that relatively little of this technology can be directly exported from developed countries, most of which are in the temperate zones whereas most of the developing countries are in the tropics. This is not to say that improved production technology is the only requirement necessary to stimulate increased food production in the developing countries. It is believed, however, that it is a basic requirement in the sense that if it is not developed and made available to farmers together with the production inputs necessary to put it to use, food production in developing countries will continue to increase at a dangerously slow rate.

In addition to increased financing of production-oriented research on food crops in developing countries, the Foundation also has helped finance accelerated food production programs in such countries as India and Pakistan.

Factors Influencing Choice of Programs To Be Developed. It could perhaps be said that in the early 1950's the Foundation provided substantial support for community development programs in a number of developing countries in an effort to help raise general levels of living in rural areas. Other kinds of grants related directly or indirectly to agricultural development also were made, but there was heavy emphasis on community development projects of the type that were common at that time. Beginning in the late 1950's, as the world's food problem came into sharper focus, the Foundation began to concentrate more heavily on projects intended to help increase food production. The payoff on some of these, such as strengthening graduate education in agriculture in developing countries with a view to increasing the number of persons with high-level professional training, will necessarily be slow. It is hoped that others, such as the accelerated food production programs which the Foundation is helping to support in Pakistan and India, will pay off more quickly. Still others, such as the International Rice Research Institute in the Philippines, are expected to yield both short-term and long-term returns.

Approach to the Problems. The Foundation has so far followed a general policy of seeking to strengthen indigenous programs and institutions in developing countries rather than undertaking operating programs of its own. It has made extensive use of United States institutions and agencies to assist in carrying out the projects it has helped to finance.

Chief Accomplishments. It is difficult to measure accomplishment in overseas technical assistance. Certainly one could list many institutions and programs in developing countries now operating effectively which the Ford Foundation has assisted. But these institutions also have had local support and in many cases support from other aid agencies.

It probably is not too much to say that the International Rice Research Institute appears to be well on the way to revolutionizing rice production in the tropics. Accelerated wheat and rice production programs in Pakistan, with which the Foundation has been assisting, appear to be well on the way to success. Similar programs in India are now moving well as is an accelerated rice production program in Malaysia and a maize program in Egypt. The wheat program in Pakistan and the maize program in Egypt are based on varieties and production practices developed in Mexico by the Rockefeller Foundation-Mexican maize and wheat improvement programs there.

Administration of the Program

Organization Within the Foundation. The Overseas Development Program of the Ford Foundation is administered on a regional basis with operations in South and Southeast Asia, the Middle East and Africa, and Latin America and the Caribbean. Each regional program is headed by a program Director with headquarters in New York. The three program Directors report to a Vice President for International Programs who reports to the President of the Foundation.

Funds for the Overseas Development Program are appropriated by the Board of Trustees prior to the beginning of each fiscal year on the basis of program planning budgets recommended by the President. Grant proposals originate through the offices of the Foundation's 19 overseas representatives who are responsible for investigating or originating proposals and presenting them to the New York office with recommendations. Grants are approved by the President. In advance of each meeting of the Board of Trustees, a list of grants made since the last meeting of the Board is circulated to Board members and, if they have questions, become the subject of discussion at the next meeting. It is common practice to discuss with the Board unusually large grants or grants involving questions of policy before they are made.

Organizations in Foreign Countries. As stated earlier, the Foundation has nineteen overseas Representatives in developing countries. Each Representative reports to the program Director in New York for the region in which his office is located. Representatives have varying numbers of program advisors on their staffs in such fields as education, agriculture, population, etc., who assist in the investigation of grant requests and in preparing grant recommendations for submission to New York.

Problems in Administering Programs. Administering any kind of technical assistance program in a developing country presents problems. Chief among these is the problem of attracting and keeping overseas highly qualified specialized personnel from developed countries for sufficiently long periods of time to do the kind of quality job that needs to be done. This problem has been no greater in the case of food programs than in the case of programs in other fields.

New Procedures for Program Development. During the current year the Foundation's Latin American program has undertaken to make a series of agricultural benchmark studies in the countries in which it is operating. The purpose of these studies is to get as good an indication as possible of the progress currently being made in agriculture in each country and to highlight the factors which appear to be preventing or slowing down progress. Country studies will be reviewed both by the Foundation's overseas representatives and their respective staffs and by the New York office. It is hoped that this approach to program development will enable the Foundation to do a better job of making grants in agriculture and related fields in Latin America and the Caribbean. The approach is new to the Foundation and the first benchmark studies will not be completed until December 1966.

Financial Requirements

Scope and Type of Expenditures. The nature of the Foundation's grant-making programs in agriculture and related fields is described in the section entitled "Nature of the Program." The dollar volume of grants made during the fiscal years 1952–66 and 1964–66, inclusive, is shown in Table 1. During the 15-year period 1952–66 grants were made at an average rate of $6.4 million annually, and during the 3-year period 1964–66 at an average rate of $11.9 million annually.

The Foundation follows a general policy of not supporting projects in developing countries unless the host country or institution is prepared to make a substantial contribution toward the cost of the project and to continue to support the institution or program assisted after Foundation support is withdrawn. However, the extent of financing by host countries and indigenous institutions varies from project to project and from country to country.

The Foundation frequently assists in financing projects in developing countries that are also partly financed by other bilateral or multilateral aid agencies.

Problems Encountered With United States Government Financing Versus Private Foundation. Coordination of the Foundation's grant-making programs in developing countries with those of other aid agencies is the primary responsibility of the Foundation's overseas representatives. One of the functions of a representative is to keep closely in touch with other aid agencies, including AID, in the country to which he is assigned with a view to achieving as great a degree of coordination in assistance activities as is practical. There have been many cases in which the Foundation has participated with other aid agencies, including AID, in the financing of projects. Joint assistance of this kind is undertaken on a case basis. In each case the arrangements must be satisfactory, of course, to all parties concerned, including the host country or institution. The Ford Foundation has encountered no special problems in cooperating with AID and other bilateral and multi-lateral assistance agencies.

Proposed Future Emphasis

Countries Where Efforts Should be Concentrated and Nature of Assistance Recommended. As stated earlier, the Ford Foundation is currently emphasizing (1) the development of substantially improved food crop production technology suitable for use in the humid tropics and the arid and semi-arid regions of developing countries; (2) the strengthening of agricultural research and extension agencies and of accelerated food production programs in these countries; and (3) the strengthening of agricultural education at the college and graduate level in selected institutions in developing countries with a view to increasing the number of well-trained professionals in agriculture available for work in these countries. The Foundation probably will continue to work in these three fields for several years to come.

Role of United States Government, Private Foundations, and Industry. The Federal Government, industry, and private foundations all have important roles to play in helping developing countries increase food production. If they are to make the contribution of which they are capable, it is essential that each function as part of a total effort. It must be recognized, however, that United States accomplishments abroad in agriculture or any other field depend not only on the resources assigned to a particular country and the competence of United States personnel working there but upon the policies, programs and competence of the host country and its institutions.

Factors Limiting Progress. Three basic conditions must be met if a developing country is to substantially increase food production in a relatively short length of time. First, there must be improved production technology available that is capable, if put to use, of substantially increasing yields. Yield increases of even 20 or 30 percent seldom result in widespread and rapid adoption of improved practices. Yields that are at least 50 and preferably 100 percent greater than those currently obtained by the best farmers are necessary if rapid adoption of improved technology is to be achieved. Production technology capable of producing increased yields of this order is now available for use in the case of wheat in such countries as India and Pakistan and is in the process of being tested in the case of rice in a number of countries in South and Southeast Asia.

Secondly, improved seeds, fertilizers, pesticides, and other production inputs necessary to put improved technology to use must be made readily available to farmers in all important food producing areas.

Thirdly, cost-price relationships in agriculture must be such as to provide strong incentives for farmers to increase output.

Agricultural extension, agricultural credit, good transportation, good marketing facilities, etc., all contribute toward the rapid adoption of improved farming practices. However, it is becoming increasingly clear that major current impediments to increased food production in developing countries are the lack of greatly improved production technology suitable for use in the tropics; failure to make available to farmers the production inputs required by new, improved technology; and cost-price relationships in agriculture in many countries that have stifled rather than stimulated increased food production.

THE ROCKEFELLER FOUNDATION

Countries in Which Aid Is Being Extended and the Principal Areas of Program Emphasis

Nature of the Program. Conquest of Hunger is one of the five major areas of interest of The Rockefeller Foundation. Most assistance in this area is concentrated on increasing the production of the world's basic food crops particularly rice, wheat, corn, potatoes, sorghum, and millets. Support is also given to work in the animal sciences and also to certain agricultural colleges and universities in developing countries.

Factors Influencing Choice of Programs in Agricultural Services. The Foundation presently supports those agricultural activities which it believes will contribute most effectively to the rapid increase of food production. Programs have been supported, with approval of the Foundation's trustees, in nations which indicate a strong desire to raise their agricultural production and their willingness to provide support in the form of local currency, personnel, facilities, and governmental policy.

Approach to the Problems. Much of our work has been concentrated on the development of the materials, knowledge, and technical personnel which are prerequisites for rapid increases in production. This is, in large part, accomplished by the Foundation's staff of professional agriculturalists stationed throughout the world (in Mexico, Colombia, Chile, India, the Philippines, Ecuador, Thailand, and East Africa). Through research, these men attempt to resolve the technological problems impeding achievement of increased yields in the regions in which they are working. They cooperate closely with local scientists and institutions; train young nationals to assume positions of agricultural leadership; and once they have a package of cultural practices that work well in that region, they encourage the adoption of the new materials and practices on the farms. Research, training, and extension generally are integrated.

The Foundation provides partial support of international centers such as the International Rice Research Institute in the Philippines and the International Maize and Wheat Improvement Center in Mexico, both in funds and in scientific personnel. These centers cooperate with regional and national programs throughout the world to facilitate the development and rapid spread of new technology.

Chief Accomplishments. An outstanding example of a successful agricultural program can be found in the 20 years of close cooperation between the Government of Mexico and The Rockefeller Foundation. For the story of this program, see *Campaigns Against Hunger* by Drs. E. C. Stakman, Richard Bradfield, and Paul C. Mangelsdorf, Harvard University Press, 1967.

The International Rice Research Institute (supported jointly by the Ford and Rockefeller Foundations) has been successful in developing new varieties and practices. These are increasing yields in a number of Asian nations. For further information, see the Annual Report of the Institute.

Administration of the Program

Organization Within the Foundation. Agricultural Sciences is one of the four program divisions of the Foundation, which has its main office in New York City. The Director for Agricultural Sciences, the Deputy Director, and five Associate Directors are stationed in New York. Each of the Associate Directors has primary responsibility for one area of the world or for one type of activity (for example, animal sciences) on a world-wide scale.

There are field offices in other parts of the world, each headed by a field director. There is no rigid pattern of organization; rather, there are variations from one field program to another to suit the unique conditions of each.

Organizations in Foreign Countries. The Foundation works with already-existing organizations in the host countries—agricultural universites, national research institutions, ministries of agriculture. A variety of mechanisms for cooperation and collaboration are used, but the goals are always to strengthen the cooperating institutions and to encourage them to strive to increase agricultural production in the regions they serve.

Problems in Administering Programs.—These vary greatly, depending upon geography and circumstances. There is no single solution, but problems can be minimized by (*a*) joint establishment of clear goals by the nation being assisted and the assisting organization, (*b*) by provision of continuous and capable leadership for projects, and (*c*) by adequate and continuous funding.

Effective Procedures. Much can be accomplished by continuous and capable leadership—having one man responsible for a certain program over extended periods of time. Short-term assignments, particularly for project leaders, often are unsatisfactory.

Administrative organization of programs is kept as simple and flexible as possible to permit maximum progress. Constant cooperation among the various field programs and with host institutions is encouraged.

Foundation staff members stationed abroad are encouraged to train substantial members of nationals to assume leadership of national programs.

Agricultural leaders of some developing nations have been encouraged, usually through travel grants, to visit United States institutions or international centers such as the International Rice Research Institute or the International Maize and Wheat Improvement Center in Mexico. This often permits them to return to their home countries with a greater appreciation of the prospects for agricultural development and an increased determination to improve the agricultural sectors of the economies of their countries.

Financial Requirements

These vary greatly. The Foundation provides support for its field staff, plus some back-up funds for certain dollar costs. The host country is expected to provide local currency support, plus land, labor, and other facilities, except for international centers. For details, see the Foundation's annual reports.

Proposed Future Emphasis

Countries Where Efforts Should Be Concentrated and Nature of Assistance Recommended. The Foundation is placing increasing emphasis on international activities, rather than on country programs *per se*. Support of the two major international centers now operating, the International Rice Research Institute and the International Maize and Wheat Improvement Center, is of a continuing nature. A new tropical agricultural institute is being established in Colombia, and one in West Africa is under consideration. Support continues for the

Inter-American Potato Improvement Project with headquarters in Mexico, the Inter-Asian Corn Improvement Program, headquartered in Thailand, the Northern Andean Corn Program, and the Central American Food Crop Program. An Inter-American Rice Improvement Project is now being establishment with headquarters in Cali, Colombia. A regional wheat improvement program for the countries in the Middle East and North Africa is under discussion, and the Foundation is considering the possibility of expanding its international work in sorghum.

Roles of Governments, Foundations, and Industry. The roles of governments, foundations, and industry in agricultural development are complementary but differ significantly. The role of a foundation should be exploratory and demonstrational, identifying new approaches and methods which, if successful, other types of institutions may adopt. Both foundations and governments can perform public services—research, education, extension—which then will permit industry to provide efficiently the multitude of things for which a demand has been created—seed, fertilizer, pesticides, transport, and equipment.

Though their roles are somewhat different, progress can be greatly speeded by communication and cooperation between the three types of institutions.

Factors Limiting Progress. One of the factors that is and will continue limiting agricultural progress in developing countries is the lack of agriculturalists with training and experience relevant to present needs. And there are disturbingly few institutions in the United States or abroad to which young men can be sent for highly relevant agricultural education.

There are too few agricultural universities abroad which have the kind of active, practical, production-oriented research programs which are essential to the rapid improvement of agriculture in the regions they serve.

There are several limiting factors which can be eliminated only by changes in government policies of the nations concerned. A poor ratio of cost of inputs to commodity prices discourages the farmer from adopting new technology, as does the unavailability of credit and the lack of a dependable market. Foundation representatives work with government leaders to identify government policies which will encourage the farmer to rapidly increase production.

For more complete information on the programs briefly described above, see "Progress Report: Toward the Conquest of Hunger, 1965–66," published by the Foundation and available upon request from

The Rockefeller Foundation, 111 West 50th Street, New York, N.Y. 10020.

THE KELLOGG FOUNDATION

Countries in Which Aid Is Being Extended and the Principal Areas of Program Emphasis

Nature of the Program. The Foundation is chiefly concerned with the application of knowledge; hence, its resources are largely limited to supporting educational activities. The following is a listing of Foundation-aided programs related to certain aspects of world food supply.

United States. Iowa State University received assistance for the program of the Center for Agricultural and Economic Development. This program is an effort to discover, evaluate, and disseminate information pertaining to problems of agricultural adjustment and public policy, and to stimulate activities in agricultural improvement and economic development in less advanced countries.

The University of California at Davis received aid from the Foundation to assist with the development of its program to train Americans for effective overseas service in international agriculture and in agricultural development. The purpose of the International Agricultural Development Program at the University is to give improved training to specialists through a teaching program geared to foreign agricultural problems, especially in nations developing, and supported by related research.

Western Europe. Since 1953, a total of 578 fellowships have been awarded to outstanding young agriculturalists to enable them to come to the United States for a period of study and/or observation in their field of specialization. Up to 1960, fellowships were awarded primarily for developing competencies in the production aspects of agriculture. Subsequent to 1960, fellowships have been directed to develop competencies in the areas of extension, adjustment, and management to meet the changing needs of agriculture in Europe.

The Institute of Land Reclamation and Improvement in Wageningen, The Netherlands, received funds to assist in establishing, operating, and housing an institute for the worldwide dissemination of information relative to land reclamation and improvement.

The University of Helsinki received assistance to establish a program of education in food science and food technology as a means to reduce Finland's reliance on imported foods.

The Swedish Agricultural College in Uppsala and the University of Newcastle upon Tyne in England received funds to establish programs to study problems of agricultural adjustment and to develop educational programs in this area.

The University of Reading in England, the Agricultural Research Council of Norway and the Federation of Small Holders Associations in Denmark received grants to assist the development of their programs which provide pre-service and in-service training for extension personnel.

Latin America. The National Institute of Nutrition of Ecuador received aid for the development of its library in support of its educational program.

The Institute of Nutrition for Central America and Panama has received continuous assistance since its establishment for a broad range of investigative and educational activities. Two of the Institute's most outstanding achievements have been the preparation of food composition tables based on the chemical analysis of 600 food items consumed in Central America and the development of a low-cost, high-protein food additive which is being marketed commercially today.

The National University of Colombia received aid for a cooperative program established with Michigan State University to expand and improve the educational programs in agriculture at the Faculties of Agronomy in Palmira and Medellín. Following this initial aid for education, assistance was provided for a national survey of agriculture in Colombia. The survey revealed a need to establish one central agency to coordinate agricultural efforts in education, extension, and research. Consequently, the Colombian Institute of Agriculture was established for this purpose. The Institute is receiving assistance under a multipartite agreement. AID is providing funds for undergraduate education; the Ford Foundation is financing improved teaching and research programs in agricultural economics; the Rockefeller Foundation is providing funds to support investigations in animal and plant sciences; and the Kellogg Foundation is supporting the establishment of a Division of Information and Development which is responsible for extension activities.

The Victor Fund for International Planned Parenthood received assistance for developing comprehensive programs of education in birth control in Latin America.

Factors Influencing Choice of Programs to be Developed. Not applicable to our situation since the Foundation does not operate programs of its own. Applicants for aid retain full responsibility for pre-program planning as well as the administration and orientation of proposed activities.

Administration of the Program

Organization Within the Foundation. Foundation grants to institutions or agencies for the development of health, educational, and agricultural programs are made through seven Divisions: Agriculture, Dentistry, Education and Public Affairs, Hospitals, Latin American, Medicine and Public Health, and Nursing. Each Division is headed by a Director who is responsible for the evaluation of requests and the supervision of the grant in his professional field.

Organizations in Foreign Countries. The Foundation is not involved in this type of activity since its assistance is extended only to institutions already in existence.

Financial Requirements

Scope and Type of Expenditures. The resources of the Foundation are largely devoted to the development of educational activities. Support is not ordinarily provided for research, per se. Nor are funds given for capital facilities, except where such facilities are an essential part of an ongoing Foundation-aided program.

Foundation support is provided on an annually declining basis spread over a three to ten year span depending upon the nature and scope of the program involved. The extent of Foundation aid is determined by the scope of the proposed activity, the appropriateness and adequacy of the various budgetary items, and the resources available to the requesting agency.

The requesting agency is expected to share initial expenses and annually increase its support as Foundation aid decreases. The agency is also responsible for arranging permanent funding after termination of assistance from the Foundation if the program warrants continuation.

The Foundation often participates in multipartite financing; however, it has no specific requirements in this regard.

Problems Encountered With United States Government Financing Versus Private Foundation. We have had only one contact with Federal Government financing for an international program, and this experience is so recent that we are not in a position to offer constructive comment.

Proposed Future Emphasis

The Kellogg Foundation plans to continue its emphasis on educational programs, according to the geographic scope of our interests as defined by our Board of Trustees. It is unlikely that we will make any substantial investment in efforts to research the problems related to world food supply.

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CHAPTER 8

UNITED STATES INDUSTRIAL INVOLVEMENT IN RESEARCH AND DEVELOPMENT ABROAD

Introduction

There are many reasons for the interest of the private sector of the United States and other developed nations in the research and development that may contribute to more effective planning, financing, and implementing of economic development in a developing nation. Industries operating at the international level have a direct interest in inter-country relationships and economic growth that may affect their financial progress. The problems of meeting food needs in the developing nations are likely to affect a greater segment of the United States industries presently conducting or planning for overseas operations than any other endeavor. These problems involve a wide range of industries considered significant in the economic development of any nation including agricultural production, marketing and distribution, transportation, communications, pharmaceutical, health, and education.

It is expected that the private sector of the economy will be actively involved in any program relating to world food needs and a significant portion of the cost of programs designed to meet these needs may be borne by industry. United States industrial interests are interested in opportunities for investments in developing nations where there are indications of stability of governments. The United States Government is encouraging participation of private industry in the "War on Hunger." An example of this encouragement is the request in President Johnson's Foreign Aid Message of February 9, 1967, to the 90th Congress that an "Office of Private Resources" be established in the Agency for International Development.

With the interest and need for United States industrial research and development in the developing countries, the President's Science Advisory Committee Panel on World Food Supply sought to determine—

(1) the extent of present research and development on food and nutrition problems in foreign countries, and

(2) the extent to which companies operating at the international level might be expected to become involved in such research and development.

A survey was conducted by use of a questionnaire circulated to agricultural industries having membership in the Argicultural Research Institute. Special assistance in preparation of the questionnaire was provided by Dr. S. G. Younkin, past president, and Dr. Howard S. Sprague, Executive Secretary of the Agricultural Research Institute. Dr. Sprague was exceedingly helpful in all facets of work related to distribution and collection of the questions from the 85 companies holding membership in the Agricultural Research Institute at the time of the survey.

The Questionnaire

The following are the questions used in the survey.

1. Classification of your organization (biologics, chemicals, feeds, food, machinery, seed, transportation, etc.)
2. Names of countries in which your organization is presently conducting research and/or development.
3. Classification of research and development conducted by your organization in foreign countries according to fields of science.

Percent

(a) Biological (biochemistry, microbiology, etc.) ______________ ______
(b) Physical (chemistry, engineering, physics, etc.) ____________ ______
(c) social (economics, education, communications, etc.) _________ ______

4. Classification of research and development conducted by your organization in foreign countries according to activities.

Percent

(a) Conservation, development and use of soil, water, forest and related resources (includes resource description, inventory, management, and evaluation of alternative uses) ___________________ ______
(b) Protection of man, plants and animals from losses, damage or discomfort caused by insects, diseases, parasites, nematodes, weeds, fire, and other hazards_______________________________ ______
(c) Efficient production and quality improvement (includes management, mechanization and improvement of biological efficiency and quality in production of farm and forest products) __________ ______
(d) Product development and processing (new and improved food and non-food products from farm and forest products) __________ ______
(e) Efficient marketing of quality products (by studies of quality, marketing efficiency, development of domestic and foreign markets) ____ ______
(f) Improvement of human nutrition and satisfaction (includes composition, nutritional value, consumption, and eating quality of foods, and utilization of family resources) ___________________ ______
(g) Development of human resources and of economics of communities, areas and nations (economic and social change and development) ____ ______
(h) Evaluation of public programs, policies and services (research which cannot be allocated to one or more of the above) __________ ______

Percent

5. Classification of research and development conducted by your organization in foreign countries according to resources or commodities.
   (a) Soil, water and related resources (such as watersheds, air, and climate) -- ______
   (b) Timber, forest products, and related resources (such as range, wildlife, fish and recreational resources) --------------------- ______
   (c) Crops and crop products (includes horticultural, vegetable, ornamental, citrus, deciduous, and small fruits, grain crops, pasture and forage, fiber and oil crops, tobacco, etc.) --------------------- ______
   (d) Animal and animal products (poultry, beef, dairy, swine, sheep. etc.) -- ______
   (e) General purpose farm supplies and facilities (including equipment, structures, fertilizers, and pesticides) ----------------- ______
   (f) Human resources, organizations and institutions (includes people as individuals; the family; the farm as a business; communities and their institutions and organization; marketing, processing and farm supply firms; marketing system and agricultural economy of the United States and foreign countries and sectors thereof) -- ______
6. *Research and development staff.* Indicate the size of your research and development staff in each foreign country named in Item 2 above. Research and development personnel working in your own facilities in foreign locations is to be reported in terms of professional man years. Each full time research and development worker with an M.S. or Ph.D. degree is to be reported as one professional man year. Supporting employees are not to be reported.
7. *Research and development personnel supported by your company in private or public institutions in foreign countries.* In this case, indicate size of research and development staff which you are supporting in each foreign country shown in Item 2 in private or public institutions rather than in your own facilities. Each full time research and/or development worker with an M.S. or Ph.D. degree is to be reported as one professional man year. Supporting employees are not to be reported.
8. Estimate percentage change in total research and development effort in foreign countries by your company by 1976.
9. Does your company provide financial support for education of foreign students?
   If "yes," indicate the number of students your company will support in (a) foreign universities during the next year ______ and (b) the number of foreign students your company will support in United States universities during the next year ______.
10. Would your company seriously consider conducting a research and/or development program in an underdeveloped country if the program was supported by the United States Government?
11. Enumerate major problems which your organization has experienced in connection with the planning, development or expansion of your commercial operations in underdeveloped countries.

    Are there specific changes in present United States policies and regulations that would correct or alleviate these problems? Please list.

Results of the Survey

There were a total of 71 replies received from the 85 firms contacted or a 75 percent response. Thirty-two of the 71 replies reported that *no* research and development was being conducted in foreign countries. There was some useful information in the negative replies. This information relates only to Questions 1, 10, and 11 as summarized below. None of the replies indicated an interest in starting research and development work abroad—there were no positive responses to Question No. 8 on estimate of change in research and development effort.

Negative Responses

Question 1. Classification of organization:

7	Chemicals (including fertilizers, etc.)
9	Feeds
11	Food
3	Machinery
1	Seed
3	Tobacco
1	Cotton
2	Pharmaceutical
1	Steel
*38	Total

*Some companies indicated more than one classification.

Question 10. Would your company consider a foreign research and development program supported by the U.S. Government?

5 Yes
6 No

Question 11. Enumerate major problems...

The following are some answers that were given on the questionnaire:

Enumerated problems:

(1) "Lack of capital, tight capital, extreme nationalism, devaluation of currency."
(2) "No problems. We have been busy enough helping folks in the United States to do a better job."
(3) "Uncertainty of political climate and foreign exchange. Lack of trained manpower."
(4) "Lack of foreign exchange, unstable governments, rampant inflation."
(5) "No experience."
(6) "Lack of locally available technical and skilled manpower. . . . Specific changes in U.S. policies to alleviate problems."

Specific changes:

(1) None.
(2) Unknown.

(3) Not of U.S. making.
(4) Better protection from risks of expropriation convertibility and commercial payments by an expanded insurance program.

Positive Responses

The positive replies came from 39 of the 71 respondents and all contained some information on the research and development conducted in foreign countries. Summary of the information on replies to each of the questions is as follows.

Question 1. Classification of organization:

7 Biologics
14 Chemicals (including fertilizers, etc.)
7 Feeds
16 Food
7 Seed
4 Machinery
9 Pharmaceuticals
1 Agricultural
1 Consultant

Question 2. Countries in which your company is currently conducting research and development (summarized by continents):

34 Europe
26 Latin America
19 Canada
17 Oceania
10 Japan
9 Africa
5 Asia (excluding Japan and Philippines)

Question 3. Classification of research and development as percentages in different fields of science (no data on two questionnaires):

Percentage	Biological	Physical	Social
51–100	23	10	1
26–50	3	4	0
13–25	5	2	0
0–12	1	3	5
Total	32	19	6

Question 4. Percentages of research and development activities (see questionnaire for identification of activities):

Activities	Percentages					Totals
	76–100	51–75	26–50	13–25	0–12	
a	------	------	------	1	7	8
b	6	1	2	4	8	21
c	8	------	4	9	5	26
d	5	1	3	5	5	19
e	1	------	1	6	7	15
f	------	1	1	1	8	11
g	------	1	------	------	3	4
h	------	1	------	------	2	3
Total	20	5	11	26	45	107

NOTE: Four questionnaires not tabulated.

Question 5. Percentage of research and development related to different resources or commodities (see questionnaire for identification of resources or commodities):

Resources or Commodities	Percentages					Totals
	76–100	51–75	26–50	13–25	0–12	
a	------	------	------	1	3	4
b	------	------	------	------	2	2
c	8	3	7	2	1	21
d	4	3	8	5	------	20
e	6	1	1	4	2	14
f	1	------	1	------	5	7
Total	19	7	17	12	13	68

NOTE: Five questionnaires not tabulated.

Question 6. Total number of research and development personnel working in foreign countries tabulated from 34 questionnaires:

Europe

117	United Kingdom
112	Germany
54	France
18	Italy
18	Switzerland
16	Belgium
16	Spain
2	Netherlands
1	Greece
1	Sweden
355	Total

Latin America

34	Argentina
25	Mexico
18	Honduras
8	Brazil
6	Colombia
5	Peru
4	Venezuela
2	Costa Rica
1	Guatemala
1	Jamaica
1	Panama
13	Not specified
118	Total

Asia, excluding Japan and Philippines

10	Far East
1	India
1	Hong Kong
1	Lebanon
13	Total

Others

53	Canada
28	Australia and New Zealand
17	South Africa
12	Japan
3	Philippines
1	Egypt
182	Not specified
296	Total

Question 7. Research and development personnel supported in private or public institutions:

12	No response
19	None
1	Less than one man-year
2	No specific answer
1	Two man-years in Canada
1	Five man-years in Australia
1	One man-year in New Zealand, Philippines, and Japan
2	Total of 16 man-years, world-wide
39	

Question 8. Estimate of percentage increase in research and development by 1967:

5	No response
1	Slight decrease
2	0
3	1–12
2	13–25
6	26–50
8	51–100
5	101–200
3	201–400
4	401–800 (Maximum of 500 percent)
—	
39	

Question 9. Does your company provide financial support for education of foreign students?

14	Yes*
22	No
3	No response

*Of those indicating yes, a total of 22 students were supported in foreign universities and a total of 26 students were supported in United States universities.

Question 10. Would your company seriously consider conducting a research and development program in an underdeveloped country if supported by U.S. Government?

32	Yes*
5	No
1	Uncertain
1	No response
—	
39	

*Six of *yes* replies had some reservations.

Question 11. Major problems connected with planning, development or expansion of commercial operations in underdeveloped countries:

The problem cited most frequently (in 16 of the questionnaires) as a major deterrent was lack of trained personnel. Other problems listed were government red tape and controls, lack of local capital and purchasing power, foreign exchange problems, and certain federal regulations on shipments to foreign countries.

Summary and Conclusions

Approximately one-third of the industries responding to the questionnaire were not conducting research or development in foreign countries nor did they indicate any interest in initiating such work. This would indicate that the major agricultural industries presently involved in international operations are likely to be the representatives of the private sector for any expanded activity that might be encouraged by the United States Government. Furthermore, those U.S. firms already operating in foreign countries would likely expand their operations abroad with increased stability of the foreign governments and a reasonable degree of assurance of a financially successful operation.

Industries concerned with food and chemicals, particularly fertilizer, led among the wide range of businesses reporting. More of these companies operated in Europe than any other country with Latin America the second most frequent location. Thirty-four firms had 335 research and development personnel employed in Europe including the United Kingdom. This represented about three times the personnel complement in similar work in Latin America. The firms responding to the survey were well represented with personnel in Canada, Australia, and New Zealand, but there were relatively few personnel in all other foreign countries.

A limited amount of the financial resources of the United States industry is devoted to training of personnel from the countries in which our firms are located even though the lack of a sufficient number of adequately trained personnel was cited as a principal factor limiting further development. This will become an even more acute problem as an increasing amount of resources are applied to problems on world food supply in the developing nations.

CHAPTER 9

SURVEY OF AGRICULTURAL RESEARCH AND TRAINING IN SELECTED COUNTRIES OF LATIN AMERICA, AFRICA, AND ASIA

By H. C. Knoblauch, Cooperative State Research Service, U.S. Department of Agriculture

The production of world food supplies becomes an urgent problem when considered in relation to very rapid increases in population. Agriculture is the occupation of more than half the people of the world. In the developed and industrialized countries, 10 to 15 percent of the people are engaged in food production. In the less well developed countries, as high as 80 to 90 percent of the people depend almost entirely on what they can produce from the land. The need to increase agricultural production is critical in the densely populated and poorly developed countries of Latin America, Africa and Asia.

Agricultural research is a major requirement for economic growth. Research findings in agriculture become product factors in the economy only when people apply the new knowledge. Agricultural productivity as well as productivity in other areas of the economy will increase because improvements from research reduce unit labor costs and capital and resource requirements.

The Subpanel on Research and Education of the President's Science Advisory Committee Panel on the World Food Supply, in order to carry out its assignment, examined the background and current status of agricultural research in selected countries of Latin America, Africa, and Asia. The information obtained from the survey is presented in this supplementary report.

LATIN AMERICA

The countries of Argentina, Brazil, Chile, Colombia, Mexico, and Peru were selected for study because they represent a range in the amount of agricultural land per capita, per capita income, population growth, total food demand, and food production increases over the last 15 to 20 years. Data from the agricultural research survey were categorized as follows for each country when the information was available: A. Research Areas; B. Research Support; C. Research Personnel; D. Research Planning, Administration and Organization; and E. Research and Teaching Relationships.

Argentina

A. *Research Areas.* The areas of research and the percentage of the total budget assigned to each in 1962 in 50 institutes and experimental stations operating under INTA (Instituto Nacional de Tecnologia Agropecuaria) are presented below.[1]

TABLE 1.—*Research budget for institutes and experiment stations of INTA for 1962*

Subject	*Percent of budget*
Natural Resources	15.0
Crops	34.0
Weed Control	1.0
Livestock Production	13.0
Animal Diseases and Parasites	4.0
Forestry	1.0
Biology and Agricultural Zoology	15.0
Agricultural Engineering	7.0
Farm Economic and Rural Life	4.0
Home Economics and Human Nutrition	1.0
Unclassified	5.0

B. *Research Support.* The total agricultural research budget was about $13 million in 1962. This excludes approximately $3 million budgeted for administrative and general expenses or the cost of buildings or improvements. INTA is supported by funds derived from a 1.5 percent tax on all agricultural exports.

The Instituto Agrotecnico Economico de Misiones (IATEM) is concerned with developing agricultural cooperatives of Misiones and Northeastern Corrientes. Research and service activities are provided to livestock producers in these areas at a charge of one peso per hectare for those who belong to the "Plan Pasturas."

The experiment stations are under the direction of provincial ministries of agriculture or economics. Several private companies have agricultural scientists who conduct research of interest to the company.

C. *Research Personnnel.* INTA has a staff of approximately 700 technicians, about 400 of whom are engaged in research. Of these 400, approximately 60 per cent have the title *Ingeniero Agronomo* and an-

[1] Inventory of Information Basic to the Planning of Agricultural Development in Latin America—ARGENTINA. Inter-American Committee for Agricultural Development. Pan American Union—General Secretariat, Organization of American States, Washington, D.C. 1964.

other 17 percent have the titles *Medico Veterinario* or *Doctor en Ciencias Veterinarias*. Another 10 percent have university degrees that are not in agricultural subjects. The rest have diplomas from secondary agricultural schools, except for a small number who are high school graduates.

INTA sponsors a program for continuing improvement of the capabilities of its technical experts. An appreciable number of them has been sent to other countries to do postgraduate work or to take advanced training courses. This program further includes visits to Argentina by foreign experts in various fields to conduct short national and international courses. The Departmento de Capacitacion (Department of Training) at the Centro Nacional de Investigaciones at Castelar also has a continuous training program for the staff within the special fields in which they are working.[2]

D. *Research Planning, Administration, and Organization.* INTA had about 660 work plans in operation in 1962. Approximately 30 percent of them deal with varietal improvement (Plant Genetics) which has been pursued to such an extent in Argentina that it could almost be said that the term "plant improvement" has become confused with agricultural experimentation in general. INTA has made an appreciable effort to strengthen research in other areas, but only 12 percent of the current work deals with crop production techniques and only 8 percent with animal production, including the management of pastures.

Another important gap in the agricultural research program, which will be discussed in more detail later, is the lack of emphasis on farm *economics*. Its correction will depend in large measure on recruiting qualified personnel. In the case of production research, however, the problem is one of changing emphasis rather than employing new specialists.[3]

Scientific work within the experiment stations is carried out in accordance with work plans submitted to INTA by its technical specialists. INTA publishes a series of pamphlets, documenting current work plans of the Centro Nacional de Investigaciones and each of the regional centers. The status and results of investigations also are reported in publications of INTA.

The Rockefeller Foundation is providing technical leadership in genetics and plant breeding in cooperation with INTA.

Even though Argentina is a country with an agricultural tradition, there is a surprising shortage of experimental information on produc-

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[2] Ibid.
[3] Ibid.

tion techniques, i.e., on how production should be organized to optimize resource use.[4]

E. *Research and Teaching Relationships.* There are 20 colleges and universities in Argentina with commitments to agriculture. Their research staffs consist of from 1 to 11 research workers, except for the School of Agronomy of the Unversidad de La Plata, where about 120 scientists are stationed.

The small number of research workers associated with the universities, the lack of scientific equipment, facilities and the frequent absence of experimental farms in connection with the colleges are serious limitations to the conduct of research and the training of scientists.

A study made by the Centro de Investigaciones Economicas of the Fundacion Torcuato Di Tella represents a noteworthy attempt to determine the availability of technical personnel in Argentina. The report arrives at interesting conclusions with respect to agricultural personnel. For example, the total number of graduates from 1900 to 1960 in the field of agronomy was estimated at 3,391. This is only 2.7 percent of the number of persons graduated from the ten courses of study (such as law, medicine, etc.) having the highest enrollment. Furthermore, during the five-year periods, 1951–55 and 1956–60, the number of graduates with degrees in agronomy decreased.[5]

Argentina-AID-University Relationships

1. *Agricultural Economics Institute.* Agricultural economics is presently an active economic concern of many Argentina Government agencies. The lack of information in this field is recognized by the Government as a significant barrier to agricultural advancement. A project was initiated within INTA under an AID-Texas A&M agreement in 1963. The purpose of this project is to establish, by 1968, an agricultural economics institute within INTA, which will train agricultural economists for service in Argentina Government agencies as well as in the private agricultural sector.

The project agreement with AID provided the technical services of a contract team from Texas A&M University for a 2-year period. Development of a high quality agricultural economics research and extension program has been progressing rapidly. In 1962, INTA had less than 10 partly trained staff members working on agricultural economic problems in Argentina. During the last three years, this number has quadrupled.

Contract representatives have devoted most of their time to training. Two semester-length programs were conducted at Texas A&M Uni-

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[4] Ibid.
[5] Ibid.

versity for about 40 graduate and undergraduate trainees. Future emphasis by the resident contract advisors will be placed on research and extension programs and on the development of the structural arrangements of the Institute. The AID budget for this project in 1967 was $239.000.[6]

The first national agricultural economics program review and planning meeting was held in May, 1965. Following the meeting, a full-time coordinator and a central staff of three members were named to direct the national program.

2. *Balcarce Agricultural College.* The purpose of this activity is to assist the National Agricultural Research and Extension Agency (INTA) and the Catholic University of Mar del Plata (UCMP) in the establishment of a college in Argentina where agricultural education, research and extension are combined in one institution of the land-grant type. The Balcarce College (BAC) was established in 1962 as a model for future agricultural colleges in the country.

Permanent facilities will be constructed on 150 acres of land. A pre-contract survey was conducted by Michigan State University in 1963. A team of four men from Michigan State arrived in 1965 after it was determined that six years would be required to develop the institution. The MSU team spent about one month gathering data to substantiate the request for a loan from AID. An agreement has been approved between BAC and the University of La Plata permitting students to transfer credits between the two institutions, and providing for exchange of teachers and combined short courses.

In 1967 the project was supported with a $216,000 grant and a loan of $500,000 from AID.[7]

Brazil

A. *Research Areas.* 1. *Supported by the Federal Government.* In 1961 a list of crop research projects was published on the basis of material obtained from the Centro Nacional de Pesquisas Agronomicos (CNEPA). The list contained 1,205 experiment station projects, 534 concerned with the development and testing of crop varieties and 423 involving fertilizer experiments. These two areas accounted for 80 percent of the total research effort. Seventy-four experiments were concerned with plant spacing, 63 with date of planting, and about 25 each with herbicides or fungicides, selection and treatment of seeds, and various other cultural practices. The research is performed at

[6] A Survey of AID Educational Cooperation with Developing Countries, AID, Dept. of State (Survey by Bureau of Higher Education, DHEW). 1966.
[7] Ibid.

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thirty experiment stations and 19 substations. No information was obtained on crop rotations or management systems as a whole.[8]

Control of weeds is a major area of research neglect. The only work indicated consisted of ten experiments on corn, cotton, sugarcane, coffee and a few vegetables. Minor emphasis was accorded livestock production problems.

A few national institutes have been established to conduct research in rural sociology and improve the living conditions of rural people. Six institutes are concerned with studies in agricultural economics.

2. *Supported by the State Governments.*[9] The number and location of state-approved experiment stations are presented in the following table.

State	*Number of experiment stations*
Pernambuco	7
Minas Gerais	*4
Bahia	2
São Paulo	22
Rio Grande do Sul	12

*There are five substations in this state system.

3. *Supported by Non-Government Agencies.* A research institute (IBEC) was founded by David and Nelson Rockefeller as part of the American International Association for Economic and Social Development. Twelve scientists trained in the United States are giving major attention to soil improvement, fertilizers and animal nutrition. The United States Department of Agriculture has provided technical assistance in many areas through AID funds.

The Anderson-Clayton Company is interested mainly in marketing cotton and coffee. However, the company has found it advantageous to help farmers improve their agricultural practices and obtain higher yields. It supports an experiment station at Presidente Prudente, São Paulo (chiefly for fertilizer experiments), and employs a number of agronomists to give advice and technical assistance to farmers from whom it purchases cotton or coffee.[10]

B. *Research Support.*[11] In 1962 the budget for DPEA (Department of Crop and Livestock Experiment and Research) was about $2 million.

[8] Inventory of Information Basic to the Planning of Agricultural Development in Latin America—BRAZIL. Inter-American Committee for Agricultural Development. Pan American Union—General Secretariat, Organization of American States, Washington, D.C. 1964.

[9] Ibid.

[10] Ibid.

[11] Ibid.

Far more emphasis has been placed on agronomic research than on the investigation of problems of animal production, rural economics, or other fields of activity. However, an expansion of work in animal research is planned under the general program of international technical cooperation. Under the current five-year program (1962–66), about $14 million was planned for expenditure on livestock research and $20 million on agronomic research. However, less than one-half of the above amounts has been made available.

C. *Research Personnel.* Information on the number of research scientists at the various locations was not available. The Ministry reported that they employed 827 agronomists and 290 veterinarians in 1959. More significant is a reported *deficit* of nearly 1,200 agronomists and 650 veterinarians.

D. *Research Planning, Administration, and Organization.* 1. *Recent Developments in Organization.* In 1962 a Headquarters Officer from FAO was sent to Brazil at the request of the government to assist in preparing a plan for reorganizing the Federal Ministry of Agriculture. One substantial improvement was the establishment in the Ministry of Agriculture of a unified and comprehensive research department responsible for agricultural research in all subject-matter fields. While the support that could conceivably be allocated to bringing about this improvement is negligible, the ultimate effect of this change is apt to be considerable.[12]

2. *Suggested Guidelines for SERPA (Setor de Relacoes da Pesquisa Agropecuaria) of DPEA.* The Ministry of Agriculture is responsible for the rural policy of the country within the framework of the Government's general policy. DPEA will have two main activities: the execution of agricultural policy through its regional institutes and the coordination of agricultural policy through terms of understanding, agreements, etc.

3. *DPEA and the State Research Agencies.* In the states in which state-supported agricultural research is highly developed, as in São Paulo, the creation of new institutions by the Ministry of Agriculture for direct performance of agricultural research should be avoided.

The present institutions should operate as integral parts of the state organizations. Financial resources should be furnished for research in the states wherever necessary, especially in those which support other regions of the country. Where state research programs have already been developed which are equal or inferior to those of the Ministry, coordinating committees should be instigated to assure that these institutions work harmoniously, each concentrating their activ-

[12] D. C. Kimmel for Viggo Andersen, Dir., Rural Institutions and Services Div., FAO, to Merril M. Blevins, 1st Secy. of Embassy FAO Affairs, U.S. Embassy, Rome, Italy, 12.29.66.

ities in different specialized or geographical areas. Integrated research plans should be developed containing assurances that federal or state governments would not establish new units or new research without a previous understanding. Considering the costs of agricultural research, the smaller states and those with less financial resources should not be stimulated to create their own institutes; instead, they should be invited to support federal institutions of agricultural research.

4. *DPEA and Research at the Universities.* Universities and agricultural colleges which are situated near the regional research institutes should not be stimulated to carry out research independently, but they should provide an opportunity for their professors and pupils to participate actively in the research work of the institutes, utilizing their facilities and results in behalf of both research and education. In turn, the research institutes should take steps to insure that their technicians participate in the educational activities of the universities, to insure better dissemination of the research results and to utilize existing technical knowledge.

The most rapid progress should result when the universities have administrative independence and the federal government is free to guide and prepare its own agricultural research programs. For this and other reasons, the merger of federal and university research programs should not be considered. They must be kept administratively independent, but cooperation between them is essential.

For the universities which have an agricultural research program but are not situated near the research institutes of DPEA, the government will have a policy similar to that in connection with the secretariats of agriculture of the states mentioned above.

Until there is greatly improved cooperation between the DPEA research institutes and the universities, Brazil will miss the potential benefits of close association between teaching and research. If the universities are to be effective in teaching, they should be provided with funds for research and for graduate student training.

5. *DPEA and Several Regional Development Agencies.* SERPA should propose joint activity to the regional development agencies. This would facilitate their concentration on local problems without duplicating the federal research institutes in their respective regions. However, when there are state institutions and universities carrying out research in an area of interest to a regional development agency, DPEA, through SERPA, should propose priority plans and indicate the institutions which should carry them out.

6. *DPEA and the National Research Council.* The National Research Council is the coordinating agency for all national research.

As an agency of NRC, DPEA should be responsible for the coordination of all agricultural research. SERPA should be associated with the agricultural sector of the Research Council under the direction of the Ministry of Agriculture.

7. *DPEA and International Technical Assistance.* International technical assistance to Brazilian agricultural research also should be coordinated through SERPA. This organization should use the same guidelines for international technical assistance as it does with other agencies that suggest new research activities and opportunities.

E. *Research and Teaching Relationships.* The inventory of the physical plants of schools of agriculture, veterinary science, and home economics indicates that facilities are available for teaching almost twice as many students as are currently attending the schools.

The Ministry of Agriculture has formulated a 5-year plan to double the capacity of the schools of agronomy and veterinary science. The plan would be carried out by the Ministries of Agriculture and of Education and Culture. Although existing facilities in a number of schools of agriculture are not being utilized fully, an increase in capacity, along with additional training for teaching personnel, is undoubtedly justified. If research and extension work were expanded to meet present needs and the salaries of professional personnel raised to adequate levels, there is no doubt the facilities would be utilized to capacity.[13]

Brazil-AID-University Relationships

1. *University of Minas Gerais-Purdue University.* The present University of Minas Gerais contract with Purdue University has been in effect for the past seven years. The Home Economics Department has had technical assistance for the past fourteen years. This department has trained 212 students in graduate work (45 M.S. degrees have been awarded).

Under this cooperative program, 3500 farmers and teachers have been given short courses at the university. Undergraduate enrollment since 1958 has increased from 300 to more than 1,000. The freshman class in 1965 increased 30 percent over the 1964 class. Enabling legislation has led to the establishment of the land-grant college trilogy of teaching, research and extension. The university has been given control over the use of its budget. More than thirty new full-time staff members have been added to the faculty since January 1, 1965.

Among the new facilities that have been provided are plant and soil laboratories, a seed laboratory, and a research building for forestry.

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[13] Ibid.

The Graduate School has been reorganized and new standards established.

2. *University of Rio Grande do Sul-University of Wisconsin.* Nine professors from Wisconsin are currently at work in Porto Alegre and one is in Rio de Janeiro. Twenty-three students have completed their first semester of graduate work at the University of Rio Grande do Sul. Fourteen veterinary students completed a special postgraduate course in July of 1965. A statewide coordinated program has been initiated in research, extension and training. A long-range program for the University's improvement has been developed and assistance requested. Many of the results of research projects have been put into use locally.

3. *University of São Paulo-Ohio State University.* Nine Ohio State professors and one research assistant are on cooperative assignment at the University of São Paulo. Two others are expected to complete the team. Investigations are being conducted under 42 research projects in seven major areas. Advanced students are working on these projects for experience. A program in an eighth area, home economics, was started in September, 1965. Student enrollment has increased from 680 to more than 1,000. Results of the research already are being used to improve the production of crops and livestock.

4. *University of Ceara-University of Arizona.* Arizona staff began to arrive at the University of Ceara under a contractual agreement in early 1964. About a dozen agricultural scientists are currently on site. They are surveying the needs for specialists for this area of Brazil. The University has no specialized departments at this time.

Groundwork has been laid to develop departments in animal science, crops, and soils. Work has begun on an experiment station. English language training is being given to prospective participants. Although this project is in its early stages, student enrollment increased from 333 in 1964 to 424 in 1965.[14]

5. *Proposed Development of Coordinated Research Program in Campo Cerrado Areas of Brazil and the Midwest University Consortium for International Activities (MUCIA) (Universities of Illinois, Indiana, Wisconsin, and Michigan State).* The Campo Cerrado is a classification based on vegetative cover. It means "closed fields" indicating that the land is covered with scrub brush. It refers to a vast area of Brazil with low soil fertility, including campo or campo limpio (clean or open fields), campo sujo (dirty or scattered scrub and grass cover), campo cerrado, and cerradao (closed fields with trees and

[14] A Survey of AID Educational Cooperation with Developing Countries, AID, Dept. of State (Survey by Bureau of Higher Education, DHEW). 1966.

brush of some size). The area covers about 772 thousand square miles (larger than the states of Texas, Oklahoma, New Mexico, Arizona, and California combined) and represents an enormous potential for food production and employment for Brazil's population. A program of research has been proposed by the Technical Executive Commission (Commissao Tecnia Executiva) established by the National Research Council (Conselho Nacional de Pesquisas), with collaboration from the Ministry of Agriculture.

The plan represents an extraordinary opportunity for providing external assistance to the technical and scientific field and the training of the scientists and managers who must ultimately carry out the task of utilizing the potentials of this vast area for food production. AID and the United States universities have been working closely with the research council of Brazil on plans that have been developed. The beginning and effective development of the proposed program is dependent on greatly expanded financial support.[15]

Chile

A. *Research Areas.—Ministry of Agriculture Research Stations—*

1. *In cooperation with the Rockefeller Foundation* (see Table 2).
2. *Universities, Institutes and Industry.*[16]

	Areas
Universidad de Chile, Maipu (Santiago)	Cereals, forage corps, fruit trees, corn, livestock, entomology, irrigation.
Universidad Catolica de Chile, Pirque (Santiago)	Corn, soil studies, cereals, livestock management.
Universidad de Concepcion, Chillan (Nuble)	Forage crops, livestock, irrigation.
Universidad Austral Valdivia (Valdivia)	Forage crops, potatoes nonirrigated farming.
Sociedad Nacional de Agricultura (Santiago)	Corn, cereals, irrigation.
Universidad Catolica de Valparaiso, Quillota (Valparaiso) (being organized)	Forage crops, vegetables, avocados, entomology (oriented toward nonirrigated farming).
Industria Azucarera Nacional, S.A., Los Angeles (Bio-Bio)	Sugar beets (fertilizers, disease control, seed production, etc.).
Campania Explotadora de Tierra del Fuego (Magallanes)	Adaptation and management of pasture grasses.

[15] Coordinated Research Program in Campo Cerrado Areas of Brazil. Translated by Walter Crawford and Lawrence Witt. International Programs, Michigan State University, for Midwest Universities Consortium on International Activities, Inc. August 1966.

[16] Inventory of Information Basic to the Planning of Agricultural Development in Latin America—CHILE. Inter-American Committee for Agricultural Development. Pan American Union—General Secretariat, Organization of American States, Washington, D.C. 1964.

TABLE 2.—*Chilean Agricultural Program Cooperating Experiment Stations* [1]

	Location	Soil types	Principal fields of investigation	Type of agriculture in region served
MINISTRY OF AGRICULTURE STATIONS				
Central Experiment Station.	Santiago	Noncalcic Brown; Alluvial.	Corn, cereals, beans, forage crops, oil crops.	Crops, fruit, livestock, dairy (irrigated).
Substation	Ovalle	Calcic Brown; Alluvial.	Cereals	Dryland farming (supplementary irrigation).
Substation	Cauquenes	Reddish-brown Laterite.	Range management.	Dryland farming.
Southern Experiment Station.	Temuco	Alluvial; Volcanic Ash (Trumao).[2]	Cereals, potatoes, forage crops, oil crops, soil fertility.	Crops, livestock, dairy (supplementary irrigation).
Southern Regional Substation.	Osorno	Trumao	Cereals, forage crops.	Crops, livestock, dairy (dryland).
MINISTRY OF AGRICULTURE—UNIVERSITY OF CONCEPCION				
South-Central Experiment Station.	Chillan	Trumao with Grumosol inclusions.	Corn, cereals, forage crops, oil crops, animal nutrition.	Mixed farming (supplementary irrigation).
UNIVERSITY STATIONS				
University of Chile	Santiago	Noncalcic Brown	Corn, cereals, fruit, forage crops, dairy science.	Mixed farming (irrigated and dryland).
Catholic University	Santiago	Noncalcic Brown (modified).	Corn, cereals, forage crops, poultry, dairy science.	Mixed farming (irrigated).
University of the South	Valdivia	Trumao	Potatoes, forage crops.	Crops, livestock, dairy (dryland).

[1] The Rockefeller Foundation Program in the Agricultural Sciences, An. Rpt. 1964–65, July 1965.
[2] The "Trumao" soils of southern Chile are similar to the Ando soils of Japan, the Yellow-Brown Loam of New Zealand, and some of the volcanic formations in Oregon, United States.

In the field of animal production outstanding work has been done on use of byproducts of vegetable origin in the feeding of livestock, ensiling techniques, and improved methods of pasture utilization.

The Veterinary Institute of the Ministry is conducting tests on the digestibility for livestock of Chilean products. The effect of adding various vitamins to feed also has been studied. Additional work on poultry nutrition, the feeding of swine, the action of antibiotics on swine, and the use of milk substitutes and concentrates in the feeding of calves is done at various stations.

Most effort has been placed on varietal improvement of crops. Research on crop production practices, time of planting, harvesting, and irrigation systems has received little attention as yet. Investigations of the economic returns from the use of fertilizers, machinery and management systems have been ignored in the past. These factors are now receiving minor attention.

Applied research on the use of fertilizers and pesticides, the utilization of water, and similar problems has not been designed to facilitate analysis from the economic viewpoint. Generally speaking, the only estimates made have been of the differences in total cost at two or three levels of intensity of application. Seldom is a functional relationship sought that would make it possible to determine the economically optimum levels for use of these inputs.[17]

The Rockefeller Foundation Report on Agricultural Sciences gives the following account of recent developments in cooperative efforts with the Agricultural Research Institute of the Ministry of Agriculture at the Central Experiment Station at Santiago:

> The Research Institute is making encouraging progress in developing a program of problem-oriented research designed to counter the widening deficit in food production. Improved salary levels and the growing number of local staff who have completed specialized training abroad serve to strengthen the research program and to ensure immediate and efficient use of the modern research facilities now available.
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> The wheat and forage work, until recently conducted by the Office of Special Studies, is now an integral part of the Institute. With the departure of the Foundation's staff animal nutritionist in February, the work in this field is also now being directed by Chilean scientists, five of whom have had advanced training abroad. The research results of these programs, which until last year were summarized in the Foundation report, will in the future be published in *Technical Agriculture*, the official journal of the Agricultural Research Institute of the Ministry.
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> It is recognized that continuing technical guidance in the form of Foundation staff, as well as support of graduate training abroad for selected local research personnel, will be desirable in the immediate years ahead, especially in the areas of pasture and livestock management. The Institute, however, is steadily building up a staff with the competence to provide leadership in an increasing number of areas.
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> During the past nine years seven Ph.D. degrees and thirty-one M.S. degrees have been earned by Chilean research workers who studied abroad under Rockefeller Foundation Auspices. Of this number, three Ph.D.'s and fourteen with the M.S. are members of university faculties. Only one holder of an advanced degree under this program is working outside the country. For the current academic year, nine additional candidates have been selected to pursue graduate studies at foreign universities.
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> One of the prominent aims of the Institute is to work in close coordination with the research programs of the several universities, both in agronomy and

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[17] Ibid.

animal sciences. It is stipulated in the Institute's charter that four of the ten members of the board of directors be the deans of the following faculties: Agronomy, University of Chile; Agronomy, Catholic University; Agronomy, University of Concepcion; and Veterinary Medicine, University of Chile. Already several joint research projects are under way, and more are under consideration. In this way, better use of research facilities and personnel is being achieved.

Another aid-giving agency, the Special Fund of the United Nations, has entered into an agreement with the Agricultural Research Institute to conduct a program in soils research. Through the FAO, the Special Fund will provide specialists to work with institute agronomists in soil fertility and management.[18]

B. *Research Support.* Information on budget availability and actual expenditures for research is difficult to obtain. The estimate of expenditures for research in 1962 was approximately $14 million. About one-half of the amount was for salaries of technical personnel.

The Rockefeller Foundation, in cooperation with the Ministry of Agriculture, has established an Office of Special Studies. This office is primarily concerned with research on wheat and other cereals and forage crops, and the organization of agronomic experiment stations and the coordination of their work with the universities and with industry. The Foundation funds supporting this effort are about $450,000.

C. *Research Personnel.* In 1962 there were 215 agronomists with the degree *Ingeniero Agronomo* employed by the Ministry of Agriculture. Thirteen more individuals had completed course work but had not prepared the required thesis for a degree. There are an estimated 100 professors at the universities who spend some time doing research.

D. *Research Planning, Administration and Organization.* Information on progress in the culture of a number of crops is published in the special bulletins and annual reports of the Departmento de Investigaciones Agricolas of the Ministerio de Agricultura. Examples include information on the development of new varieties of wheat for irrigated and nonirrigated land, adaptation of forage plants to irrigated and nonirrigated farming, the development of sunflower and corn hybrids, varietal improvement, and the control of rust in lentils.[19]

E. *Research and Teaching Relationships.* Progress has been made in agricultural education at the university level, both in number of students and quality of training. The quality of training has been raised through the employment of teachers who have done graduate work in other countries. The establishment of schools in the provinces,

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[18] The Rockefeller Foundation Program in the Agricultural Sciences, An. Report. 1964–65, July 1965.

[19] Inventory of Information Basic to the Planning of Agricultural Development in Latin America—CHILE. Inter-American Committee for Agricultural Development. Pan American Union—General Secretariat, Organization of American States, Washington, D.C. 1964.

in addition to those in Santiago, will result in increased attention to regional problems.

The present condition and future possibilities of agricultural training seem relatively favorable. Although there is still much to do, Chilean technical experts appear to be aware of existing problems and are ready to face them. Perhaps the most important of these problems is to decide what kind of agronomic training should be given, considering the needs of farmers and the requirements for research and extension work.

Generally speaking, Chile is training considerable numbers of agricultural technicians at both university and secondary levels, although there are still some forgotten branches of study (such as fruit growing and efficient use of water) and others in which activities have only been started (such as stock raising and agricultural economics). A major danger is that the current effort may be frustrated if the employment situation and salaries paid to agricultural specialists are not carefully examined. The training centers should be aware of this problem and be flexible enough to adjust their emphasis to those particular lines of study most in need of attention at a given time.[20]

Regional and ecological boundaries have been steadily replacing national boundaries as criteria for determining the outlines for program development. The arid lands, the humid tropics, and, to some extent, the altiplano of South America furnish cases in point. The Dry Lands Research Institute was established by the University of California a year ago with partial support from the Rockefeller Foundation to investigate the agricultural potential of arid regions.

The establishment by Chile of the Agricultural Research Institute under the leadership of a distinguished Chilean geneticist enabled Rockefeller Foundation staff in the Chilean Agricultural Program to turn from direct participation in forage crop and wheat improvement investigations within the Ministry of Agriculture to other problems important to Chilean agriculture. One of these tasks is to strengthen the faculties of agriculture and veterinary science which may be accomplished best by general university development. The provision of short-term special staff to the newly created Institute of Agricultural Research in the Ministry of Agriculture and to the faculties of the universities will assist in coordinating the activities of these institutions and in fillings gaps that currently exist in the teaching and research programs.[21]

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[20] Ibid.

[21] The Rockefeller Foundation Program in the Agricultural Sciences, An. Rpt. 1964–65, July 1965.

Colombia

A. *Research Areas.—Ministry of Agriculture, Bogotá, Colombian Institute of Agriculture (ICA)* (see Table 3).

Colombia possesses 13 experiment stations that are among the best in Latin America. Work is being continued to obtain complete maps of the station areas and detailed plans of the research as well as to continue with the building of roads, drainage systems, and other projects to improve the stations.[22] Research was reported on problems in agricultural economics and home economics, but no information was available on expenditures in these areas.

Rice is one of the principal cereal crops of Colombia and indications are that 1964 plantings increased over those of 1963. Growers are now faced with rising costs for inputs such as fertilizer and machinery. This makes the development of higher yielding varieties to obtain maximum income per hectare imperative. The rice program is being continued to develop better varieties with high yield, good quality, and disease resistance. Research is also being continued on the development of insect control practices which might result in higher yields. Five nurseries were planted in Palmira to determine the resistance of United States rice varieties to hoja blanca and rice blast diseases.[23]

1. *Corn, Wheat, Oats, and Barley Breeding Programs.* Corn research in Colombia is conducted at four principal locations. These efforts are supplemented by breeding and testing activities at five substations. Within reasonable limits, these stations are located in the major climatic regions of the country and present a wide range of environments. Corn grown on the highland may require from 9 to 11 months to reach maturity while in areas near sea level, it matures in four months or less. Distinct adapted types must be produced for each of these regions. Corn breeding activities are further complicated in Colombia because not all areas have a sufficiently well-developed marketing system to make the sale of hybrid seed practical. For this reason, research leading to the production of improved varieties, synthetic varieties, and hybrid stocks must frequently be carried on simultaneously.

The expansion of the international phases of the Colombian corn program of the Rockefeller Foundation has been accelerated. This development will be of great value both to Colombia and to other parts of the world where similar conditions exist. More than 30 new composite populations of superior corn types have been created and maintained by random mating for use in these studies.

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[22] Ibid.
[23] Ibid.

TABLE 3.—*Experiment Stations of the Colombian Institute of Agriculture* [1]

Location	Name	Soil types	Principal fields of investigation	Type of agriculture in region served
MAIN STATIONS				
Bogota, Cundinamarca.	Tibaitata	Clay and silt loam.	Corn, small grains, potatoes, beans; horticulture; forage crops; soils; entomology; animal sciences; plant and animal pathology.	Diversified; all crops and animals.
Medellin, Antioquia.	Tulio Ospina	Loam	Corn, beans; soils; entomology; plant pathology: poultry.	Corn, beans; beef and dairy animals.
Palmira, Valle del Cauca.	Palmira	Clay loam	Corn, rice, beans, sugar cane, vegetables; soils; entomology; plant pathology; animal sciences.	Corn, rice, beans, sugar cane; soybeans; pasture crops; poultry; cotton.
Espinal, Tolima	Nataima	Sandy loam	Rice, vegetables; forage crops; soils; entomology.	Corn, rice; sesame; cotton; beef animals.
Cerete, Cordoba	Turipana	Clay loam	Corn; forage crops; entomology; animal sciences; plant and animal pathology.	Corn; cotton; beef animals.
SUBSTATIONS				
Pasto, Narino	Obonuco	Silt loam	Small grains, potatoes; entomology; dairy animals; plant and animal pathology.	Small grains, potatoes; beef and dairy animals.
Duitama, Boyaca	Surbata	Clay	Small grains, potatoes	Small grains, potatoes; beef animals.
Soacha, Cundinamarca.	San Jorge	Clay	Sheep; animal pathology.	Sheep; potatoes.
Rionegro, Antioquia.	La Selva	Silt loam	Corn, potatoes, beans vegetables; Forage crops; entomology; plant pathology.	Corn, potatoes, beans; dairy animals.
Villavicencio, Meta.	La Libertad	Loam	Beef animals; animal pathology.	Rice; beef animals.
San Jose, Antioquia.	El Nus	Loam	Beef and dairy animals; animal pathology.	Beef animals.
Armero Tolima	Armero	Sandy loam	Beef animals; animal pathology.	Corn, rice; sesame; cotton; beef animals.
Toluviejo Bolivar	Toluviejo	Sand	Beef and dairy animals; animal pathology.	Cotton; beef and dairy animals.

[1] The Rockefeller Foundation Program in the Agricultural Sciences, An. Rpt. 1964–65, July 1965.

In addition, varieties known to be superior in their respective areas of adaptation in the Andean region have been brought to Colombia and crossed in all possible combinations. These were grouped into two diallel sets, one made up of 14 varieties from lowland areas and the other of 10 varieties from the highlands. The 91 possible crosses of the lowland group are already under yield tests at six locations in the

Andean region. The agronomic data and the genetic stocks themselves will be made available for further corn improvement.

The new superior composites are also being subjected to selection to improve their usefulness as sources of future breeding stocks. Phenotypic recurrent selection for more insect resistance, increased ear number, and improved plant type is being carried out at several locations and in several plant populations. Also in progress are various systems of mass selection and recurrent selection for yielding ability.

2. *Veterinary Science.* The main objectives of the veterinary science program are to determine the diseases of greatest economic importance to the livestock industry of the country and to gain information on the control of these diseases through treatment, control practices and management.

3. *Economic and Social Studies.* Research in future projects should be concerned with economic factors as well as communication materials and methods. This became clear as one communicator worked to introduce a new potato variety to a small group of farmers. It was not enough to convince them that they should plant the new variety. At harvest time, the communicator had to devote a good deal of time to explaining net profit and helping farmers calculate returns over costs with the new variety as compared to the old. This again emphasized the need to include the economic aspects of production in both information programs and technical recommendations.[24]

4. *Land Use.—FAO Special Fund Project Center for Agricultural Training and Research—Cauca Valley.* The FAO started a project in October 1961 which was terminated in June 1966. Its purpose was to set up a basic program of agricultural research for the Cauca Valley Corporation, with particular reference to land use. The total Special Fund allocation for this project was $866,600. Approximately 40 percent of the expenditure was for research.[25]

Research on wheat, oats and barley breeding has been under way for 10 to 15 years. Highly significant yield increases have been obtained in many areas. The need for improved storage, transportation and marketing facilities is critical. More effort needs to be directed to the determination of economic returns from the culture of improved varieties.

5. *Pasture and Forage Program.* In the pasture and forage program, scientists have continued to test a number of species at various elevations, levels of fertility, and other variables. An interchange of plant materials with the United States Department of Agriculture has

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[24] Ibid.

[25] D. C. Kimmel for Viggo Andersen, Dir., Rural Institutions and Services Div., FAO, to Merril M. Blevins, 1st Secy. of Embassy FAO Affairs, U.S. Embassy, Rome, Italy, 12.29.66.

been highly beneficial to the program, since many of the introductions show promise for commercial use in Colombia. A cooperative project with the Esso Research and Engineering Company on testing different sources and levels of solubility of nitrogen and phosphorus fertilizers is being continued. A fertilizer that is released in the soil relatively slowly should be of great value, particularly in lighter soils where leaching is a problem.

6. *Soil Testing.* The new soil testing laboratory in Palmira, with a capacity for 200 soil tests daily, began functioning during the year. This is the first time that extensive soil testing facilities have been available to Colombian farmers. Two short courses were held recently to teach extension workers how to take soil samples correctly.

7. *Animal Science.* Animal scientists have been analyzing the factors limiting beef production in Colombia for the past several years. This program includes research on management, nutrition, breeding, and physiology. Intensive trials show that yields of beef can be more than doubled by improved management, including fertilization, drainage, and irrigation of pastures. Several ranchers are now carrying up to eight animals per hectare on a year-round basis rather than the two animals per hectare formerly carried under the best grazing conditions in Colombia.

Up to 2.5 tons of beef per hectare have been obtained when oat silage alone is fed to animals in confinement. If oat silage is supplemented with 2 kg. per day of concentrate, up to 3.5 tons of beef per hectare can be obtained. The injection of female hormones generally increases growth 15 to 20 percent under extensive grazing or intensive stable-feeding conditions.

The poultry industry in Colombia is growing very rapidly. The number of chickens in Colombia has increased from approximately 15 million five years ago to 36 million at present. Approximately two-thirds of the industry is based on egg production. Feed represents from 60 to 70 percent of production costs. It is essential that ways be found to produce more poultry and eggs cheaply.

Most of the poultry research is directed toward better nutrition and the formulation of cheaper diets. The price of feedstuffs fluctuates greatly during the year. By knowing the various combinations of well-balanced rations, the poultry farmer can select the diet which will be most profitable to him under any set of price conditions. Such items as molasses and other low cost feedstuffs are being tested as substitutes for corn. It has been found that the addition of 10 percent molasses to the diet will reduce feed costs considerably while efficiency and growth rate are not appreciably affected.

Very little research has been done on fruit, which could be one of the most important items for export diversification.[26]

B. *Research Support.* The operating budget of ICA which was $6,561,000 in 1964 was approximately doubled in 1965. Because of a certain amount of peso devaluation, the larger amount does not represent a doubling of buying power. The budget has been allotted on a program, project, and subproject basis. This means that ICA now has its funds allocated so researchers and other technical people know exactly the amounts available to them for the year. Sufficient flexibility is maintained so that budget transfers can be made near the end of the year if they seem justified.[27]

C. *Research Personnel.* There were 338 professional personnel engaged in research in 1962. Most of the scientific staff are agronomists and veterinarians, but some chemists, engineers and other professional people are included.[28]

D. *Research, Planning, Administration, and Organization.* Agricultural research is conducted by the Colombian Institute of Agriculture at Bogotá (ICA). Early in 1965, ICA was committed to its organizational pattern according to statutes. The plant and animal sciences departments were organized in April 1965. Staff members of the Rockefeller Foundation were invited to head these departments, and to help develop departmental programs in research, extension, and teaching.[29]

E. *Research and Teaching Relationships.* Colombia has made tremendous progress in agricultural research in recent years due mainly to a systematic graduate training program and close association with research programs through the Division of Investigations of the Ministry of Agriculture. It is reasonable to expect that existing research gaps will be narrowed significantly within the next few years.

The ICA five-year development plan for 1965 to 1969 was completed recently and presented to the seven organizations that have shown interest in supporting it. This development plan received prior approval by the Colombian National Planning Board. The plan was studied by the supporting international organizations and was found

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[26] Inventory of Information Basic to the Planning of Agricultural Development in Latin America—COLOMBIA. Inter-American Committee for Agricultural Development. Pan American Union—General Secretariat, Organization of American States, Washington, D.C. 1964.

[27] The Rockefeller Foundation Program in the Agricultural Sciences, An. Rpt., 1964–65, July 1965.

[28] Inventory of Information Basic to the Planning of Agricultural Development in Latin America—COLOMBIA. Inter-American Committee for Agricultural Development. Pan American Union—General Secretariat, Organization of American States, Washington, D.C. 1964.

[29] The Rockefeller Foundation Program in the Agricultural Sciences, An. Rpt., 1964–65, July 1965.

to be feasible in size and scope of program. Agricultural education in all aspects must be intensified to make a real impact on the national economy.[30]

The University of Nebraska is giving leadership under an AID contract in the further development of programs of agriculture and veterinary medicine at the Instituto Colombiano Agropecuario.

A critical need exists for the establishment of an effective procedure for getting research information into practice. At present agricultural extension activities are handled by a multiplicity of organizations.

Mexico

A. *Research Areas* (see Table 4). The agency listed first in Table 4, Instituto Nacional de Investigaciones Agricolas (INIA) is responsible for improvement of crop varieties, research in management of soil and water, prevention and control of plant diseases and pests, diffusion of scientific information, and studies of the economic aspects of agriculture.

Several programs dealing with the improvement of crop varieties recently have been organized with international cooperation. The International Center for Improvement of Maize and Wheat has been set up with major assistance from the Rockefeller Foundation. The maize improvement program is tied in with the Germplasm Bank which maintains a collection of some 4,000 samples of maize in Mexico and 1,500 in Central America.

Research under the wheat improvement program has been successful in developing high yielding varieties adapted to Mexican conditions. The program cooperates with other wheat improvement organizations in the Americas and abroad through FAO. There is also an Inter-American Potato Improvement Program under which a wide variety of wild potatoes have been collected for testing and use in developing resistance to diseases.[31] Veneizan and Gamble (7) have provided a review of the Mexican agricultural program giving more details of these and other developments.

B. *Research Support.* Table 4 shows average annual support for the three-year period 1962–64. The main support was from the government with some contributions and revenue from the sale of produce. The long continued financial and technical support of the Rockefeller Foundation has been basic to the success of the program.

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[30] The Rockefeller Foundation Program in the Agricultural Sciences, An. Rpt. 1964–65, July 1965.

[31] Inventory of Information Basic to the Planning of Agricultural Development in Latin America—MEXICO. Inter-American Committee for Agricultural Development. Pan American Union—General Secretariat, Organization of American States, Washington, D.C. 1964.

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TABLE 4.—*Agricultural research: Institutions and resources*

Institution	Agricultural professionists & technicians employed	Budget (millions of U.S. dollars)	Experiment Stations Operated	Fields of Research
1. Instituto Nacional de Invest. Agricolas.	231	2.08	27	Crop improvement (corn, beans, cereals, oilseeds, cotton, sugar cane, cacao, horticulture, potatoes, etc.) phytopathology, soils and fertility entomology, poultry, agricultural economics, etc.
2. Centro Nacional de Invest. Pecuarías.	46	.191	4	Range management, animal nutrition, reproductive physiology, animal pathology, vaccines, animal breeding.
3. Instituto Nacional de Invest. Forestales.	69	.616	6	All forestry research (forest management, soils technology, photogrammetry, etc.)
4. Inst. Mex. del Cafe	54	N.A.	1	Coffee culture, disease and pest control, coffee producing areas, handling of coffee, beans, etc.
5. S.R.H., Direccion Gral. Distritos del Riego.	30	N.A.	9	Irrigation engineering; salinity problems and drainage in relation to agricultural production.
6. Centro de Investigaciones Agrarias.	8	.05	0	Land tenure and agrarian reform problems.
7. Inst. de Mejoramiento Produccion Azucar.	N.A.	N.A.	5	Breeding new varieties, pest and disease control, soils and fertilizers, etc., for sugar cane.
8. Esc. Sup. de Agricultura.	121	----------	5	Crop improvement (all major crops) soil management and fertility, entomology, plant pathology, agricultural engineering, agricultural economics, rural sociology, etc.
9. Inst. Mex. de Investigaciones Technologicas.	25	(1)	0	Human and animal nutrition aspects of agricultural products; industrialization of food crops; industrialization of tropical woods; agricultural fibres.
10. Fundacion Rockefeller (Country, Regional-International).	9	.776	0	Crop breeding: (corn, wheat, sorghum, beans, potatoes, etc.) pest and disease control; soil fertility and management; animal pathology and nutrition; agricultural information; etc.

[1] Variable projects 50–67% financed by contracting enterprises.

C. *Research Personnel.* In 1962, INIA employed 231 persons with technical training, including assistants. Twenty individuals held Ph.D. degrees, 51 possessed M.S. degrees, and another 98 persons had the degree of *Ingeniero Agronomo.* Of the total, 131 were employed in plant technology, 28 in entomology and plant pathology, 20 in soils work, 10 in extension activities, and 7 in agricultural economics.[32]

About 300 additional research and support personnel were employed at other research centers, universities and institutions in the country.

The higher education enrollment in agriculture has increased 112

[32] Ibid.

percent from 1,470 in 1958 to 3,123 in 1963. This increase was almost equal to that which occurred in career training in commerce and more than twice as great as that in engineering or medicine. This reflects the greatest emphasis on professional training in agriculture of any of the Latin American countries.

The striking advances in corn and wheat production in Mexico during the last 20 years are being extended to other countries of the world through the recently established International Center for Corn and Wheat Improvement at Chapingo. Rockefeller Foundation staffs in genetics, soil science, and agricultural communications in Mexico are being shifted to this Center. They will continue to collaborate with Mexico's National Institute of Agricultural Research (INIA) and the Graduate School at Chapingo through specific projects to bring about still greater efficiency in the production of maize and wheat in Mexico. At the same time, they will promote research and other activities leading to an improvement in production of these two crops in other countries.

Although most of the Foundation's staff in the plant sciences now have broader responsibilities (regional and worldwide), considerable effort was concentrated in further strengthening the work of INIA. This year 15 highly competent research workers were awarded Foundation scholarships or fellowships to enable them to work toward advanced degrees abroad. Preference was given to Ph.D. degree candidates. Master's degree candidates are being urged to study at Chapingo.[33]

D. *Research Planning, Administration, and Organization.* Research is carried on through a system of experiment stations. INIA is now coordinating research at the stations with that carried on at the higher level agricultural schools. Continuing effort is being directed to research planning to meet needs in other areas. Support for agricultural development is being increased each year.

E. *Research and Teaching Relationships.* Iowa State University is participating in the development of the Graduate School at Chapingo with Ford Foundation support. Further effort will be needed to achieve effective linkage of education, research, and extension in Mexico, but this integration is in process.

The National Institute for Agricultural Research and the National School of Agriculture with its Graduate School in Mexico will be associated with the Agricultural Center at Chapingo with support from the Ford and Rockefeller Foundations, the Inter-American

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[33] The Rockefeller Foundation Program in the Agricultural Sciences, An. Rpt. 1964–65, July 1965.

Development Bank, and AID. The nationwide program of research aided by the Rockefeller Foundation since 1943 furnishes the "National System" focus in Mexico as in Colombia and India.[34]

1. *Integrated Agricultural Program of Education, Research, and Extension, Chapingo.* This project commenced in October 1964 and will be completed in October 1968. It involves the National School of Agriculture, the National Extension Service, and the National Institute of Agricultural Research. Its purpose is to develop an agricultural research program particularly in the tropical zone of the country, and to link research more closely with the farmer through a closer liaison with the Extension Service. The total available from the Special Fund is $1,714,000, of which $960,379 was allocated by the end of October, 1966. Approximately 30 percent of these funds is expended for planning and coordination of research.[35]

2. *Inter-American Institute of Agricultural Sciences, Turrialba, Costa Rica.* This project, which became operational in January 1964, involves an FAO Special Fund expenditure of more than $4,000,000. The project is designed to strengthen postgraduate education and associated research in soils, crops, forestry, economic and social sciences, animal husbandry and agricultural engineering. It is expected to make a considerable impact on improved planning and coordination of research through: (1) strengthening the staff of the Institute which is actively involved in coordinating agricultural research in Latin America; and (2) preparing senior staff who will be concerned with planning and administering programs in research and other aspects of agricultural development in all of the Latin American countries. While the project operates at centers in Turrialba, Costa Rica (the principal site), La Molina, Peru and La Estanzuela, Uruguay, it benefits all Latin American countries.[36] The USDA has cooperated with the Inter-American Institute in planning and conducting research in several programs of regional significance.

Peru[37]

A. *Research Areas.* In 1965 the national network of agricultural research facilities included one national research station, five regional experiment stations, eight regional substations, fourteen experimental fields, and thirteen zone offices. The locations of these centers and the subject matter areas with which they are concerned are described in Table 5.

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[34] Proceedings of the St. Paul Conference, University Directors of International Agricultural Programs, University of Minnesota, St. Paul, Minnesota. June 8–9, 1966.

[35] D. C. Kimmel for Viggo Andersen, Dir., Rural Institutions and Services Div., FAO, to Merril M. Blevins, 1st Secy. of Embassy FAO Affairs, U.S. Embassy, Rome, Italy, 12.29.66.

[36] Ibid.

[37] Compiled from miscellaneous sources by A. J. Coutu, Director, North Carolina State University Mission to Peru. January 31, 1967.

TABLE 5.—*Research facilities and subjects studied*

Stations	Location of Work	Subjects
National (SIPA):[1]		
La Molina	Countrywide	Cotton, corn, potatoes, fruit, rice, beans, forages.
Regional (SIPA):		
Lambayeque	North coast	Potatoes, cotton, rice, livestock.
Tulumayo	Upper jungle	Chocolate, coffee, tea, corn, forages, fruit.
Tingua	North sierra	Grains, fruit.
Huancaya	Central sierra	Potatoes, grain, forages.
Ica	South coast	Fruit, vegetables.
Regional Substations (SIPA):		
Las Cerdos	North coast	Grain, fruit, tobacco.
Hurangopampa	North sierra	Potatoes, forages, livestock.
Yurimaguas	Lower jungle	Rice, livestock, forages.
Tarapoto	Upper jungle	Tropical livestock.
Bellavista	Upper jungle	Tropical livestock.
Juan Jui	Upper jungle	Tropical livestock.
Cuzco	South sierra	Grain, potatoes, forages.
Arequipa	South sierra	Grain, fruit, forages.

[1] Servicio de Investigacion y Promocion Agraria.

A program for expanding the agricultural universities in Peru has been underway during recent years. Whereas the principal institution for training and research at the national level continues to be the Universidad Agraria, located at La Molina, other public and private universities serve the various regions of the country. These are listed in Table 6.

TABLE 6.—*Public and private universities offering specialization work in agricultural subjects*

	Location of Work	Subjects
Principal Public Universities:		
Universidad Agraria (La Molina).	Countrywide	Agronomy, livestock, agricultural engineering, social sciences, forestry.
Universidad Tecnica (Piura)	North Coast	Agronomy, social sciences.
Universidad del Norte (Lambayeque).	North Coast	Agronomy, livestock.
Universidad de Agraria (Tingo Maria).	Selva	Agronomy, livestock.
Universidad de Cuzco	South Sierra	Agronomy, livestock.
Private Universities:		
Sociedad Nacional Agraria (La Molina).		Genetics, entomology, cotton.
Associacion de Productores de Canete.	Canete Valley	Genetics, soils, entomology, fruit, cotton, potatoes, corn.
Associacion de Productores de Ica.	Ica Valley	
Liga Agricola y Ganadera del Chira.	Piura	
Malteria Lima S.A		Barley.

The experimentation division of SIPA has special programs for rice, corn, beans, potatoes, forage crops, cattle production, cereals and horticulture. In 1964 research was being performed under some 220 projects. In addition, there are special research programs underway on coffee, tea, fibers, oil and yucca, all supported by associations of private producers.

Recent changes in SIPA have included the addition of statistical and economic research sections. Particular attention has been devoted by these to analyses of the results of experimental work on fertilizers. Estimates have been developed of regional fertilizer production coefficients and the economic implications of variation in fertilizer and commodity prices. Regional land use and farm management studies have also been initiated.

Because the research activities of private societies and associations are planned to supplement the work of government agencies rather than compete with them, there is a much greater private research effort in Peru than in neighboring countries.

AID, through a contract with North Carolina State University, is contributing to the activities of SIPA and the Agrarian University at La Molina.

B. *Research Support.*

TABLE 7.—*Budget for Peru's national agricultural research programs for 1962, 1964 and 1966*

Year	Amount (Dollars)	Increase over 1962 (percent)
1962	777,000	----------------
1964	1,299,000	67
1966	1,555,000	100

These budget estimates refer only to research conducted by or under contract with the Ministry of Agriculture. Additional research support is provided to the Universidad Agraria from grants or earned income. A small amount of research is supported by private national crop and livestock associations. Other agricultural research is underway at five provincial universities, San Marcos University (faculty of veterinary medicine) and by the National Planning Institute. However, the Ministry's agricultural research budget is a major source of research support. For example, the total budget for Universidad Agraria in 1962 was $1.6 million. This budget has increased substantially since 1962, but the increases have been used principally for salary adjustments and additional staff. Additional data on Universidad Agraria for 1964 (Table 8) indicates that about 41 percent of the full-time staff have training above a Bachelor's level. Faculty time devoted to research varies from 22 to 51 percent.

TABLE 8.—*Advanced training and allocation of faculty time at Universidad Agraria, Lima, Peru, 1964*

Item	Total	Faculties					
		Agronomy	Applied Science	Forest Science	Social Science	Agr. Engineering	Animal Science
Total No. of fulltime professors	210	48	37	16	33	30	46
Professors with advanced training	85	21	19	4	8	9	24
Professors with advanced training outside Peru	47	9	12	1	5	5	15
Allocation of professors' time (percent):							
Teaching	....	29	39	29	32	34	14
Research	....	24	27	22	32	37	51
Administration	....	47	34	49	36	29	35

Source: Unpublished results of survey conducted by J. Gazzo, Research Director, Universidad Agraria, 1964.

C. *Research Personnel.* The staff of SIPA in 1964 was composed of about 125 *Ingenieros Agronomos* including a limited number with M.S. and Ph.D. degrees plus technical assistants and field workers. It is expected that the combined efforts of AID, North Carolina State University, and the Rockefeller and Ford Foundations will enable the Agrarian University to increase the number of graduates in agronomy to 250 a year by 1968 and the number from the Veterinary School to 200. Additional increases are planned beyond 1968.

Table 9 indicates that Peru has started to make significant progress in training badly needed research workers.

TABLE 9.—*Agricultural research workers per 100,000 people active in agriculture* [1]

Country	Agricultural Research Workers [2]
India	1.2
Mexico	3.8
Peru	8.0
Colombia	9.0
Argentina	14.0
Japan	60.0
Netherlands	133.0

[1] Changes in Agriculture in 26 Developing Nations 1948 to 1963. Foreign Agricultural Economic Report No. 27, Economic Research Service, U.S. Department of Agriculture. 1965.

[2] Data for Peru refers to 1961—all other countries 1960.

D. *Research Planning, Administration, and Organization.* From 1962 to 1964, SIPA prepared a plan for further development of a national agricultural research program. Extensive organizational and research program changes were suggested regarding nationwide research programs, probable contract research activities and support for basic research. Further planning and some implementation have occurred during the last two years.

The Agrarian University has experienced substantial development and growth. Increased support from the Government of Peru, the Ford and Rockefeller Foundations, AID, the Inter-American Development Bank, other foreign governments and the United Nations has permitted extensive changes in education and research, philosophy and organization, curricula, staff training, administrative organization and capability, and new physical facilities. Since 1961, North Carolina State University has contributed to increased growth of the Agrarian University by providing long- and short-term advisors in administration and programming, agronomy, animal science, applied science, social science, architecture and related fields. North Carolina State University and other contract organizations also have provided assistance in staff training, research support, library development and related areas.

E. *Research and Teaching Relationships.* The relationships with North Carolina State University and the Rockefeller and Ford Foundations discussed above are increasing the rates of growth in research, extension and teaching. These are essential components of development which should be strengthened and expanded if the increases of annual agricultural output required by expanding population are to be achieved.

Summary

In most of the Latin American countries agricultural research effort in the past has been directed to crop variety improvement. Much of this research effort has failed to provide information basic to the formulation of agricultural production systems that can be used to increase food supplies and improve the income level of farm people.

Some of this deficiency of agricultural research information is the consequence of failure to recognize the importance of productive and efficient agriculture as a foundation for industrial and total economic development.

Another factor that cannot be overlooked is the low social status of agriculture teachers or agricultural research scientists in relation to other professional workers. An associated factor is the inadequate financial remuneration of agricultural personnel which has resulted in a shortage of competent scientific manpower.

A few notable examples of significant research contributions to expanded crop production are represented by the increases in yields of corn and wheat in Mexico, coffee and corn in Brazil, wheat in Argentina, and cotton in Peru.

Little or no research attention has been given to the economic or social problems or rural people. Farm management problems such as the economic operation of small farm units and the selection and combination of farm enterprises to maximize production or farm income have received very little attention. Limited research to correct this deficiency has been started recently in several countries.

Research on animal and plant diseases has received considerable attention in most countries. Increased efforts in this area using modern research methods offer promise of early returns because of the serious losses from diseases and pests, including weeds.

Livestock feeding and management problems have been seriously neglected. For example, little effort has been directed to studies of range management and livestock feeding during dry periods. Present exceptions include some of the research programs of INTA in Argentina, work in Sao Paulo and Minas Gerais in Brazil, in Colombia, and in Chile.

A factor that is of predominant importance in many countries, particularly in the rural sections, is the lack of adequate staff to train agricultural scientists and educators to evaluate food and food production problems and plan remedial research and education programs.

Improvements have been made in recent years in research support, planning and coordination as well as in the training of badly needed scientists.

The United States Department of Agriculture has provided valuable advice on research planning to several countries in recent years. In addition, the U.S. Department of Agriculture scientists stationed in Latin American countries have given effective leadership. These efforts need to be expanded.

AFRICA

The countries of Kenya, Nigeria, and Tunisia were selected for the survey of agricultural research. Although these three countries can hardly be considered an adequate sample of the many nations on the African continent, they do represent a range in ecological conditions, in attention previously and currently directed to agricultural research, in previous historical and cultural development, and in food production potential. Also of great importance in the vast continent is the range in willingness to accept new ideas.

Kenya

A. *Research Areas.* Much of the information in Table 10 which includes a listing of the research centers and stations, the subjects on which research is being conducted, the location of these research establishments and whether they are national or regional in scope was taken from Lee (5). Several of the Kenya stations listed in Table 10 have additional field locations which permit them to carry out variety trials in different ecological zones. Variety and agronomic trials are also placed on farms in cooperation with farmers to broaden the scope of applied research and to serve as community demonstrations.

Nearly all of the research establishments have a rather specific objective or assignment which is indicated by their names. The East African Agricultural and Forestry Research Organization warrants special explanation. This organization has a comprehensive research program that deals largely with problems common to all of the East African nations. It has the following divisions: Animal Husbandry, Army Worm Research, Chemistry, Forest Tree Breeding and Silviculture, Forest Entomology, Nematology, Physics, Plant Pathology, Plant Physiology, Sorghum Breeding, Statistics, and Systematic Botany.

In addition to the research centers listed in Table 10, there is a small farm survey unit in the Ministry of Economic Planning and Development. This unit makes economic studies of farm organization and farm management.

Plans are underway to initiate major research programs in horiticultural crops and sugar production. Fulfillment of these plans may result in expansion of some existing establishment or building at a new location.

B. *Research Support.* Much of the support for agricultural research in Kenya is provided by foreign aid particularly through the assignment of research personnel. However, some of the support comes in the form of equipment and other material needs. Specific financial data are not available.

Kenya itself provides a large amount of the commodity stations' support through the levy of a cess (assessment) on the marketings of these commodities. It is relatively easy to make these collections on the commodities which enter export channels.

The East African commodity institutions are financed through contributions from the three supporting countries (Kenya, Uganda, and Tanzania) which are based on the share each country has of a particular export crop. Support of the East African Agricultural and and Forestry Research Organization (EAAFRO) is also on a three

TABLE 10.—*Information on research establishments—their location and kinds of research being conducted—Kenya*

Type of Establishment	Location
Kenya Establishments:	
National Laboratories	Nairobi.
Soil Chemistry and Soil Survey	
Plant Pathology	
Legume Bacteriology	
Entomology	
Plant Breeding:	
Maize Breeding Center	Kitale
(Units at Embu, Kakamega and Katumani directed from here)	
Wheat and other small grains	Njoro
Commodity Research Stations:	
Coffee Research Institute	Ruiru
High Level Sisal Research Station	Thika
Cotton Research Station	Kibos
Pyrethrum Research Station	Molo
Sugar Research Unit	Kisumu
Horticultural Research Station	Thika
Horticultural Research Station	Molo
Grassland/Livestock Stations:	
National Agricultural Research Station	Kitale
Nyandarua Agricultural Research Station	Ol Joro Orok
Marindas Agricultural Research Station	Molo
General Purpose, Outlying Stations:	
(Variety trials, agronomic practices, fertilizer, herbicide and pesticide trials and general animal husbandry—all applied research)	
Coast Agricultural Research Station	Kikambala
Eldoret Agricultural Research Station	Eldoret
Embu Agricultural Research Station	Embu
Katumani Agricultural Research Station	Machakos
Nyanza Agricultural Research Station	Kisii
Western Agricultural Research Station	Kakamega
Irrigation Research Units:	
Kano Irrigation Research Station	Ahero
Mwea-Tebere Irrigation Research Unit	Embu
Perkerra Irrigation Research Unit	Marigat
Tana Irrigation Research Unit	Galole
Veterinary:	
Department of Veterinary Services	Kabete
Division of Animal Husbandry	Nairobi
Division of Range Management	Nairobi
East African Establishments:	
Tea Research Institute of East Africa	Kericho
East African Agricultural and Forestry Research Organization	Kikuyu
East African Veterinary Research Organization	Kabete
Wellcome Institute for Research on Foot and Mouth Disease	Nairobi
University College—Faculty of Veterinary Science	Kabete

country basis. In addition, the Rockefeller Foundation contributes the salary of the Director.

The Rockefeller Foundation is also providing part of the funds and personnel for maize and wheat research. Its requirement is that the program must have at least regional significance.

C. *Research Personnel.* A tabulation of the number of scientists in the various national research establishments, not counting personnel at the regional East African institutions, shows that there are 271 members above the technical assistant level. Of these 147 are of senior and full-officer rank. In this latter group about two-thirds are expatriates, whereas at the assistant level less than one-third are expatriates. This gives some idea of the recruitment and training effort needed to maintain continuity in the research program. Desirable expansion would require at least 75 additional members of senior and full-officer rank and about 30 of assistant rank. Most of these individuals probably would have to be recruited through aid programs. These staff requirements do not provide for personnel needs of some of the major proposals now being developed.

In most instances the recruitment of additional staff of senior and full-officer rank requires new housing. This is not so essential near urban centers like Nairobi, but at the more isolated locations housing is almost mandatory. At a few places, such as the National Laboratories and the Plant Breeding Station at Njoro, some type of guest house or flats would be desirable to accommodate visiting scientists, temporary staff members, and students.

Greater program productivity and continuity could be achieved if foreign aid for research was used to sponsor concentrated effort on major research problems of food production. Under such a plan individual scientists might stay for a period of only two years, but the agency would be responsible for refilling positions and maintaining continuity in the program.

In addition, foreign assistance for research should include training of local leadership so that Kenya's citizens can contribute to enlargement of the research staff and capabilities. Research competence must be developed on-the-job since the colleges and university in Kenya are not yet geared to meet this need, nor are enough trainees sent abroad to more than partially meet demands.

D. *Research and Teaching.* There is little coordination between research and teaching in Kenya because of the policy of divided responsibility. The research stations are separated from each other and also from any teaching responsibility.

Teaching in agriculture is carried out at the diploma level at Edgerton College, a private institution located at Njoro, near Nakuru. The degree-level teaching in agriculture is conducted at Makerere, Uganda, a unit of the University of East Africa. The University of West Virginia is assisting the staff at Edgerton with its teaching in agricultural engineering, forestry, and agronomy. It is likely that a limited research program will be developed primarily to provide teaching support.

The Faculty of Veterinary Science, Royal College, Nairobi, is also a part of the University of East Africa. It has no research responsibilities, but it is located in close proximity to other organizations which perform veterinary research and services. Colorado State University has a team located at this institution to assist in developing veterinary instruction and research.

E. *Research Planning, Administration and Organization.* The many research organizations and agencies listed in Table 10 carry out their own planning and operations, largely independently. The applied stations have their proposed programs reviewed by senior research officers in the Ministry of Agriculture. There appears to be little need for major efforts at coordination because of the specific responsibilities of each station. Grouping of research personnel at central locations would improve library and other overhead services as well as facilitate staff and research continuity.

Program plans in the East African Research Organization are cleared through advisory committees representing the three countries.

Nigeria

A. *Research Areas.* The federal government provides an organizational structure for research through institutes on cocoa, palm, stored products, industrial products and on other problems not specifically related to agriculture. The Federal Ministery of Economic Development also includes a Department of Agricultural Research. At two federal universities, Ibadan and Lagos, limited research is carried on by the faculties of agriculture.

The Ministries of Agriculture and Natural Resources in the eastern, western, midwestern and northern regional governments report a research function. Three regional universities, Ahmadu-Bello, Ife and Naukka, lack adequate staff or facilities for research as shown in the report by Rowat (6).

Europeans are continuing to provide excellent programs in certain fields such as sorghum breeding at Ahmadu-Bello University at Samaru and corn breeding at Ibadan. USDA augments the corn and sorghum research at these locations.

The Rockefeller Foundation initiated a corn breeding program at the University of Ibadan in 1964 using the facilities of the Department of Agriculture and the University Farm.

B. *Research and Education Support.* The federal government has allocated funds for capital expenditure during the present quinquennium for each of the universities. It is suggested that some priority requirements for the use of federal funds be indicated by the federal government to the regional authorities and to the universities. Urgent priority should be given to expansion of the four faculties of agriculture if they are to develop the capabilities to provide instruction for the anticipated enrollment of 1,250 students. Further investment of not less than $8 to $10 million will be required for buildings, equipment and accommodations for staff and students. Comparable increases are required to provide for recurrent expenditures.

Assistance has been provided from the Netherlands, United Kingdom, UNICEF, FAO, West Germany, Peace Corps, Ford Foundation, Mobil Oil, and MacMillan Publishing Company according to Rowat (6).

C. *Research Personnel.* Amid the vast needs of Nigeria for scientific and technical manpower, both now and in the country's future development, those of agriculture stand out. Many international authorities, such as Professor F. Harbison, and the Ashby Commission, have emphasized the critical manpower situation in the agricultural field.[38] The range of government services to agriculture is already wide, covering animal health and disease control, production, processing and marketing of the principal export crops, cooperatives, community development, forestry and fisheries, farm settlement and other development schemes, in addition to a steadily growing amount of agricultural education, extension and research work. While there will be a rapid growth of the commercial or private sector in agricultural and also in the technical services which that sector will provide in the expanding economy, the main load of development will continue to fall on government services for some time to come. Expansion will be necessary in such comparatively new fields as agricultural credit, agrarian structure, farm management and organization, food technology, and in work with rural women and young people.

As the schools of agriculture develop the capabilities to meet expanding regional needs, the research institutions are experiencing increasing difficulty in recruiting and training personnel needed to assist their professional research staffs with field and laboratory duties. So seriously is the problem regarded that it has been suggested that a new (Federal) College of Agriculture be established for the specific purpose of training intermediate-level staff. This institution would be located in an existing building at the Federal Department of Agricultural Research, Moor Plantation, Ibadan, where much of the teaching could be done by the research officers.

While the total number of intermediate-level research staff is not

[38] Ashby Commission. "High Level Manpower for Nigeria's Future," *Investment in Education.* Report of the Commission on Post School Certificate and Higher Education in Nigeria, Lagos, 1960.

large, amounting to some 500 in all, they may form as much as 50, 60, or even 75 percent of the total staff at any one center. Of the established positions, 25 percent were vacant at the time of inquiry (December 1963) with a slightly higher proportion of vacancies among the laboratory staff.

The Federal Agricultural Research Department has recently authorized the regional schools of agriculture to recruit locally and train agricultural assistants to fill vacant positions. The research divisions of the Ministry of Agriculture must compete for staff with the extension services, and as a result are no better off in this respect than the institutes. The retention of scientific recruits is probably the greatest problem of the research centers. This situation can be expected to continue with the many opportunities for trained personnel to improve their academic qualifications and to gain admission to a university or to move to posts in other, larger services offering greater remuneration and more rapid promotion.

D. *Research Planning, Administration, and Organization.* The administrative structure for agricultural research and development established in 1965 is under the Ministry of Economic Development. A division, Agriculture and Natural Resources, is the nucleus of research and training activities in the Ministry. Included in the organization are the Department of Forest Research which includes the forestry training school at Ibadan and the research stations associated with the school; the Department of Agriculture with research stations; and the Department of Veterinary Research with the veterinary training school at Vom with its associated research stations.

At the regional level, agricultural research and development in western Nigeria, midwestern Nigeria, eastern Nigeria and northern Nigeria are under a Council of Ministers which includes a Ministry of Agriculture and Natural Resources. The administrative arrangement is essentially the same in each regional organization and includes departments of agricultural research, extension, animal health and forestry.

In northern Nigeria the Agricultural Research Institute at Ahmadu-Bello University is under the Ministry of Agriculture.[39]

E. *Research and Education Relationship.* There is critical need for establishing a plan for cooperation among the different universities, the regions, and the federal government.

Proposal for Coordination of Agricultural Education and Research Training

With the rapid growth of the schools of agriculture and prolifera-

[39] Agricultural Development in Nigeria 1965–80—FAO—Rome. December 1965.

tion of courses in its various aspects, there is need for a national coordinating body that can advise the federal government; and, through it, the regional administrations on the requirements of the system and how to meet them. This advisory body could have the following responsibilities:

1. To interest itself generally in the development of agricultural education at all levels and in all subject-matter fields in Nigeria.
2. To advise on, and perhaps later to be responsible for, the setting and maintenance of standards for diploma awards in agriculture and other subjects.
3. To provide a forum for the consideration of university degree courses, requirements and standards in the fields of agriculture, and to express its views and give advice to the federal government and the National Universities Commission.
4. To foster useful and effective links among the several faculties of agriculture, the schools of agriculture and the research centers, and to provide a meeting ground for the discussion of common problems and of future development.
5. To consider and advise the government on scholarship policies, staffing, equipment and financing of the agricultural education institutions.

For such a council to be effective, its membership should be kept as small and flexible as possible. It is important that those appointed to the council should be able to attend meetings regularly and devote time to its work. Both the functions and the membership should be reviewed periodically in the light of changing conditions.

Tunisia

A. *Research Areas.—Limited work on fertilizer response.* Fertilizer usage in 1963 was only 2.7 pounds per hectare of N, P, and K.

Tunisia being an arid country, water is the limiting factor to expansion of arable land. Soils of the oasis areas, because of centuries of use of manure and water, have become highly productive.

The Soil Conservation Service of USDA currently has ten technical staff members working on soil survey and land classification in Tunisia. Major attention is being given to the Medjerda Plains where increased irrigation will permit greatly expanded production of fruit and market garden crops. The objective is to obtain information on soil and water conditions that will be useful in converting the agriculture of the area from a monoculture based on cereals to a more diversified system in which pulses, forage crops and such industrial crops as flax, sugar beets and cotton would be raised.

An intensified research program will be required to solve the problems arising from irrigation of the poorly drained lowlands with water that is salty in certain seasons. Tunisia, when compared with 26 other developing countries, has an excellent program of plant breeding, introduction of improved varieties, seed certification, seed testing and seed distribution to farmers. AID has supported a horticulturist who works with the Ministry of Agriculture at Tunis on the introduction of improved horticultural crops, particularly citrus.

B. *Research Support.* When compared with 25 other developing nations, the program of agricultural research during the 1950's was given a rating of 3 from the standpoint of overall technological features using a scale of 1 as the best and 3 as the weakest.[40] There are very few qualified scientists, and support of research is minimal.

C. *Research Personnel.* The need for agricultural research scientists and teachers is critical. The potential for expanding agricultural production through the use of additional land is poor as more than 75 percent of the arable land in the country is under cultivation; so, more effective use must be made of existing resources. No available information is available on the size or current assignments of the research staff. A highly qualified extension staff is also needed.

D. *Research Planning, Organization, and Coordination.* A basic plan needs to be developed for a research program. Unfortunately, the soils in the heavy rainfall area of Tunisia have suffered greatly from overgrazing and bad farming practices. Erosion and runoff on cultivated land are more severe in Tunisia than in any other area of North Africa.

E. *Research and Teaching Relationships.* Texas A&M University is working currently under an AID contract with the Secretariat of State of Agriculture of the Government of Tunisia to develop programs of agricultural education and research. Another AID-Texas A&M University contract provides for the development of an agricultural school at Chott-Marie in consultation with a small Tunisian staff.

The University of Minnesota is working under an AID contract with the Government of Tunisia to develop a research program in agricultural economics and a plan for more effective use of natural and human resources.

Summary

The African Continent is comprised of 42 countries, over half of which have gained their independence within the last five years. Governments of Africa have tremendous opportunities for developing their countries as a result of this change in the status of their people.

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[40] Proceedings of the St. Paul Conference, University Directors of International Agricultural Programs, University of Minnesota, St. Paul, Minnesota. June 8–9, 1966.

Their difficulties are likely to be great also. A demographic revolution is underway throughout the region. The administrative cadres are depleted, and their reorganization is giving rise to complex problems. The pressures for higher standards of living are increasing. Exceptional determination and great foresight will be required to give the African economy a new and basic impetus.

Progress in the past has been substantial but uneven. Many basic problems are still unsolved though the physical obstacles to development are in some ways less formidable than those encountered in Asia and the Far East. In Africa there is unemployment and underemployment of both manpower and land, giving greater flexibility in land use policy. In many ways, progress seems harder to achieve than in other areas. There is a need for health facilities to combat debilitating diseases and the lack of education is deplorable. In most countries, more than 80 percent of the population is illiterate.

The region exhibits the characteristics of underdevelopment to an extreme degree including a large primitive subsistence sector of the population that has been unable to achieve a better life. Over 80 percent of the region's population is occupied in the rural sector at a low level of productivity. Most of the countries are dependent on no more than two or three main export products. The region produces hardly any of its capital equipment.

Even the relative abundance of land is in some ways a liability due to wide dispersal of the population. It increases the cost of essential infrastructure; it necessitates unusually heavy capital investments to obtain increases in income; and, in many cases, it hinders radical improvements in production methods. The combined effects of increase in population and loss of soil fertility may soon produce as critical a situation in Africa as anywhere in the world.

The serious erosion problem in practically all zones is evidence both of the great predisposition of many of the soils to erosion and of the failure to devise compensatory cropping patterns and conservation techniques. In fact, the major limitation to increased production in areas where field crops are grown presently is that few methods have been developed and still fewer applied to conserve the soil or to recover and maintain its fertility through stable farming and cropping systems.

The existing research institutions have done considerable useful work in the past, especially on export crops. This work should continue and be broadened to include products designed mainly for domestic use. Unfortunately, neither manpower nor means are available to maintain the existing institutions, let alone broaden their scope. In view of the fact that ecological regions cut across national frontiers, agricultural research undertaken on a regional basis could economize on scarce manpower and at the same time demonstrate the potential of inter-African cooperation. If such research is not rapidly organized, it is probable that the newly independent countries will be unable to ensure the continuation of present effort. Moreover, the situation is likely to lead existing research establishments to orient exclusively to the immediate needs of the country in which they are located, and greater opportunities for increasing agricultural, forestry and fishery production would be lost.[41]

ASIA

Most of the countries of Asia have experienced continuing series of disasters with the rate of food production increases behind the rate of population growth. The countries where food needs are large are subject to extremes in weather. For example, in 1965 extreme drought conditions in India and Pakistan resulted in short food supplies, starvation, and riots.

Agriculture in Turkey has been neglected for over fifty years, and there is critical need for additional technical information on methods for increasing food production.

Agricultural research and training in East and West Pakistan, India, and Turkey were surveyed as representative of Asian programs.

India

A. *Research Areas.* India has a great diversity of soil, plant, and climatic conditions. For example, the number of flowering species is over 20 thousand, which is far greater than is found in countries larger in land area. In fact, Chalam (1) states that the only country with a larger number of plant species is Brazil.

According to Chang (2), there were 107 agricultural experiment stations, institutes, and regional stations that give research attention to one or more of the major crops in the regions in which they are located. There are also research stations concerned with the improvement of deep-sea fishing.

The extensive program of research supported by the Rockefeller Foundation covers work with wheat, maize, sorghum, and millets at 16 main research stations and at 20 substations as part of the Cooperative Central and State Experiment Locations. The research effort includes experimentation in genetics, breeding, pathology, entomology, soil fertility, and water use. The USDA is working on research problems in several areas in close association with the Indian Council of Agricultural Research and the foundations.

[41] FAO Africa Survey—The Possibilities of African Rural Development in Relation to Economic and Social Growth—Rome. 1962.

TABLE 11.—*Amounts of budgets of the 12 central agricultural research institutes in India for the year 1960, as reported*

Name of the Institute	Budget 1960
Indian Agricultural Research Institute	$1,531,300
Central Potato Research Institute	246,600
Central Rice Research Institute	442,667
Indian Sugar Cane Research Institute	183,667
Sugar Cane Breeding Institute	88,016
Central Fisheries Technological Research Station	79,500
Central Inland Fisheries Research Institute	273,000
Central Marine Fisheries Research Institute	215,000
Central Arid Zone Research Institute	194,000
National Dairy Research Institute	668,250
Indian Veterinary Research Institute	834,200
Total	$5,430,700

B. *Research Support.* The funds available in 1960 to the 12 central agricultural research institutes are listed in table 11.

Financial support is provided by the central government, commodity committees, provincial governments, regional research stations, and the Indian Council for Agricultural Research according to Chang (3). The funds available for support of research at the Indian Agricultural Research Institute during the period 1951 to 1960 are presented in Table 12.

TABLE 12.—*Annual budgets of the Indian Agricultural Research Institute for the 10-year period 1951–60, as reported*

Year	Budget (Rs.)	Dollars
1951	2,054,200	342,366
1952	2,391,900	398,650
1953	4,219,400	703,233
1954	5,718,400	953,066
1955	7,325,700	1,220,950
1956	7,015,000	1,169,166
1957	9,057,300	1,509,550
1958	9,157,600	1,526,266
1959	8,386,200	1,397,700
1960	9,187,800	1,531,300

The Indian Council of Agricultural Research in the year 1961–62 appropriated a total of Rs. 10,002,711 to support research. The Council generally meets 50–100 percent of recurring expenditures provided nonrecurring expenditures are either wholly or substantially borne by the institute concerned.

C. *Research Personnel.* The number and training level of research personnel at each of the central agricultural research institutes are reported in Table 13.

TABLE 13.—*Research personnel and their training in the 12 central agricultural research institutes in India in 1960, as reported by Chang (3)*

Name of the Institute	Research Personnel and Their Training				
	Ph. D.	M. Sc.	B. Sc.	Other	Total
Indian Agricultural Research Institute	96	292	42	40	470
Central Potato Research Institute	8	25	18	--------	51
Central Rice Research Institute	10	40	4	1	55
Indian Sugar Cane Research Institute	3	24	24	3	54
Sugar Cane Breeding Institute	3	13	8	3	27
Central Fisheries Technological Research Institute	3	19	13	11	46
Central Inland Fisheries Research Institute	9	43	21	1	74
Central Marine Fisheries Research Institute	13	85	21	46	165
Forest Research Institute and College	19	70	68	72	229
Central Arid Zone Research Institute	9	17	24	83	133
National Dairy Research Institute	18	25	35	12	90
Indian Veterinary Research Institute	34	50	6	84	174
Total	225	703	284	356	1,568

In addition, technical assistance received by the eight central research institutes has averaged 70 man-years for the last ten years. This will be discussed more completely under research and teaching relationships.

The record of contributions by the large national research centers and many of the provincial laboratories to basic science is very good. The correlation between research, particularly in the past, and the problems of the farmer appears to be relatively insignificant. In the recent past there has been virtually no evidence of interest on the part of research scientists to have the findings of their research contribute to the solution of problems of the farmer.

Training in sciences related to agriculture has been limited. Orientation to problem-solving research on either basic or applied problems of agriculture has been slow.

The influence of United States universities through AID contracts, foundations, USDA, and industries, and activities of other governments are having an impact.

Some of the cultural, social and economic concepts in India cannot be stated easily in terms of researchable problems. Research must recognize these factors of human rights and not assume that sociological change must occur before agricultural research can be helpful in meeting the critical problem of hunger. A major effort must be made to train the graduates of Indian universities and the new state agriculture universities to help their own people accept new production techniques that will increase food production.

The problem of acceptance of new ideas involves more than selling "instant success." A system of small farm management must be devised that will enable a producer with no financial resources to purchase the inputs necessary for him to increase his crop production and labor efficiency and to improve his returns.

Poverty and ignorance are the way of life for over 85 percent of the people in India. Education and research in agriculture have been neglected so long that improvement can only be made by a concerted effort to restore their viability.

D. Research and Teaching Relationships. 1. *Traditional Education.* Agricultural institutions of higher learning in India are usually under the control of a state department of agriculture or of animal husbandry. Their main function is training students for government employment. These institutions are usually affiliated with a nearby university which conducts examinations and grants degrees to successful candidates. As a result of this practice, the curriculum in agriculture colleges has tended to become rigid and standardized to meet the requirements of external examination. A typical curriculum for a four-year course is as follows:

First Year: English, Physics, Botany, Chemistry, Zoology.

Second Year: Agronomy, Agricultural Botany, Agricultural Chemistry, Agricultural Zoology and Entomology, Agricultural Engineering, Animal Husbandry and Hygiene.

Third Year: Agronomy, Agricultural Botany, Agricultural Chemistry, Agricultural Entomology, Agricultural Engineering, Horticulture.

Fourth Year: Agronomy (Farm Management), Dairy, Poultry, Agricultural Extension, Agricultural Economics, Agricultural Botany, Agricultural Chemistry, Mycology and Plant Pathology.

Although a certain amount of field practice is given, the curricula make no provisions for specialization or electives to meet individual interest or aptitude. As stated earlier, training is largely designed to prepare people to meet government employment specifications. The new state agricultural universities are attempting to orient their curricula to the problems of the people on the land.

Through repeated efforts by Joint Indo-American Teams on Agricultural Education, Research and Extension, a revolution has quietly taken place in recent years in India which has resulted in the establishment of *state agricultural universities* patterned after the land-grant colleges in the United States to undertake education, research and extension under one administration. So far, such institutions have been established in seven states of India:

1. Uttar Pradesh Agricultural University
2. Punjab Agricultural University
3. Udaipur University (Rajasthan)
4. Orissa University of Agriculture and Technology
5. Mysore University of Agricultural Sciences

6. Madhya Pradesh University for Agriculture and Allied Sciences
7. Andhra Pradesh Agricultural University

Among the basic principles which must govern the establishment of a state agricultural university, the following may be mentioned:

1. Autonomous status.
2. Location of related colleges on the same campus.
3. Integration of teaching to provide a composite course.
4. Integration of education, research, and extension.

The United States land-grant universities of Missouri, Illinois, Tennessee, Ohio State, and Kansas State, under AID contracts, are furnishing assistance in establishing the Indian agricultural universities. The Government of India recognizes the potential value of such institutions and has decided that one agricultural university should be established in each state. The Indian Education Commission, composed of leading educators from India, United Kingdom, and the United States, in its report in 1965, endorsed this goal and proposed that some of the larger Indian states should have two such universities, with a total of 20 for the country.

In the past 10 years, the Indian Council for Agricultural Research has increased its support for "National Coordinated Research Schemes" for improving production of maize, sorghums, millets, wheat, and rice. The research approach is interdisciplinary and applied or problem-oriented by nature, and coordinated with the efforts of the state agricultural university research stations wherever possible. The Rockefeller Foundation is supplying cooperative professional guidance and some financial aid for equipment and supplies to support the coordinated research schemes. The USDA is also providing technical assistance and research information through a vast program of Public Law 480 grants.

There is still need in India for clarification of responsibility for research and extension at the state level to strengthen the research component, to improve the linkage with the ICAR schemes and to relate effectively to the extension and community development organizations that feed new research inputs into the villages. The basic pattern is well established; it has demonstrated its suitability for Indian conditions and is ready to grow in effectiveness as additional financial and human resources become available.[42]

2. *Example of One Agricultural University.* The Uttar Pradesh Agricultural University is the first of the seven agricultural universities which AID and five American universities are working to estab-

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[42] Proceedings of the St. Paul Conference, University Directors of International Agricultural Programs, University of Minnesota, St. Paul, Minnesota. June 8–9, 1966.

lish in India. It opened in 1960 and is the only one of the seven with all of its colleges on one campus. The university has the following colleges and schools:

1. College of Agriculture
2. College of Veterinary Medicine
3. College of Agricultural Engineering and Technology
4. The Home Science College (receiving students in 1966)
5. The School of Basic Sciences and Humanities
6. The Postgraduate School

The enabling legislation passed by the State Assembly in 1958 provides for establishing the university for the purpose of:

1. Making provision for the education of the rural people of Uttar Pradesh in different branches of study—particularly agriculture, rural industry and business, and other allied subjects;
2. Furthering the prosecution of research particularly in agriculture and other allied sciences;
3. Undertaking field and extension programs.

The Governor of the State is by virtue of his office the Chancellor of the University, but the principal Executive Officer of the University is the Vice-Chancellor. He exercises general control over the University. In addition to Administrative Officers, he is assisted by the directors of the agricultural experiment station and the extension service.

The general policy-making powers of the University are vested in a Board of Management consisting of four ex-officio members and eleven regular members. The four ex-officio members are the Vice-Chancellor of the University and the Directors of Agriculture, Animal Husbandry, and Education for the State. Academic matters are handled by an Academic Council organized within the University.

The University of Illinois has contributed actively to the development of the Agricultural University since 1955, and this cooperation is expected to continue for a few more years. Chang (4) reports on the assistance that has been provided by the Rockefeller Foundation, the Ford Foundation, and the United States Department of Agriculture.

E. *Research Planning, Administration, and Organization.* The Indian Council of Agricultural Research, which was established to promote, guide, finance, and coordinate agricultural, animal husbandry, forestry, and fishery research throughout India, functions through a governing body, a standing finance committee, an advisory board, a board of research, and a number of scientific committees. The

Council also coordinates the research activities of the central commodity committees.

The governing body is the supreme body of the Council which has the Union Minister of Agriculture as its chairman. The Council has set up a large number of scientific committees such as an Agricultural Engineering Committee, an Animal Breeding Committee and an Agricultural Economics Committee that examine research projects or schemes, and present their views on these programs to the Board of Research. The Board of Research, after reviewing research activities in the country as a whole, suggests project priorities to the Council. It also makes recommendations to the Advisory Board regarding the testing of research results under local conditions through pilot schemes. The Board of Research really functions as a working committee of the Advisory Board. The Vice-President of the Council is the Chairman of the Advisory Board.

Research institutes and experiment stations that have their own budgets for research have their projects reviewed and approved by their own organizations. The operation of the Indian Agricultural Research Institute is an illustration, the details of which have been provided by Chang (3). Research projects are normally initiated by the scientists themselves, and proposals are considered in the monthly meetings of the divisional research staff. After that, the head of the division concerned prepares an outline of the proposed project in a prescribed form, providing the necessary information on such items as the title, objective, review of work already done, plan of work envisaged, and facilities required. Then he submits it to the Staff Research Council of the Institute for final approval.

Recent changes for improving research planning and coordination are as follows:

1. The programs of all central institutes and commodity committees have been placed under the direction of the Indian Council of Agricultural Research, adding to their previous activities as a granting organization. This permits coordination of virtually all federally-supported agricultural research in India.

2. For the first time in Indian history, agricultural research is being directed by scientists rather than by members of the Indian Civil Service. The Director General and all Deputy Director Generals of ICAR now are scientists. This will permit vastly improved program management.

3. The processes of agricultural development are closely related to the growth and improvement of educational institutions. In India, years of preliminary work in a cooperative program between the Indian Government and the Rockefeller Foundation were devoted to

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strengthening the Indian Agricultural Research Institute and to expanding its scope through the establishment of postgraduate instruction programs. Parallel efforts, in which the institute also took part, went into research on maize, sorghum, and the millets to improve the varieties and management of these crops. The success of these two ventures encourage the Indian Government to revamp its agricultural education system through the establishment of agricultural universities, and to reorganize its agricultural research and extension programs.[43]

4. A recent development for more effective research planning and administration has been the formation of the Council of United States Universities for Rural Development in India (CUSURDI). This Council, working with the Indian Council of Agricultural Research, will continue to provide assistance and encouragement to the Indian Government in finding ways in which agricultural research, teaching and extension programs can be improved in organization, administration and coordination. The full advantages of the United States University Consortium provided by CUSURDI cannot be realized until the badly needed funds are provided.

East Pakistan

A. *Research Areas.* The Central Experiment Station at Dacca was established in 1911 with responsibility for the improvement of cereal crops. It is the oldest experiment station in East Pakistan. After partition in 1947, the Deep Water Paddy Research Station at Habiganj was made a substation. The Agricultural Experiment Station at Rangpor has been working on tobacco improvement for 40 years.

In 1960, three substations were opened at Dinajpur, Barisal, and Chittagong for rice improvement, and one at Pabna for work on oilseeds. In 1961, two more substations were started at Jamalpur and Jessore for rice work, and one more at Rajshahi for work on pulses.

Because of the extreme importance of jute to the economy of Pakistan, the federal government created the Pakistan Central Jute Committee in 1951 to investigate the agricultural and technological problems of jute cultivation. The Committee has built a Jute Research Institute at Dacca.

There is also a Pakistan Tea Board which has a Tea Research Station near Srimangal in Sylhet District in East Pakistan.

B. *Research Support.* Funds for research are included in the total Provincial Department of Agriculture budget. Research support is uncertain and inadequate. Salaries are extremely low.

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[43] The Rockefeller Foundation Program in the Agricultural Sciences, An. Rpt. 1964–65, July 1965.

C. *Research Personnel.* The location of the experiment stations in East Pakistan and the number and level of training of their personnel are presented in Table 14.

TABLE 14.—*Numbers of research personnel and their training at the 10 experiment stations in East Pakistan in 1960, as reported by Chang (3)*

Name of Station	Research Personnel & Their Training				
	Ph.D.	M.Sc.	B.Sc.	Other	Total
Agricultural Research Station, Rajshahi	--------	1	1	4	6
Agricultural Experiment Station Pabna	--------	--------	2	3	5
Agricultural Research Station, Jamalpur (Rice)	--------	--------	2	4	6
Dacca Central Experimental Farm	2	6	4	--------	12
Rice Research Station, Habiganj	--------	1	1	4	6
Rice Research Station, Chittagong	--------	--------	1	4	5
Rice Research Station, Barisal	--------	--------	1	5	6
Rice Research Station, Jessore	--------	--------	1	2	3
Rice Research Station, Dinajpur	--------	--------	2	3	5
Tobacco Research Station, Rangpur	--------	1	1	3	5
Total	2	9	16	32	59

International Assistance.—According to Chang (3), the following three United Nations Special Fund projects have been in operation in Pakistan since April 1964:

1. Soil Survey
2. National Forest Research and Training Institute
3. Hydrological Survey in East Pakistan

D. *Research Planning, Administration, and Organization.* In 1962, the East Pakistan Agricultural Research Institute was established at Dacca and all agricultural research under the Department of Agriculture in the Province was placed under its control. This Institute has two divisions: one concerned with rice improvement; and, the other with the improvement of other crops such as pulses, oilseeds and fodder crops.

All research conducted by the Provincial Department of Agriculture must be approved either by the economic botanist in charge of research on rice or by the economic botanist in charge of research on oilseeds, pulses, and fodder crops.

There is no organizational arrangement for research planning and coordination.

E. *Research and Teaching Relationships.* The East Pakistan Agricultural Institute, Tejgaon, Dacca, founded in 1940 with a two-year course, was changed in 1945 to provide the present three-year course for students who have passed the intermediate in science. Research was not included until 1962 and receives only very minor attention at present.

1. *Mymensingh Agricultural University.* The Government of Pakistan, with the assistance of an AID contract with Texas A&M University, plans to develop a University of Agriculture at Mymensingh which will: (1) serve as a center of higher education in agriculture and related activities through publications, resident teaching, and extension; (2) conduct fundamental and applied research in agriculture and related fields in order to develop and make available useful information for agricultural development; and (3) train professional manpower for leadership and participation in the country's agricultural development. A contract team of professors from the Texas A&M University system was acquired in 1964 to assist in the development of the university. A World Bank loan through the Institute for Defense Analyses of $2.7 million was approved in 1964 to support the program. Two new areas were added in 1965, agricultural economics and agricultural engineering. More land was also acquired for research.

2. *University of Dacca.* Texas A&M also assisted the University of Dacca in the development of agriculture and home economics training programs under an AID contract. The cooperative activities under the AID contract have not been effective in developing the needed research programs or training the research technologists needed.

3. *Academy for Rural Development.* The Academy for Rural Development was founded in 1959 at Comilla in a district with a population of 200 thousand characterized by desperate poverty.

In 1959 the formal structures for supporting rural development programs existed in Comilla and in East Pakistan generally, but they did not function effectively. On-site cooperatives and extension services did not produce results. Research personnel had not developed and tested improved practices even when they knew about them. Little coordination existed among the various units of government and technical services. A general hopelessness, a feeling that "nothing can be done," seemed to pervade both farmers and bureaucrats.

The aim of the Academy was to apply social science to the problems of the Comilla area. Its main operating technique has been improvement of communications. The patterns of village life were studied to determine why improved practices were not adopted and to discover, through consulting the farmers, what innovations were needed and how they could be introduced. The aim in communication has been to provide an interchange of information and ideas among farmers, bureaucrats, and the social scientists on the Academy's staff.

Although the Academy does not replace existing structures, it brings their personnel together in a new environment. Improved practices are still provided by research stations, and programs are carried out by the existing bureaucracy. The Academy does not execute or administer; it analyzes, evaluates, and catalyzes. The technicians who carry out the programs have shifted their headquarters to the Academy, but they remain members of the regular bureaucracy and are responsible to it. At the Academy, technicians learn the results of the Academy's research and are exposed to continuing evaluation of their programs. Less tangibly, in this new environment they absorb new attitudes toward their jobs.

The Academy's first venture was in cooperatives and extension. Early research indicated that lack of credit was the prime bottleneck to the adoption of innovations. In addition, the extension agent was not viewed by the farmers as a source of advice; instead, they turned to village opinion leaders with whom the agent was not in touch.

The moribund cooperatives were restructured on the basis of consultations with local farmers. The Academy provided the information, but it was the bureaucracy that decided to promote the new structures. The Comilla cooperatives have several distinctive features, but the essential fact about the Comilla system is that the basic responsibility for its design and operation rests with the farmers. The same principle was applied to the reform of the extension system. Since the village extension agents could not operate effectively, they have been largely superseded by "organizers" and "model farmers," chosen by their fellow farmers, who attend the Academy weekly and provide the essential link between research and the farm.

Comilla's institutional innovations have proved successful. The cooperatives are growing, and their rate of recovery of loans is high. The Academy has branched out into other fields, not all of them agricultural: mechanization—tractors and irrigation pumps; mobilizing the unemployed for rural public works; reorganization of local government; and, most recently, family planning, educational reform, and village electrification.

However, the Academy has been very cautious about expanding and has refused to supply plans for other areas. Instead, it offers to give bureaucrats the opportunity to observe its methods and apply or adapt them elsewhere on their own initiative.

Thus Comilla remains a pilot scheme. Its distinctive features are its constant self-evaluation, its studies of local society, the communication it has established between the farmers and the bureaucracy, and its effort to arouse the initiative of both village society and bureaucracy.[44]

West Pakistan

A. *Research Areas.* 1. Major agricultural research programs in West Pakistan are conducted by three research institutes which are under

[44] Comilla—Pakistan Academy of Rural Development. Akhter Hameed Kahn.

the direction of the Secretary of Agriculture of West Pakistan. The institutes are as follows: Agricultural Research Institute at Tarnab, Peshawar; Ayub Agricultural Research Institute, Lyallput; and, the Agricultural Research Institute, Tandojam.

2. Agricultural universities under the Ministry of Education occur at Peshawar and Lyallpur. The West Pakistan Agricultural University is located at Lyallpur and the University of Peshawar at Peshawar. Each of these universities has a research function as well as teaching responsibilities. Unfortunately, the research programs of the institutes and the universities are not coordinated; in fact, they are in large part duplicatory. The University facilities at Peshawar are relatively new and a strong research program has not been developed. The former Punjab Agricultural College and Research Institute, Lyallpur, was reorganized in July 1962 into the Agricultural University of West Pakistan and the Ayub Agricultural Research Institute. In most departments, senior staff members remained with the Institute which, incidentally, is located in new facilities.

3. Savar Dairy Farm—Dairy Production Food Foundation is working on the production of rice.

4. Tarnab Farm, Department of Agriculture, West Pakistan—Cereals, mainly wheat. Edible Legumes. Chick peas.

5. Hyderabad—University of Sind-Rice, Cotton and Vegetables.

6. Dera Ismal Kahn, Research Complex hybrid corn, sorghum.

7. Parachinar—Fruit—apples, pears, quinces, guava.

8. Montgomery—Ministry of Agriculture Combination Research Station: Corn, sorghum, millet and rice.

9. Deparment of Agriculture—Government Rice Station—Tatta. Work minly on rice—20 scientists, 200 areas irrigated land, dry land also for development.

B. *Research Support.* Inadequate and uncertain support is the major reason for weak programs. The lack of funds for salaries frequently makes it necessary for research staff members to have additional employment. More adequate funds and a change in the interest of the government in the welfare of the farmer are essential before a beginning can be made.

C. *Research Personnel.* Personnel are poorly trained for the problems that need research. The number of scientists listed at a location is a poor measure of the quality of the research. More trained people are needed at all levels.

D. *Research Planning, Administration, and Coordination.* There is no provision for planning or effective organization for coordination of research conducted by the research institutes and that conducted by the universities.

E. *Research and Teaching Relationships.* The University of Peshawar, West Pakistan, with the assistance of Washington State University under an AID contract, is giving leadership in both research and education program development. Basic objectives are to have the University become involved in research and train more students from West Pakistan to take part in agricultural program development.

A World Bank loan through the International Development Association was provided to the University of Peshawar in the amount of $5.9 million for facilities in 1964.

Turkey

A. *Research Areas.* 1. The faculties of agriculture and veterinary science of the University of Ankara, the faculty of forestry of the University of Istanbul, and the faculty of agriculture of Ege University do limited research. There are ten specialized institutes of the faculty of agriculture at the University of Ankara while the faculty of veterinary sciences has nine research institutes. There are eight specialized institutes, which perform agricultural research as a part of their function, attached to the faculty of forestry in Istanbul. The University of Nebraska, under an AID contract, assisted in developing agricultural programs, which include teaching, research and extension, at the new Ataturk University in Eastern Turkey at Erzurum.

2. Specialized research institutions attached to the Ministry of Agriculture are scattered about the country. These include nine stations for seed improvement, fourteen horticulture stations and five experimental field stations. In addition there are six institutes for plant disease control and five governmental studies which are supervised and financed by the Ministry of Agriculture.[45] The limited research programs of these organizations frequently have little application in increasing food production.

B. *Research Support.* Federal research is under the direction of the Ministry of Agriculture, while university programs are supported by the national and provincial governments. Under the Ministry of Agriculture there are general directorates for agricultural research; for example, in veterinary medicine, plant protection and seed production. In addition, there are several private secretariats for many special activities. The problem of obtaining information on research expenditures is very complex.

In addition there are several Monopoly Institutes (tobacco, grapes, barley for brewing, hops, wines, beer, liquors, tea and salt) that support some research activities.

C. *Research Personnel.* Turkey has critical need for research scien-

[45] Turkey (Statement of organization for agricultural research), FAO 22996. 1966.

tists to plan and carry out programs leading to the solution of agricultural problems. Consideration should be given to adequate elementary and secondary training programs. College-level education should be oriented more directly to the problems of agriculture. There is need for more adequate financing of education and research programs by the central and state governments.

The universities should develop in their students an awareness of the importance of agricultural research and its relation to increased agricultural productivity. Technical assistants from this country should take a more active role in training local college graduates to take part in agricultural research, extension and development programs. Another urgent need is for increased competence in research program planning and. coordination. This need should be met by training capable personnel in Turkey.

D. *Research Planning, Administration, and Organization.* The organization of the Ministry of Agriculture and of the several directorates makes effective research planning and coordination impossible. Serious efforts are being made to reorganize the national administrative structure to improve research planning and coordination.

AID has been working with the Ministry of Agriculture in Turkey since 1960, with previous committees of the Ministry of Agriculture, and with personnel who have observed research organization, planning, and coordination efforts elsewhere. Progress, however, comes about very slowly because of the extremely fragmented agricultural research activities.

In 1962 a special advisor for research organization was appointed to the Ministry of Agriculture. Very little was accomplished because of the entrenched bureaucracy. In 1964 Turkish leaders visited the United States to study research planning, organization, and program coordination.

A proposed reorganization plan, including a recommendation that research be coordinated by a central unit, was preempted until 1965 by preparation of the First Five-Year Economic Development Plan.

The first step in improving research management and planning in the Ministry of Agriculture and in the other agencies doing research was to determine the status of current programs.

Data on present agricultural research activities have been obtained by the State Planning Office for the Second Five-Year Development Plan. This information is now being assembled by the Central Office which plans to publish it as the First Bulletin on Research Activities in Turkey.

In 1966 the directors of several of the experiment stations in Turkey visited the United States to study research organization and management. Discussions during this visit indicated that progress to date has been disappointing.

A publication entitled "More Effective Agricultural Research" is currently being prepared by research leaders of Turkey.[46]

E. *Research and Teaching Relationships.* As mentioned previously, the University of Ankara, the University of Ismir, the University of Istanbul, the Faculty of Agriculture of Ege, and the new Ataturk University at Erzurum all have associated institutes where some research is being conducted. An understanding of the relationship between good teaching and effective training for research has not permeated the educational system.

There is a need for greater rapport between teaching and research in agriculture and for a stronger focus on the problems of people of the land.

Summary

The lack of a sufficiently high governmental priority on agricultural research and education has resulted in intensification of the perennial problem of food shortages because of rapidly expanding populations and declines in soil fertility.

In the countries surveyed, illiteracy ranged from over 80 percent in India and Pakistan to about 60 percent in Turkey for the total population. In many rural areas, 90 percent or more of the people are illiterate.

State or provincial governments were given the responsibility for providing education at all levels. Under this structure, until very recently, the only planning for education in most countries was in urban areas. Very few schemes provided for any education on agricultural problems of food production.

Research in many agricultural institutes has not been oriented to the problems of the food producer. When information of value for increasing food production has been developed, it has not been effectively communicated to farmers. There continues the tradition of staying with farm practices handed down from generation to generation and this is difficult to alter.

India and Turkey have, during the past 20 years, directed much of the resources of their central governments to industrial development. Their experiences in industrial development frequently have not been successful. It appears that national leaders are beginning to realize that they must develop agricultural programs to improve production

[46] Administration and Coordination of Agricultural Research in Turkey by Charles A. Grey, Consultant. Report of Progress No. III dated Nov. 1960–Oct. 1963–July 1965. Ankara, Turkey.

efficiency and by means of mechanization reduce the number of people on the land.

The shortage of technical workers in agriculture is critical in all areas. The seven state agricultural colleges of India are beginning to have a great impact through the education of students in research, teaching and extension programs under the American land-grant colleges concept. Emphasis is placed on motivating students to return after completing their education to work with their own people on problems of agricultural production and human nutrition.

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