# *SUPPORTING PAPERS:* WORLD FOOD AND NUTRITION STUDY

## VOLUME III

*Study Team 6*

Food Availability to Consumers

*Study Team 7*

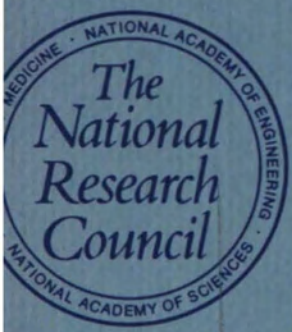
Rural Institutions, Policies, and Social Science Research

*Study Team 8*

Information Systems

*Study Team 10*

Interdependencies

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Commission on International Relations
National Research Council

NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D.C. 1977

The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Volume I

Study Team 1 Crop Productivity
Study Team 2 Animal Productivity
Study Team 3 Aquatic Food Sources

Volume II

Study Team 4 Resources for Agriculture
Study Team 5 Weather and Climate

Volume IV

Study Team 9 Nutrition
Study Team 12 New Approaches to the Alleviation of Hunger

Volume V

Study Team 14 Agricultural Research Organization

# PREFACE

Shortly after the World Food Conference held in Rome in 1974, the President of the United States wrote to the President of the National Academy of Sciences asking the Academy to make an assessment of the problem of hunger and malnutrition and "develop specific recommendations on how our research and development capabilities can best be applied to meeting this major challenge."

The study was begun in June 1975 by a Steering Committee appointed by the President of the Academy. It produced two reports for the President: an Interim Report, published by the Academy in November 1975, and a final report, World Food and Nutrition Study: The Potential Contributions of Research, published in June 1977. The Steering Committee was assisted by 14 study teams appointed by the Academy to analyze and make recommendations to the Committee on various portions of the study (Table 1).

This publication is one of five volumes containing the reports of Study Teams 1-10, 12, and 14. Study Team 11's report overlapped the other reports and has been integrated with them. Study Team 13's report of its ranking of research priorities was an integral part of the work of the Steering Committee. Consequently, it is not published here. Study Team 13's work is explained in detail in Appendix B of the Steering Committee's report.

The Steering Committee is deeply grateful to the chairmen and members of the study teams for their dedicated work, undertaken for the most part under heavy pressure of time. This work provided the greater part of the source materials for Chapters 2 and 3 of the Steering Committee's report, dealing respectively with "High Priority Research" and "How to Get the Work Done." The study teams are responsible for the content of their reports, which were reviewed by appropriate members of the Steering Committee.

Study Teams 1-12 were asked to identify areas of research and development that had outstanding prospects for helping to meet world food and nutrition problems

Table 1. Study teams, World Food and Nutrition Study

| Study Team | Title |
|---|---|
| 1 | Crop Productivity |
| | Subgroup A Pest Control |
| 2 | Animal Productivity |
| | Subgroup A Animal Health |
| 3 | Aquatic Food Sources |
| 4 | Resources for Agriculture |
| | Subgroup A Farming Systems |
| | B Land and Water |
| | C Fertilizers |
| | D Energy and Equipment |
| 5 | Weather and Climate |
| 6 | Food Availability to Consumers |
| | Subgroup A Food Losses |
| | B Food Processing and Preservation |
| | C Food Marketing and Distribution |
| 7 | Rural Institutions, Policies, and Social Science Research |
| | Subgroup A Policies and Program Planning |
| | B Research, Education and Training, and Extension |
| | C Finance, Input Supplies, and Farmers' Organizations |
| 8 | Information Systems |
| 9 | Nutrition |
| 10 | Interdependencies |
| | Subgroup A Population and Health |
| | B Energy, Resources, and Environment |
| | C International Trade Policy and Comity Between Nations |
| | D National Development Policies |
| 11 | New Approaches to Increasing Food Supplies |
| 12 | New Approaches to the Alleviation of Hunger |
| 13 | Research Priority Assessment |
| 14 | Agricultural Research Organization |
| | Subgroup A Research Organization in the United States |
| | B Global Agricultural Research Organization |
| | C Development of Research Personnel |

over the next several decades. For each such area, they were asked to respond to three questions:

-- What advances in knowledge will specific areas of research produce, and what is the scientific or technological significance of these advances?
-- If the research produces results, what effect would they likely have on reducing global hunger and malnutrition over the next several decades?
-- What supportive action will be required to conduct research for the accelerated activity recommended (e.g., more resources, policy changes, organizational changes)?

The study teams were asked to base their selection of research areas on their answers to the first two questions. Answers to the first and third questions provided insight on the feasibility of each research area. This information was used by Study Team 13 and the Steering Committee in the selection of research priorities. It also provided raw material for Study Team 14 and the Steering Committee when they considered steps to mobilize and organize resources to implement the proposed research.

Each study team's selection of high priority research areas involved two steps. In the first step, the study teams reviewed research recommendations and possibilities for research provided by existing reports, by the study team members themselves, and by hundreds of other people who were consulted, including many from other countries. From the hundreds of research possibilities, each team selected a limited set that would likely have the greatest global effect on hunger and nutrition. The second step narrowed this set to research areas whose potential was thought to stand out well beyond that of the rest of the group.

The Steering Committee hopes that these study team reports will provide rich source materials for those interested in pursuing the various subject areas in greater depth than could be done in the report of the Steering Committee.

Harrison Brown
CHAIRMAN
Steering Committee
World Food and Nutrition Study

Report of Study Team 6

# IMPROVING FOOD AVAILABILITY TO CONSUMERS

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# INTRODUCTION

## THE IMPORTANCE OF RESEARCH ON FOOD MARKETING AND RELATED TECHNOLOGY

The potential benefits of research on making food[1] available to consumers is not as widely recognized as the potential benefits of research on food production, nutrition, and policy. However, this report argues strongly that research on making food available must have priority along with production, nutrition, and policy research if the United States is to have an effective, balanced leadership role in world food and nutrition research.

Many activities are performed between the production and consumption of food. These activities (referred to in this report as food marketing) include research conducted by food scientists, engineers, and economists. Such research concentrates on making the food available at the right time, in the right place, and in the right form for consumers. This research also can make more food available by synthetic processing, by upgrading low quality foodstuffs, by making food from materials not now used, and by preventing food wastes.

Research on food marketing is important worldwide because many marketing issues affect a country's policy and trade decisions. And marketing has a substantial influence on nutrition by deciding which products will be produced, where, and for whom.

Food production, nutrition, and marketing are related in many ways. For example, the relationship among crop breeding, quality of food, and nutrition is reflected in a guideline proposed by the U.S. Food and Drug Administration. This guideline states that new food crop varieties should have no less than 80 percent of the nutritive value of the conventional variety, and that natural toxicants in the new variety should not be increased by more than 10 percent over the conventional variety (USDA and National Association of State Universities and Land Grant Colleges 1976). In another example, a farm product can be bred to withstand field

harvesting, transporting, and processing, any one of which may have an effect upon food availability or nutritional value.

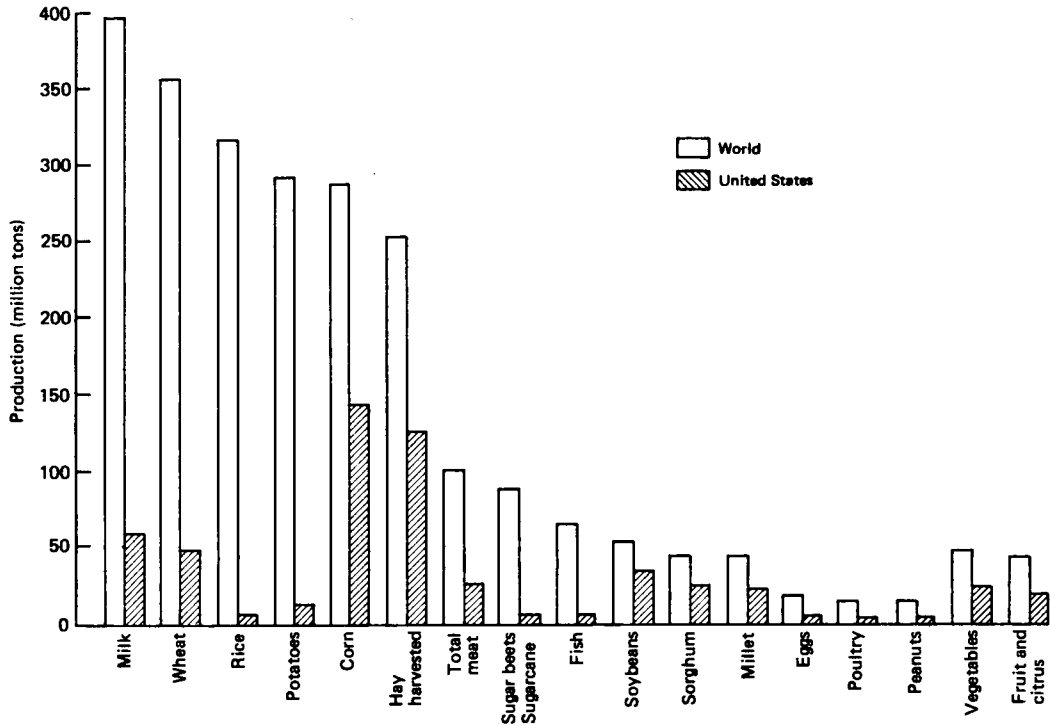
Research on food marketing and related technology is especially important now because much of this research will prevent waste, upgrade products, provide new resources, or use resources more efficiently. The emphasis on general scarcity in recent years, symbolized by the shortage of fossil fuels, places priority on such research.

World production available for processing into food and feed is diverse and substantial (Figure 1). Much of the food and many secondary raw materials now lost to the food chain are potentially available for feed and food. For example, potential food is often lost because of mold or because of other microbial or physiological change. This material could be used for food if an appropriate chemical or other treatment were used. Many animal feeds could be used for human consumption. However, the economics of the prevention of losses or the use of wastes is important. In an informed society many losses would be prevented or wastes utilized if it were economically feasible to do so. Likewise, foods must be acceptable to the potential consumer based on his or her religious beliefs, social practices, and cultural backgrounds.

Although the prevention of losses and the use of wastes are important, the safety of a food product, whether from natural or artificial treatment, is also extremely important. Foods must not be a health hazard to the consumer; however, it is not possible to make a food completely safe. Therefore, any risk incurred naturally or artificially must be related to the benefit derived. A small risk-to-benefit ratio is usually demanded, but it is important to recognize that circumstances may require flexibility in this relationship. Where the benefit is large, it may be desirable to increase the acceptable risk. If the benefit is survival as opposed to death by starvation or malnutrition, there is little to lose by accepting a greater safety risk.

In consideration of world food problems, recognition must be given to the fact that standards of safety for foods can be adjusted within limits to a particular situation. Judgment regarding the risk applicable to a given situation is required and government decision making must consider this risk-benefit ratio when developing and enforcing food safety regulations, codes, and standards. Failure to do so may mean inability to meet a food need.

Many marketing activities are highly responsive to national and international price policies. The marketing system serves as the instrument for the




SOURCE: U.S. Department of Agriculture data.

FIGURE 1 Food and feed production for the United States and the world, 1975.

execution of pricing policies, from production to consumption. Likewise, the food marketing system is related to national and international trade. And trade is essential to meeting food distribution requirements.

The ultimate measure of the effectiveness of food marketing research is its effect on improved health. Many reports, including the World Food and Nutrition Study: The Potential Contributions of Research (NRC 1977) document this important fact (see also Popking 1971, U.S. Department of Agriculture 1968).

## THE U.S. FOOD MARKETING SYSTEM

The U.S. food marketing system is complicated and advanced. Marketing services absorb about two-thirds of the average consumer dollar spent on food. This system requires continuous research on advanced technology, basic food science, and the policy, regulatory, and economic problems of marketing. Much information from U.S. research, when properly adapted, can be used by the developing countries, but the task of giving leadership is much more than simply transferring technology.

The U.S. marketing system has emphasized private sector development, with a blend of private and public effort. The system has placed substantial emphasis on the commercial profit motive because of the affluence of the U.S. society. This balance between private and public research is a difficult research planning task. This becomes more complicated and impinges sharply on research recommendations necessary for U.S. assistance in developing countries, particularly where the U.S. private sector is suspected by the planners of a given country.

## THE WORLD FOOD MARKETING SYSTEM

Systems of food marketing vary widely worldwide. A general description is not possible or useful, yet some characteristics can be noted.

The quantity and quality of food available to consumers depend in large part on the efficiency of a chain of services linking production with consumption. The chain can be short, involving only the farmer and household members; intermediate, as in the farm-market system in which farmers bring their produce to local marketplaces; and long, as in the complex marketing systems of the high-income countries.

Most farmers in the developing countries produce some part of their output for sale, and do not produce all the food they consume. Thus the efficiency of food

marketing plays a major role in even the least developed countries and rural areas.

Another characteristic of marketing in some developing countries is the predominant role of women in the processing and trading of food. Often the role of women extends from selling in the local market to operating large-scale, sophisticated marketing services, e.g., the wide-ranging marketing trucks of West Africa. In many areas, female entrepreneurs may need only modest encouragement and opportunity to expand and improve distribution and processing.

The state of a country's development will dictate to some degree the type of marketing research program that should be adopted. Kriesberg and Steele (1972) have identified countries at three different levels of development in order to help orient those who plan marketing research and development work. They rightly point out that the categories probably run together and that countries within each classification vary widely. Their three levels (with some adaptation) are:

1. Countries with traditional subsistence agriculture--population largely rural: Often 65 percent or more of the people make their livelihood from farming activities. Productivity and incomes are low. A two-track system of agriculture exists--the commercial export crops and the subsistence food crops. There is an absence of new technology and government policies supporting agriculture development in the food crops. Change is taking place slowly in agricultural production processes, little is marketed, and most of the food crops sold move short distances. A few basic grains, root crops, or pulses make up the bulk of the peoples' diets. Marketing systems and facilities expand more or less automatically to meet limited expansion of marketable food supplies. A single city within countries at this stage of development may have elements of a more advanced marketing system.
2. Countries with transitional, production-oriented agriculture: Often urban populations are as large as rural. Production of food crops is a priority sector in development plans. Commercial agriculture in food crops is growing; public and private capital is going into farming and agribusinesses to support it. Temporary surpluses may appear for some food crops; marketing and distribution constraints emerge. With advances of income and shifts in population, more food crops are moving greater distances to market, with stress on facilities

and exchange arrangements. Underlying demographic differences and economic ideology will influence the way marketing systems develop.

3. Countries with market-oriented agriculture--urban population dominant: Urban populations may be 60 percent and more; commercial agriculture becomes the dominant form in food crops as well as in traditional export commodities. Problems of resource allocations to and within the agricultural sector emerge; producers and governments face new problems of balancing supply and demand. Problems of food supply begin to shift from issues of production to distribution, from commodities to nutrition. Improvements in incomes and technology continue and become more general throughout the economy. More food is processed and packaged; a food industry emerges keyed to consumer preferences for new food products. A national marketing system may be possible. Underlying demographic differences and economic policies continue to influence the way marketing systems develop.

Research on food marketing must be planned with an awareness of the fact that nutrition, hunger, and health are as fully related to a given society, and of the quality of life therein, as they are to the type and availability of foods consumed. Such research must fit within a country's societal and economic framework. Work on prevention of waste, food preservation, improved delivery and storage, and utilization of foods not presently considered viable must be oriented to a country's existing food system. The background for such an orientation is well developed in the reports of Study Team 9, "Nutrition," and Study Team 12, "New Approaches to the Alleviation of Hunger."

The U.S. marketing system has many somewhat unique characteristics which make it difficult to transfer U.S. food technology directly to other countries. U.S. culture is quite affluence oriented. As a result, the U.S. marketing system has such characteristics as: the creation of demand through advertising, rigid protection against health problems, built-in regulations to improve food (e.g., iodine in salt), and adaptation to and promotion of changes and fads in consumer habits.

Fortunately, these problems of adaptation are offset in many ways by the depth of U.S. scientific knowledge in food marketing, particularly in basic food and nutrition science. This knowledge allows a certain division of labor, that is, U.S. food marketing scientists can concentrate more on basic research for

which they have an advantage, while researchers in poorer countries can concentrate much more on adaptive research. This report will emphasize particularly how the United States can provide the poorer countries leadership in adaptive research specifically useful to them.

## Special Research Problems of the Developing Countries

There are problems with doing research on the food marketing systems of the developing countries. However, these problems also illustrate the opportunities for marketing research. Some of these problems are:

-- The complexity of a marketing system as it develops from a given culture. Research can be designed to deal with this complexity. Because of differences among countries in technological developments, social practices, religious customs, and economic systems, food marketing technology must have a basic infrastructure if it is to succeed in each country. This infrastructure includes: (1) basic scientific capabilities; (2) engineering capabilities; (3) water, energy, and transportation resources; (4) human resources including management, labor forces, training and educational facilities, and means of communication; and (5) government regulations providing standards for food quality and nutrition and marketing services. The infrastructure must evolve as technology evolves.

-- The cost of food marketing. An often substantial public investment is required for the infrastructure. And advances in new foods, services associated with food, and improved nutritional quality also can add substantially to the cost of food. Developing countries simply cannot afford such costs now and will not be able to for some time. Thus food marketing research for the poorer countries must emphasize efficiency through low-cost, simple technology that is feasible for the society in question.

-- The controversy that often surrounds food marketing (Forman 1975). For example, the conflict between consumer price policies and farm price policies has long been recognized as an important problem in economic development. Food marketing is often caught up in politically sensitive areas such as equity of pricing among different income groups, food export programs, nutrition intervention programs, health regulations, and safety

regulations. The availability of food almost always tends to cause controversy about who gets how much of what food at what price. The related problem of applying U.S. technology involves the fact that U.S. marketing technology is largely in the hands of private enterprise whose entry developing countries are often reluctant to accept. The policies and inclinations of the developing countries in this area must be considered, together with the regulatory policies that most governments have affecting the incentives of farmers, the structure of markets, and the role of private enterprise in improving marketing technology.

-- The fact that many developing countries have never had a marketing system as discussed in this report; thus just to get started is a complicated task. What is needed first--production, infrastructure, technology, policy decisions, or a combination of all? Often marketing is not viewed as a place for improvement. Parker (1976) defined the problem saying, "Often in developing countries, systems deficiencies are not even noticed let alone perceived as opportunities for remunerative efforts." The task of upgrading of knowledge is a formidable one. Business personnel as well as government employees have little specialized training to prepare them for innovative actions or appropriate application of known technology. Research must help to identify human resource needs, to demonstrate the importance of appropriately designed human resource development, and to provide for training opportunities.

-- The fact that many countries do not have the production program to sustain a marketing system. Marketing often depends upon specialization and many countries limited to a survival orientation have not been able to move toward specialization.

-- The high cost of transportation in the developing countries and the fact that transportation policy involves many other factors. Often food is not produced where it is needed. To transport food to where it is needed can often mean using expensive processing or preserving techniques. Often, too, time becomes an issue and storage can be expensive.

-- Poor communication between producers and consumers in the developing countries. For example, more and different kinds of food would be produced if farmers were better informed about consumer demand, and more and different kinds of food would be purchased by consumers if they were available.

The complexity of the food marketing system makes it difficult to make explicit recommendations for

priority research such as those made by other study teams concerned with food production, for example. The research recommended by those study teams is more straightforward in nature and could be applied in many parts of the world. But such may not be true of food marketing research. Thus some of the recommendations made in this report are primarily illustrative. The total report proposes and illustrates an adaptive research framework which can be adjusted to fit many current and changing circumstances worldwide.

## SELECTION OF RESEARCH PRIORITIES

Much information now available in the high-income countries can be helpful to the poorer countries. We recommend that the United States continuously assess this information and that our programs of technical assistance emphasize food availability where feasible.

Research on food marketing must be expanded if we are to give leadership to world food and nutrition programs. This includes basic and applied research important to our own agribusiness industry and collaborative research especially designed to assist the poorer countries. The research priorities selected were chosen with this in mind. They were chosen from an array of problems thought to be of importance, but, some were considered to be significantly more important than others (American Society of Agricultural Engineers 1976, Krochta et al. 1975).

The research given priority will be discussed in three profiles: "Reducing Losses in Quality and Quantity of Food,"[2] "Improving Food Processing and Preservation," and "Improving Food Marketing and Distribution." These research areas will include products grown on land and in the water, more effective use of synthetic food processes, better recovery and distribution of food to consumers, and more feed for animals and fish. This research will assist in providing better nutrition by improving: (1) grades and standards for greater availability of more nutritious products; (2) nutrient supplementation of processed foods; (3) coordination of handling, processing, and transportation for more timely and better quality foods; (4) packaging and handling techniques with fewer losses in nutritive value and products; and (5) retail outlets (also see Study Team 9's report). This research will contribute important findings to those who deal with fresh products, canned foods, packaged products, and dry foods.

The research suggested will provide both predictable and unpredictable results. This mixture of research is needed so that immediate problems are

solved and the storehouse of knowledge is expanded to serve long-range needs.

This research can be accomplished only with substantially increased resources, and probably a major expansion in facilities. These needs are approximated in the individual profiles and the aggregate needs are discussed under "Some General Program Needs," at the end of this report.

## Profile 1

## REDUCING LOSSES IN QUALITY AND QUANTITY OF FOOD

### INTRODUCTION

Significant quantities of additional food could be made available by the recovery of food now lost. Subgroup A of Study Team 1 discusses research needs to reduce preharvest losses, while this report recommends research to reduce food losses between harvest and consumption.

Neither the magnitudes of these postharvest losses nor their locations are well defined. Food and feed losses occur in processing, storing, packaging, and transporting. The sources of such losses are many, including rodents and chemical deterioration. Decomposition can set in as soon as food is harvested. It is estimated that in some parts of the world as much as 50 percent of the food supply from plants and animals is lost between harvest and consumption. In humid tropical climates, the problem is acute since food deteriorates rapidly and methods of preservation such as refigeration are inefficient, costly, and scarce. Losses occur at many locations and from many causes. The procedures for preventing losses are not well known, and means of reducing losses of one product, or in one location, may not be effective for other products in other locations. In the final analysis, the costs of reducing losses will be the major factor determining whether it is feasible to reduce losses.

Research on food losses must have priority. We know some about the physical magnitude of losses, the pervasiveness of losses throughout the world, the potential of some lines of research to avoid losses, and our desire to prevent the waste of our increasingly scarce food supply. These facts establish the high priority of this research.

Research on food losses would need to be conducted on a large-scale basis and would need to be well

coordinated with related research. This research has the potential for substantial U.S. and worldwide collaboration, with important results expected for all countries.

Five main research needs for reducing losses are identified and developed in this profile (Table 1). Although the scope of this work is expected to be broad, the first important need identified is research to quantify more accurately what losses actually occur and to establish where they occur. Other priority needs relating to losses are preventing and eliminating pests; improving storage, packaging, and transportation methods; establishing physiological and biological interactions in foods; and analyzing metabolic processes of microorganisms causing losses.

## RESEARCH NEEDS

### Quantifying and Locating Losses

The most important immediate research task is to establish more accurately the kind and extent of losses by commodities, by countries, and by different locations in the marketing chain.

This research would provide a good global picture of losses for the first time. Several piecemeal studies have been done but the methods used, the time periods covered, the products covered, and many other factors varied. The most quoted figures have been those from surveys by the Food and Agriculture Organization (FAO) of the United Nations. These data are now outdated and have long been recognized as an inadequate base upon which to organize a global approach to this problem.

This research must include specific, high-loss, researchable food products in key parts of the world. Global coverage will be sought, but this research must be selective--it cannot be just an attempt at a detailed description of all products in all countries, which would be unmanageable in both time and cost. Detailed planning of the approach is important.

A standard procedure should be developed for identifying, quantifying, and reporting the losses for all foods in all countries. Initially, each country's most dominant food products will be selected for study so that the most advantageous and fastest impact on nutrition will be realized. Both the magnitude and cause of losses must be ascertained. Many of the present food loss figures are merely estimates and could be quite misleading; however, those estimates considered to be more accurate and greatest in

magnitude should be used to identify the food products to be investigated initially.

After losses are identified it will become clearer where research is needed and how the greatest return will be realized from future funding. Research can determine whether these losses are attributable to poor management, inappropriate pricing and policy, or lack of needed technology. Lines of research and development that promise the most improvement at the least cost then could be chosen, both for the high-income and the developing countries.

A study, currently being undertaken by the National Academy of Sciences, "Postharvest Food Conservation," will provide some of the needed information for this research. Also, the U.S. Agency for International Development (AID) and other development assistance agencies have already undertaken some exploratory work on postharvest losses.

## Preventing and Eliminating Pests

Pests such as insects, rodents (Canby 1977), and birds cause significant postharvest losses in food commodities such as grains, fruits, nuts, and animal products. Increased research is needed to reduce these losses and the deterioration in quality of foods caused by pests during handling, shipment, storage, and merchandizing.

Improved pest-resistant packages and storage containers must be developed. Materials for containers must be carefully considered depending upon geographic location in both the high-income and developing countries. New developments in hermetic storage containers for agricultural commodities may reduce the need for insecticides, fumigants, or other chemicals for pest control in selected products. Such packaging and storage should be low cost.

Pest control techniques developed in this country may be adaptable to other countries, but much more in-country, adaptative research will be needed before U.S. leadership can be effective. Adaption of methods by the private sector must be developed with the encouragement of public programs. Policies for implementation by the poorer countries will be a significant factor. This research should be coordinated with that proposed by Subgroup A, Study Team 1 for an international pest control center.

The potential of sterilization for suppressing rat populations needs to be studied. Success in this area would have wide-ranging consequences in the public health field as well as in the reduction of food losses. Other pest control techniques, such as

Table 1. Reducing losses in quantity and quality of food—summary data

| Research needs | Study team priority: For next 15 years | Study team priority: After 15 years | Cost/year* ($ million) | Expected duration (years) |
|---|---|---|---|---|
| 1. Quantifying and locating losses | High, worldwide | Lower, worldwide | 4 | 8 |
| 2. Preventing and eliminating pests | High, worldwide | High, worldwide | 10 | 10 |
| 3. Improving storage, packaging, and transport | High, in some countries | Medium, in some countries | 2 | 20 |
| 4. Establishing physiological and biological interactions | Medium, particularly in the United States | High, in some countries | 6 | 20 |
| 5. Analyzing metabolic processes of microorganisms | Medium, in some countries | Medium, in some countries | 0.25 | 20 |

*Approximately one scientist-year for each $50,000.

| Probability of success | Impact: High-income countries | Impact: Developing countries |
|---|---|---|
| High | Better research orientation and less expensive food | More and less expensive food |
| High | Less expensive and higher quality food | More and less expensive food and improved trade potential |
| High | Higher quality and possibly less expensive food | Better availability of food and improved trade potential |
| High | Improved base for applied research and greater training potential | Better training of technical people for future needs |
| Medium | Better understanding of spoilage process and greater opportunity to assist developing countries | Much better availability of more and less expensive food and wider variety of food |

radiation treatments, use of juvenile hormones, development of natural pest predators, and studies to identify natural chemical components that suppress pest populations, merit study.

## Improving Storage, Packaging, and Transportation

Both food quantity and quality are lost because of improper methods of storage, packaging, or transporting. Research must be directed toward developing and applying technology that will permit the design of acceptable methods, especially for the developing countries. The unique demands placed on their food systems, such as marketing requirements, product life, product properties, and distribution requirements need to be identified.

Many foods are highly perishable and seasonal in nature, which means harvesting and processing them in a short time period. Glut and scarcity, quality problems, and a shortage of raw materials can place a tremendous burden on the processing plants at the time of harvest, and in many instances the time from production to processing is so long that losses in quality prevent the use of the product for food. In other cases, if improved storage, preservation, and processing techniques were developed, crops could be harvested more quickly so that a second or third crop could be planted. The additional crops could increase the supplies of the raw product and add to the processing efficiency.

Root crops, particularly cassava, are sometimes stored in the ground in the field because an effective storage has not been designed to preserve them. The design of such storage would allow removal of such crops and would free the land for an additional food crop.

This research must look carefully at existing methods of storage, preservation, and transportation and why they have evolved. Adaptation of some of the technology used previously in the United States may be the logical evolutionary step in developing methods suitable for other countries. Some of the problems may be solved by simply transferring information and improving local technology. Costly research appropriate to the high-income countries may not be needed. Research to establish when and where such situations exist can be extremely valuable.

Each important commodity must be studied so that its special requirements can be matched with the proper packaging and storage. Losses that should be studied in this connection include chemical and biochemical

deterioration during handling, storage, and marketing, as well as conventional physical losses through spillage, pilferage, and pests.

Some of this research that should be undertaken is the development of bulk storage and transportation technology for perishable foods and possibly the development of alternatives for the tin can if resources dictate the need. The high cost of some food packaging materials such as tinplate is prohibitive for poorer countries even where it is available.

It may be possible to apply technology that no longer fits U.S. conditions to many situations in the poorer countries. One example is the utilization of a reusable bulk transport unit which is moved to the point of consumption where it serves as a short-time supply for consumers who provide their own individual containers. The shorter product life of the food is now less of a problem since the food will be consumed in a short time.

## Establishing Physiological and Biological Interactions

Research on food losses will in many respects be adaptive, and it must be country-specific. However, basic research should be continued. U.S. food science researchers have expertise in the basic sciences. The multidisciplinary science encouraged by the World Food and Nutrition Study will establish fundamental biological and physiological results necessary for long-run improvement of the U.S. food science industry. Increasingly, the scientists of developing countries will need this type of understanding.

Research on the physiological and biological interactions in foods has many important purposes: (1) to attain a stable state for foods before losses can occur; (2) to aid in regulating the biological factors of food during preharvest and postharvest so that losses during storage, packaging, processing, and transporting are reduced; (3) to learn more about preharvest and postharvest changes affecting losses during storage, packaging, and transporting; and (4) to learn more about ante-mortem and post-mortem physiology and mechanisms causing chemical and physiological changes in the components of marine animals used for food.

Procedures need to be identified that will help foods attain a stable state before losses can occur. Areas to be studied include: controlled environment for packaging and storage; hermetic packaging and storage; packaging materials; chemical additives; isolation of cryoprotective proteins; and

identification and measurement of selected properties such as solubility, freezing point, isoelectric point, amino acid composition, and organoleptic quality. Also, such research may be able to identify natural food substances in stable products that can be used to stabilize other foods.

Physiological and biological changes in foodstuffs should be monitored under normal and induced conditions to gain a better understanding of how losses in quality can be reduced. Specific factors to be studied include those affecting uniformity in ripening to facilitate once-over mechanical harvesting, prolonged product life in the ripened state, the browning phenomenon, and the texture of foodstuffs.

### Analyzing Metabolic Processes of Microorganisms

More basic research is needed on the relationships affecting the metabolic processes of microorganisms. This research will provide the background for more applied work on microorganisms in control procedures for food losses in this country. Such research also paves the way for developing preservation and storage methods for the tropics.

Microorganisms can cause food losses at many points in the distribution system. In some instances, the microorganisms compete directly for the same nutrients needed by humans. In other cases, microorganisms render the food unfit for human consumption and may, in addition, produce toxic substances. In order to destroy microorganisms, with reduced processing, we must learn more about their metabolic processes.

Increasingly, aflotoxins are being recognized as a contaminant in food products. To prevent such losses, it is not unusual to treat a food product so severely, such as by heating, as to cause a loss of food quality. A better understanding of the microbial living process could greatly assist in reducing processing requirements.

## IMPACT

The impact of much of the research on food marketing is difficult to document. A great deal is directed toward preventing costs (facilitating a myriad of economic activities), providing a higher level of services, and improving diets. The direct effects of changes are measurable only when an obviously bad situation has existed. Marketing improvements result in savings that are often effective for long periods of time and accumulate from many sources. Because

marketing savings often occur jointly with production or policy savings, it is especially troublesome to evaluate the impact of improved food marketing.

## Quantifying and Locating Food Losses

Quantifying and locating food losses would be valuable in planning, evaluating, and estimating potential savings from research on food losses.

The results of this research will have an immediate impact on the food potentially available to the consumer. The long-term impact will result from identifying where the greatest return can be realized if research funding and other resources are directed toward solving difficult but high-return problems.

Some indication of the potential savings from a concerted research effort on food losses is possible. For example, 10 to 30 percent of all vegetables produced in the United States are lost between production and consumption. If 50 percent of these losses could be saved, at least 1.1 million tons of vegetables in the United States alone could be saved annually.

Coursey and Haynes (1970) estimate that tropical roots provide staple food for some 400 million people or about one-tenth of the world population. Manioc is the most important root crop, followed by yams, sweet potatoes, plantain, taros, dasheen, and breadfruit. In 1969, FAO estimated that horticultural crops in the tropical countries of the world amounted to 207 million tons, with manioc at 82 million tons. Losses in these crops in the tropics were estimated at 25 to 50 percent of production. Any reasonable savings here would add important food in areas where it is badly needed.

Losses of cereal grain (probably documented more accurately than other categories of feed and food) are conservatively estimated at about 10 percent of production. The world production of grains is 1,119 million tons, of which 265 million tons are produced in the United States. Grains make up approximately one-half of the world food supply. A reduction of 20 percent (that is, reducing losses from 10 to 8 percent) would amount to 22 million tons annually, enough to meet the food grain demands for 60 million people.

World food wastes (secondary raw materials) can help alleviate world hunger if research can help us use them for food. Present customs, habits, and practices result in the use of only a portion of the total food materials as food. The unused portion, often identified as wastes, constitutes a large potential source of food, if appropriate preservation and processing methods can be used with necessary economic

considerations. As an example, 500,000 people could be provided enough protein for an adequate diet if the fish now caught incidentally with shrimp, but discarded, could be utilized (see Study Team 3's report). Meat discarded with bones and hides is approximately 5 percent of the total meat production. Research on the mechanical deboning of meat holds promise, especially in the high-income countries.

Also, results of research on improved methods could lead to savings of nonrenewable resources and energy and improved health and productivity of consumers.

## Preventing and Eliminating Pests

Research on reducing losses due to pests should have the greatest initial benefit in the poorer countries where pests cause severe losses. We estimate that research on this problem could mean a savings of about $1.5 billion annually in the United States and up to $20 to $50 billion annually worldwide.

The food that could be saved as a result of this research is estimated to be enough to feed at least 15, and possibly as many as 50, million people. By saving more of the product grown, the return per unit of seed, fertilizer, land, and energy also is increased.

The basic studies, such as sterilization for suppressing the rat population, juvenile hormones, etc., will require at least 15 years before they can be expected to affect the food supply. While the more basic work is in progress, the technology that now exists can be applied to the development of pest-resistant packages and storage containers.

## Improving Storage, Packaging, and Transportation

Research on storage, packaging, and transportation would have an impact on many products. This research should upgrade the quality of products and make them available in areas of the poorer countries where current methods simply cannot make usable, quality food available. This research could mean substantial savings in the United States, but it is especially important in the developing countries if food is to be made more available to the world's poor.

Since packaging materials represent an important cost in food marketing, a great potential savings could be realized by such research.

By reducing the loss of fruits and vegetables, an increase of 15 to 30 percent of such products could be immediately realized. Bulk storage developed for

processed tomatoes alone has been estimated to save 20 percent (10 tons/hectare). Preliminary basic research is already underway in this area. Development of the technology and making it available to those in need of it will assure this project of a very high probability of success.

Significant parts of the proposed research on new methods will be completed in 10 to 15 years. New systems will continue to be needed as new products are developed, new demands are made by the consumer, and availabilities of resources change significantly. A 20-year effort is anticipated.

### Establishing Physiological and Biological Interactions and Analyzing Metabolic Processes of Microorganisms

The last two areas of research proposed--establishing physiological and biological interactions and analyzing metabolic processes of microorganisms--are quite basic in nature. To quantify their impact is probably impossible.

The research proposed on physiological and biological interactions is broad and extensive. Therefore, there is a high probability of succeeding in reducing food losses in several areas. Because of the large number of foods, the program should be planned for a 20-year commitment. The complete goal of this work can only be achieved over a long time. In several areas, partial goals will be achieved in a short time, such as attaining uniform ripening for several important products.

The principal significance of research on microorganisms relates to improvement in product quality. Reduction in processing costs is difficult to estimate. The project will extend beyond 15 years, and must be continuously evaluated for success. It is assumed that learning more about the metabolic processes of microorganisms will enable us to attain this objective. This assumption cannot be tested beforehand. The risk that such knowledge may not reduce costs, plus the nature of the information sought, makes the probability of success uncertain. However, the potential impact warrants a serious effort in this line of research.

## IMPLEMENTATION

The research proposed on food marketing, and especially on food losses, will be the most effective if there is greater collaboration among countries.

Some progress can be cited. International collaboration on research in food preservation is becoming important. Research in the high-income nations is being pooled by a recently formed group of international donors who will explore postharvest technologies including those for reducing losses in the developing countries. The new United Nations University is planning research, in cooperation with other universities and institutions, on better conservation and use of food already produced.

The research on food losses proposed in this profile will require a comprehensive, coordinated effort by domestic and international agencies and governments to assure adequate funds to obtain the information needed. Since many of the results will directly benefit commercial organizations, in addition to alleviating the world food shortage, funding should come from both the private and public sectors. The research effort should be initiated immediately so that further funding can be directed efficiently.

## Quantifying and Locating Food Losses

Research on food losses requires a continuing study. The initial effort to identify losses will take approximately 4 to 6 years. A continual monitoring of food losses will help identify new problem areas that develop so that the effects of these losses are alleviated immediately.

Funding should be sufficient to accomplish the initial task of identifying the losses and is estimated at $4 million per year. A continuing commitment to keeping information current must then be made at an estimated annual rate of 20 percent of the funding of the initial concentrated study.

## Preventing and Eliminating Pests

The research proposed on the effects of pests on food losses will benefit from the research on stored product pests now being undertaken in the high-income countries. Approximately $10 million annually will be needed to support public and private sector research in these areas. Initial planning should be for a 10-year study. Such research would be conducted in U.S. facilities, such as the U.S. Department of Agriculture (USDA) Regional Utilization Laboratories, and by contract with overseas facilities that have significant research capabilities in stored product pest control, e.g., the Tropical Stored Products Centre in England.

### Improving Storage, Packaging, and Transportation

This research is estimated to require funding at a level of $2 million annually. Additional staffing is needed together with more research equipment and support personnel. No unique new facilities are needed, but in some situations it might be necessary to provide additional but conventional research space. Basically this research builds on and strengthens much ongoing U.S. research. Adaptation facilities and staffs will have to be built up in the developing countries over time.

### Establishing Physiological and Biological Interactions

The physiological and biological research will require approximately $6 million per year initially. Further funding will depend upon the direction indicated for this research from the initial results of the study. Present state, federal, and private research facilities for this type of work are adequate now, but the entire study will require expanded facilities, particularly in some developing countries, as the work progresses.

### Analyzing Metabolic Processes of Microorganisms

The microbiology research proposed may require a new food science and technology laboratory, including special capability in food microbiology, and possibly a food engineering laboratory. These are estimated to require funding of $250,000 per year for 20 years.

## Profile 2

## IMPROVING FOOD PROCESSING AND PRESERVATION

Food processing and preservation vary widely among countries and among products. The methods that have evolved over the centuries are influenced by culture, wealth, climate, food tastes, health standards, and a host of other factors.

Food production alone cannot solve world food problems. Present supplies of food need to be better used; new food services must be developed; and food trade must be expanded--all of which require improved food processing and preservation.

Often the changes may seem nominal compared to methods currently used in a poorer country. But the nominal change may be highly important. For example, extending the life of perishable products by three or four days, without the use of refrigeration, would improve the family diet and greatly expand the market radius for farmers in the developing countries and would make food available to many.

The research proposed in this profile is designed not only to meet the needs of the poorer countries but also to strengthen the U.S. and other high-income country food processing industries (Table 2). Historically, food research and development have been centered around the research laboratories of the land-grant colleges, selected public agencies such as the USDA regional utilization laboratories or the U.S. Defense Department Natick Laboratory, a few specialized private research companies, and the laboratories of rather specialized private companies.

Many of the old-line food companies are now divisions of large conglomerates. Conglomerate divisions have steadily become more competitive for research funds and, as a result, support for research in the food divisions has not fared well. Some evidence suggests a declining emphasis on private food research generally. Public research, which is more basic in orientation, also has suffered. Therefore, the whole U.S. research thrust, particularly in

processing and preserving, (and even more specifically in basic research) needs emphasis if the United States is to give leadership for world food processing and preservation.

Research on processing and preservation needed in the developing countries will be highlighted by the special preservation problems of the tropics, an upgrading of current local processes which have often developed, products that can meet the needs of emergency food programs or nutrition intervention programs, and products needed to satisfy increased consumer well-being and nutritional concerns.

The need for processing and preserving foods increases as nations become more developed. Urbanization and development brings about specialization which then requires the processing, preservation, and marketing of food--all of which are related. The research in this profile is to improve processing and preservation operations generally. Because of their importance, certain processes are identified for specific action, including water removal, fabricated food development, and the use of microorganisms in food preservation. Work on these processes should upgrade many other operations.

The food supply can be enlarged by processing food materials now available but currently not utilized for food. These materials come from plants, animals, and aquatic sources. The proposed research also could increase the efficiency with which the resources (energy, water, and materials) required for processing and preservation are used, and could develop alternatives where needed. And research is proposed to better measure the physical and chemical properties of food. Such research will yield results needed for improved processing.

Because women are most often responsible for the preservation of food, researchers should consult with them on the methods they use. Women also should collaborate in the development of any improvements that can be made.

Plant species that are genetically resistant to particular types of deterioration should be investigated by means of collaborative research between food and production scientists. Postharvest or postproduction technologies vary greatly. For the product that must be maintained at near-fresh condition, food and nutrition needs could be more nearly met by slightly extending the time period during which the product is fresh enough to be used. In contrast, considerable change may be involved in putting the product in a form for further processing, for extended storage, or for consumption.

Table 2. Improving food processing and preservation—summary data

| Research needs | Study team priority: For next 15 years | Study team priority: After 15 years | Cost/year* ($ million) | Expected duration (years) |
|---|---|---|---|---|
| 1. Utilizing and/or upgrading food materials | High, worldwide | High, worldwide | 5 | 20 |
| 2. Developing new methods of processing and preservation | High, in some countries | Medium, worldwide | 4 | 20 |
| 3. Reducing use of nonrenewable resources | Medium, in some countries | Medium, in some countries | 3 | 20 |
| 4. Improving efficiency of water removal | Medium, in some countries | Lower, in some countries | 2 | 20 |
| 5. Developing formulated foods | Medium, in some countries | Medium, in some countries | 2 | 20 |
| 6. Increasing use of microorganisms in preservation | High, in some countries | High, in some countries | 0.5 | 15 |
| 7. Analyzing properties of food | Medium, particularly in United States | High, worldwide | 1.25 | 20 |
| 8. Developing foods for emergencies and disasters | Medium, in some countries | Lower, in some countries | 1 | 5 |

*Approximately one scientist-year for each $50,000

| Probability of success | Impact: High-income countries | Impact: Developing countries |
|---|---|---|
| High | Less expensive food | More, available food |
| High | Less expensive, improved food and improved nutrition | Possible more food, but more availability and better quality of food |
| Medium | Less expensive food | Less expensive food |
| Medium | Less expensive food and better training potential | More available food and more food; probably improved health |
| High | Wider variety of foods, possibly less expensive | Wider variety of foods, possibly less expensive |
| High | Better understanding of fermentation process and more chance to aid developing countries | Much better availability of food, less expensive food and a wider variety |
| High | Better knowledge base for applied research | More preparation of scientists for future research needs |
| Medium | Possible commercial gain, and better assistance to developing countries | Prevention of starvation and generally more availability of food |

## RESEARCH NEEDS

### Utilizing and/or Upgrading Food Materials

We must identify currently or potentially available large-volume foodstuffs or food ingredients which are not now a viable segment of the world food supply because, in their natural or normal recovered state, they exhibit one or more of the following deficiencies:

-- They occur normally in a very dilute solution (e.g., whey protein, soluble protein from protein extraction operations).
-- They exist as culls, basically because of aesthetic or quality considerations (e.g., overripe, overage vegetables or fruits).
-- They contain unacceptable levels of natural toxicants (e.g., cottonseed meal, rapeseed meal, sorghum meal).
-- They lack functional properties that would permit fabricating them into acceptable foods other than by simply adding them as an inert powder (e.g., single-cell protein, algal protein, fish protein concentrate).
-- The technology or recovery is not fully developed (e.g., palm kernel protein, krill, leaf protein).

Fundamentally, the research on such food materials falls into two broad classes. First, we must identify and rank the key food materials and the problems of utilizing such materials. Second, we must find available technologies or develop new ones that will help utilize those materials.

Research has shown and experts have suggested many opportunities for using such food materials (Scrimshaw et al. 1975 and Study Team 2 report). A partial list follows.

### Dilute Coproduct Streams

Several examples of dilute coproduct streams have been cited: cheese whey, soy and other vegetable protein extraction streams, and dilute starch or other carbohydrate streams from potato, gluten, or corn processing/milling operations. Some technical solutions that have been suggested include: heat coagulation, osmotic concentration, vacuum concentration, precipitation techniques, controlled specificity chromatographic techniques, and utilization as nutrient streams for fermentation (League for International Food Education 1973, Anonymous 1975:17,68).

## Market Culls

Particularly in the more developed countries, but also in developing countries where large tract nonculture is practiced (e.g., bananas), significant quantities of culls (undersized, damaged, over or underripe, misshapened) are either discarded or underutilized as animal feed. This practice needs to be examined within the context of utilizing such materials for human consumption.

## Removal of Natural Toxicants

Potentially large quantities of high quality protein are excluded from the world food supply because of the presence of certain natural toxicants of flavor/color components that make the product unacceptable for human consumption (NRC 1973, MIT 1975:39-41). Many of these toxicants have been identified, and techniques for removing or reducing them to acceptable levels have been developed to various degrees. Examples include gossypol in cottonseed meals, tannins in sorghum grains, and glucosides in rapeseed and many other examples could be given. However, the above three represent crops that are currently cultivated worldwide and for which protein extraction and texturization techniques are more or less developed.

Many scientists have been interested in the potential use of cottonseed as a human food. This has resulted from cotton's importance worldwide, especially where many of the poor live. The Steering Committee of the World Food and Nutrition Study, early in the course of the study, encouraged a staff analysis of this problem. Interestingly, Subgroup A of Study Team 1 also developed an analysis of this area, which is included in this report as Appendix A. This analysis illustrates the significance of this approach to upgrading potential food materials.

## Nonfunctional Protein Resources

Many protein-rich coproducts or by-products exist essentially as inert powders, lacking any functional properties (e.g., water-binding, capable of being texturized, etc.). Their only use has been as an inert additive to simple protein systems. Generally, protein-fortified foods based on single-cell protein, algal protein, leaf protein, fish protein concentrate, etc., have not become a reality. As a general rule, these foods are organoleptically unacceptable. A study

should be made of ways of preserving the native protein or of incorporating it functionally into the processed protein (MIT 1975:41-43).

## Potentially Nutritious Food Materials

Oil palm cultivation and extraction is a rapidly growing agribusiness worldwide. Palm kernel meal, an extraction by-product, is a potentially utilizable protein source. World production of palm kernel meal was over 550,000 tons in 1975 (Anonymous 1976b:21). This product represents an exploitable source of about 100,000 tons of good quality protein, most of which is currently either burned or fed to animals. A still greater quantity of by-product protein is available from the coconut oil extraction business (Anonymous 1976b:21), and there are other examples in this general category (MIT 1975:70-71, 82-83).

The economics and feasibility of upgrading such protein resources should be evaluated. Fishing vessels preserve on-board waste or underutilized seafood by placing them in a holding tank and treating them with a proteolytic enzyme (e.g., pepsin) and acid. The enzyme converts the protein materials to a liquid. Upon landing, the aqueous part of the liquid is converted to a stable powder by appropriate drying procedures (e.g., spray drying). The powder is then used in the preparation of foods and provides a nutritious protein component.

## Upgrading the Nutritive Value of Carbohydrate Foods or Food Materials

Certain microorganisms can be grown on carbohydrate-rich media that contain other simple materials such as ammonia, phosphates, minerals, etc. The microbes are harvested and utilized as food materials containing nutrients, including protein. Certain fungi can convert cellulose derived from plant sources to substances having food value.

# Developing New Methods of Processing and Preservation

We must develop specific new methods of processing and preserving foods. Rising food costs in the United States and the many new needs of the developing countries make expanded programs necessary at this time.

This type of research is varied. It must be flexible as one new development often leads to others. Some effective techniques and approaches to this research already have evolved. The research we propose would include:

-- developing new processing procedures;
-- developing new equipment, such as mobile processing units;
-- developing combination processes;
-- employing minimum processing to achieve the purpose;
-- comparatively evaluating batch and continuous processing, and manual and automatic operations;
-- applying optimization techniques to individual and combination methods, considering various inputs, effect on the product, relationship to pre- and postprocessing and cost;
-- employing simulation and modeling techniques and the use of pilot plant studies;
-- where appropriate, utilizing technology from other fields.

These principles apply to both the high-income and developing countries. Many developments that the United States would use in the short term could be later adapted by other countries.

Some U.S. technologies that have been discarded because of inadequate scale under our cost patterns may be quite effective in poorer countries. Also, many of our processing and preservation methods that have been discarded as being too labor-intensive need to be evaluated for the labor-intensive countries.

It is not easy to establish appropriate technology in food processing and preservation. Many factors must be considered and much of this research will need to be adaptive. Collaboration between U.S. scientists and scientists in the developing countries would be quite useful. We hope that new programs such as those to be funded under Title XII of the Foreign Assistance Act can facilitate this research.

An example of appropriate technology is the use of ionizing radiation to preserve food. This development has implications for the United States as well as for other countries. Irradiation can control spoilage, microorganisms, and insects. Several applications of irradiation have been developed. Among these is the commercial use of irradiation to inhibit the sprouting of white potatoes in Japan.

An important potential use of irradiation is the treatment of fresh fruits. Radiation can control insects carried by such fruits and, in addition, may delay spoilage due to aging. Radiation of cereal

grains for insect control and mold growth is a proven technique. Both effects would improve trading opportunities and would allow such crops to move into new markets. An example of this is the irradiation of Hawaiian papayas to control the Oriental fruit fly. If approved, this fruit can be exported without the use of chemical pesticides.

New processing and preservation methods must be suitable to the country at the time of development. There are several approaches to providing processing plants for poorer countries. These processing plants may be reproductions of those in the high-income countries, which range from small to large operations, depending on the economics. Portable or mobile units are available and may be economical, particularly for seasonal operations. Different fuel supplies might dictate a redesign of equipment.

An example of appropriate technology for a developing country is that which puts emphasis on outturn (percent of end product from a given raw material). This type of extraction processing has been used quite successfully in countries such as India and has resulted in substantial modernization of processing. Four types of such modern processing technology spreading in use are: (1) modernized rice mills replacing older ones that used stone wheels or steel drums; (2) oilseed mills using solvent extractors rather than crushers; (3) modern sugar mills, some of which have solvent extraction; and (4) modern milk processing plants. Often the appropriate technology takes time for adaptation, but the type of research proposed would look for such more mechanized processing opportunities. Much of this type of modernization is still possible with adaptive research on a collaborative basis rather than designing completely new techniques. Of course, some problems may be solved by information transfer. Where this is possible, research may not be needed. But such research on new problems must continue.

## Reducing Use of Nonrenewable Resources

To preserve natural resources worldwide, we must reduce our use of energy and other materials, especially those that are nonrenewable. Research is needed to evaluate alternative processes that could use nonrenewable resources efficiently (Crosson 1976, National Association of State Universities and Land Grant Colleges and USDA 1976).

Food processing requires great amounts of energy. Many of the developing countries simply cannot consider the type of energy-intensive food processing,

preservation, and marketing systems that have evolved in the United States. The need to adapt our own marketing systems to our higher-cost, increasingly scarce sources of energy helps justify the type of collaborative research proposed here.

Because energy has become such a high-cost commodity (particularly oil) we must consider opportunities for using indigenous fuels, such as wastes from food and nonfood products. Poor quality water, often of limited quantity, also makes process development difficult. Thus the simple processes of poorer countries such as sun drying must be emphasized.

It should be noted that this research will need to concentrate on product acceptability and other factors which have caused resistance and have delayed wider use of energy-saving approaches.

Approaches to reducing use of energy include: (1) evaluating present energy usage and developing procedures for energy conservation; (2) comparing methods of delivering energy to the product for processing, such as microwave, ultrasonic, and plasma; (3) designing units and processes that utilize alternate energy sources, such as solar energy; (4) designing units and processes that reduce dependence on nonrenewable resources (e.g., energy, materials, water); (5) considering the use of indigenous sources for energy and materials for processing operations; and (6) designing and developing equipment to utilize solar energy for refrigeration.

In this country we may be able to find new sources of energy, and this research must be coordinated with the total U.S. energy research program. Food needs must be integrated into the total research design. Thus the World Food and Nutrition Study should emphasize food energy needs in the total research plan just as it emphasizes food research in areas such as climate and weather, information systems, nutrition, and health relationships.

Overall, specialized research programs on special processes and preservation needs such as outlined in this profile must be initiated. However, where possible, they should be coordinated or even superseded by more general nonrenewable resource research programs.

## Improving Efficiency of Water Removal

Research on water removal is singled out as a high priority area. Water is expensive to transport and handle in most aspects of food marketing. However, water can be removed and later replaced, often with overall savings because of reduced handling and

transportation costs. The special potential application of this research in the tropics justifies its being singled out.

The removal of water from foods is a major means of preservation. Many methods of water removal exist, but each has limitations and some apply only to certain foods. Some methods are costly (e.g., freeze-drying), while others are relatively inexpensive (e.g., sun drying) but may create problems with the quality of the dried product. Some methods use energy sources that are not renewable (e.g., natural gas and oil for grain drying).

New methods of water removal should be developed. This research should be conducted jointly with scientists from other countries emphasizing simple, low-cost techniques (e.g., sun drying) that can be applied in the developing countries. Simple sun drying can be improved in many ways (see Subgroup D, Study Team 4). However, its hazards also must be considered, although much information is now available on this process. Some countries can be helped greatly by adaptative research so that they can learn more about technology that would be useful in their situation.

## Developing Formulated Foods

Designed or formulated foods will undoubtedly play an increasingly important role in feeding the world's population by making it possible to utilize food components not now used and by incorporating components to improve nutrition (Scrimshaw et al. 1975). Many food components are amorphous in nature with a texture not generally acceptable to the consumer. One objective in formulated foods is to give structure to the product.

These developments will be based on learning more about the properties of present products, the energy for conversion, the food values, the efficient use of materials, and the eating habits of prospective consumers. Food quality can be improved by blending, fortifying, processing, and modifying organoleptic characteristics for greater consumer acceptance.

Individuals have food preferences and ordinarily will accept or reject food according to those preferences. While some more or less universal preferences (e.g., most people like sweet-tasting foods) exist, other individual or group preferences are not shared. Even under fairly disparate circumstances people may not abandon their usual preferences. It is important, therefore, that a new, modified, or formulated food have characteristics that are acceptable to the consumer. In poorer countries, an

important part of the task is to provide acceptability in accord with consumer preferences and the nature of their culture. Components added for nutritional purposes can usually be incorporated without greatly affecting the acceptability. Also, research in this area must recognize that changes in food habits usually take place slowly.

Ordinarily the sensory qualities of a food determine its acceptability. To a degree these sensory qualities are intrinsic for a given food, but frequently they are subject to some modification. The possibility of modification provides an opportunity to meet the food preference requirements of the intended consumer while assuring that adequate nutrition is obtained. A major function of technology is to meet these needs.

Many food materials are nutritious but are not attractive to consumers because of form, flavor, color, or perceived value as food (e.g., soybean meal). Some foods contain natural components, but in excessive amounts, and are undesirable for some people from a health standpoint (e.g., eggs). Some foods lack chemical stability (e.g., freeze-dried pork). Some compounded foods normally contain components that are relatively expensive (e.g., ice cream). These "defects" can be corrected through modification, and this form of processing can lead to "fabricated" foods.

One research approach is to develop synthetic fiber, natural plant fiber, or other edible supporting structures to provide a familiar texture and form for a fabricated food. The supporting structure would then be permeated with an amorphous filler which acts as the nutrient carrier and also provides taste and mouth feel. A variety of different food types could be developed by modifying the texture and form of the supporting structure and by changing the nutritional content and organoleptic qualities of the amorphous filler. Particular approaches applicable to each requirement must be developed to attain the indicated objective.

This is a major area where food scientists, economists, and engineers can contribute. Many amorphous foods--available from palms, and from meat, fish, plants, and single-cell protein--are not acceptable as food until the product is given texture and form. These foods can be a major source of food.

In the developing countries this research must emphasize altering diets long fixed by necessity and culture. Simple, low-cost techniques for food fabrication are needed. The economic, social, and cultural analysis component in this research will be quite significant (Scrimshaw et al. 1975:35-36).

## Increasing the Use of Microorganisms in Preservation

Fermentation processes are a well-known method of preserving food. Pickles, sauerkraut, and many other fermented vegetables and fruits are widely used. Cheeses have preserved milk products throughout the world.

Much of the fermentation research in the high-income countries has emphasized speed, efficiency, and other factors not so relevant to poorer countries. Research should study methods previously used. Much of this research should concentrate directly on the feasibility of solving fermentation problems as they exist in the developing countries.

In the short term, existing and any newly developed fermentation technology will have to use presently available microorganisms. In the long term, new strains of organisms will be developed to fit the needs of particular fermentation processes.

Fermentation is an inexpensive preservation technique that can provide the poor and rich alike nutritious food. It can be scaled to meet the demands of a small village or that of a large industry that markets around the world. Fermentation reduces or eliminates the need for refrigeration, drying, and other energy-intensive operations. The process itself, while slow, requires a low energy input.

Chemical changes accompanied by structural changes occur as a result of fermentation. These structural changes will have to be acceptable to consumers. Because there are structural changes, it may be acceptable to use culls or otherwise discarded food products for preservation by the fermentation process. Thus more food would be obtained from the food production system. Conversion and preservation of lower value foodstuffs in this manner should not only provide additional food but will preserve it so it becomes an available, consistent, and dependable supply throughout the year.

Those working on fermentation should collaborate closely with nutritionists. Eating habits can be altered. The widespread acceptance of yogurt and other fermented dairy products in the United States in recent years is a good example. This also illustrates the feedback potential of such research--yogurt has been a widely accepted product in many parts of the world for a long time.

## Analyzing Properties of Food

The proposed research would develop a methodology for standardizing the measurement and characterization of physical, chemical, and functional properties of foods so that the effects of processing, storage, and transportation can be identified and quantified (Scrimshaw et al. 1975, USDA and National Association of State Universities and Land Grant Colleges 1976:12-15). These properties include texture, nutrient content, water binding qualities, and emulsification characteristics. Another objective is to make the data readily available to those who design food processes, systems, and equipment and who develop quality evaluation and control procedures.

For all significant foods, the properties needed to define the effects of storage, processing, and transportation should be determined. Standard testing procedures should be adopted or developed to measure the physical and chemical properties of foods in their intact state and many processed states. These properties will then be used by food engineers and food technologists to analyze and predict changes in the physical and chemical states of foods as they undergo treatments from the time of production to consumption. These data are badly needed in both the private and public sectors. These data also are of great importance in food safety issues (Scrimshaw et al. 1975).

Much of this research would first benefit scientists in the high-income countries. However, it will be invaluable as scientific capabilities in the poorer countries evolve. The data will be especially useful in training programs for both professionals and paraprofessionals in the poorer countries, and these data will form a standard for collaborative research. An index of properties of foodstuffs, such as the International Critical Table, would serve as a basic reference worldwide.

## Developing Foods for Emergencies and Disasters

We must develop stable, easily prepared, nutritious foods packaged with minimum weight and volume, which not only can be efficiently transported where needed for disaster relief, but which are acceptable to the recipient as well. In addition, we need to analyze the costs and benefits of implementing alternative methods of distribution, including (1) development of international food reserves (see Study Teams 7 and 10), especially for nonperishables such as grain; (2)

development of technology to increase postharvest product life, especially in tropical countries; and (3) development of concentrated minimum weight and volume food rations for disaster food relief.

Natural disasters such as earthquakes, tornadoes, fires, floods, as well as famine precipitated by prolonged drought, can create emergency situations in which food must be delivered immediately to sustain human life. Conventional foods may not be suited to this purpose. Research should concentrate on developing stable foods that: (1) are of minimum weight and volume (fabricated, dense, or compressed foods); (2) provide the nutrients needed under stress conditions; and (3) are designed to be eaten out of hand with minimum preparation. Equally important is the development of compact and lightweight packaging suitable for air delivery.

A supply of emergency food should be viewed for three different time periods:

-- Very short run--emergency food relief for victims of natural disasters, e.g., floods, typhoons, and earthquakes. Concentrated food rations could play a key role in this time period.
-- Moderate run--emergency food relief for countries or regions suffering crop failures due to drought, pest infestations, or breakdowns in the food distribution system.
-- Longer run--emergency food relief to counteract food shortages due to cyclical variation in production or marketing, as well as longer-run climatic trends, primarily in the high-income countries. There is also a longer-run humanitarian need that requires a more or less consistent supply of food as economic development takes place, e.g., the Food for Peace program.

In evaluating alternative methods of supplying emergency food, a number of factors should be considered. Methods should complement or supplement rather than supplant normal commercial channels for food distribution, especially for moderate and longer term emergency food relief. Furthermore, the price-stabilizing effects of such food relief should be within a fairly broad range of prices between minimum prices for producers and maximum prices for consumers.

An assessment of each method should include consideration of the necessary policies and facilities in terms of (1) what volume of emergency food reserves are needed, (2) where should they be located and at what cost, (3) who should participate in such programs, (4) who should finance such emergency reserves, and (5) who should manage emergency food reserves.

## IMPACT

The research proposed in this profile will have many important effects, but they are difficult to quantify. For example, food preservation programs in the developing countries have diverted production from the more perishable products toward those that keep well under tropical conditions. Such practices poorly serve the needs for better nutrition, higher incomes, and more productive mixed farming systems. Thus effects would go beyond the obvious food savings.

### Utilizing and/or Upgrading Food Materials

This research fits a current worldwide effort to use our natural resources more efficiently. If successful, this research will have wide popular appeal and use. However, the results are difficult to predict. For example, the total impact of successfully providing a new protein source is difficult to assess, but the upgrading of one crop, sorghum, supplies most of the protein requirements of 300 million people. Of course, one should not consume only sorghum protein and not all sorghum could become human food, but such a calculation indicates the overall magnitude of the potential impact from just one unutilized or underutilized protein source.

Another way of assessing impact would be to consider the total requirements for food calories. A moderate subsistence diet is comprised of 2,500 calories per day. At normal rations of fat, protein, and carbohydrate, most food materials are about 5.5 calories per gram, dry weight (2,500 calories/day divided by 5.5 calories/gram = 450 grams/day = 1 lb./day = 365 lb./year = 166 kilograms (kg)/year). In the case of cottonseed, there are about 40 million tons produced annually (FAO 1976:21) which could feed 200 million people (see Appendix B).

The current annual production of palm kernel meal, at over 500,000 tons, would suggest that it is a potential new food source. Whether or not palm kernel meal is a source of total calories or mainly a protein source needs to be evaluated.

In addition to making more food available, the utilization of food materials currently not fully used (e.g., whey) may provide foods at lower cost. In certain cases, opportunities for exporting foods may be created.

The scope and complexity of many of the problems connected with this research preclude our hoping for large short-run gains. From a technical standpoint,

most of the identified problems are solvable, but economic and political issues can be more difficult.

Some aspects of economics can determine when a product will be accepted. For example, soybean protein concentrates are now only used in formulated foods and institutional foods where costs are important. When the price of beef is relatively high, protein concentrate sells well as an "extender." Apart from the technology, the success of sales depends on many competitive factors.

Thus many of the impacts from this research in the United States will be conditioned by economic and social factors. The savings can be substantial, and the effects will be spectacular worldwide if a major breakthrough could be scored, such as in the use of cottonseed protein for human food. However, most of the impact will probably come from the cumulative effects of many more indirect technological successes.

## Developing New Methods of Processing and Preservation

This research will have impact throughout the food marketing system: nutrition and health, safety, trade and distribution, consumer acceptance, and utilization of food material. Such effects are difficult to estimate, but the total effect over time makes such research highly profitable.

In the high-income countries, the trend is for more processing to provide: consumer convenience, new products, product stability (to assist distribution), marketing requirements (e.g., unit packaging), cost savings, and product safety. In the United States, for example, 80 percent of the foods consumed are processed.

In the developing countries, extensive processing is not yet as important, but as urbanization increases, processed and/or preserved foods will become more important. Development in the poorer countries requires products that can be transported over longer distances and stored a longer time. In many cases, processing is needed to obtain stable products suitable for exporting.

Some of this research can be carried out on a short-term basis; however, the overall objective can be reached only after a long-term study.

## Reducing Use of Nonrenewable Resources

We estimate that immediate research on our renewable resources may result in as much as a 10

percent reduction in the use of energy and water for processing. Such savings are important given the resource intensity of these processes. Beyond this initial stage, further improvement will require greater effort, and the probability of success will be less.

## Improving the Efficiency of Water Removal

This research will have an important impact in areas of high transportation cost or where temperatures and other conditions make moist preservation difficult. The United States must give priority to this research because drying processes are energy-intensive and thus must be made more efficient. Many U.S. products, such as grains, must be dried to prevent spoilage.

Transportation costs are one of the highest of all marketing costs in the United States, and this will become increasingly true worldwide. Products with high proportions of water can be reduced in weight by water removal and thus transported more cheaply.

Losses from spoilage in the poorer countries cannot be reduced without better preservation methods. If cheap methods, especially sun drying, can be developed the impact can be quite important.

A considerable amount of work on water removal from foods already has been done, and this work will pave the way for the new approaches needed to gain success. The probability of success is difficult to predict, but it is probably not high. The project is justified, however, because of the extensive use of drying to preserve foods and the need to overcome present difficulties.

## Developing Formulated Foods

Research on designed and fabricated foods will establish additional sources of food, much of it will improve diet quality.

Many examples of fabricated foods already exist in the high-income countries, such as meat analogs from soy protein, cholesterol-free egg products, filled ice cream, orange juice substitutes, etc. The probability of success of producing other fabricated products is high. Most of these products enhance consumer satisfaction and lower food costs. The major drive for such research in the United States has been cost reduction, particularly by shifting from more expensive livestock ingredients to cheaper grain ingredients in such production. These impacts will continue to be important in the United States.

The use of amorphous products in the developing countries will upgrade the use of materials and create products that can be used for nutritional intervention. These products may enhance trade opportunities for the poorer countries and should broaden the variety of foods available.

Much of the research on fabricated foods may result from other more general basic chemical and engineering work with food application coming as by-products at low cost. The return from these developments relative to the additional cost for such research should be quite high.

## Increasing the Use of Microorganisms in Preservation

Research on fermentation has potential, particularly in parts of the world where new, simple methods are needed. Extension of fermentation to preserve additional foods should be possible (Steinkraus 1977). The process is adaptable to batch processing and requires simple equipment which can be operated on a small or large scale. It is an intrinsically simple process not requiring a large infrastructure of technology and other resources to support it. The probability that this research will succeed is high.

Especially in the warm climates, the use of fermentation preservation may provide high-moisture foods not now available and permit their distribution without refrigeration. However, such research will need to consider the effect on such food properties as salty taste and acid content.

Adaptive research on fermentation should be possible through many in-country programs and through various collaborative arrangements. As presently practiced, fermentation processes are applicable to a wide variety of foods, including some tropical products and to other products which increasingly will be used in the tropics, such as dairy products, vegetables, fruits, meats, and fish.

Extension of fermentation to additional foods will depend upon research on better consumer acceptance. This work is particularly needed in many parts of the world where people could improve food supplies if they would accept other potentially available materials.

## Analyzing Properties of Food

This research will have an important impact. The present procedure for evaluating changes in physical

and chemical properties is time-consuming. Techniques for defining these properties are usually developed to meet the unique demands of a particular treatment or to answer a specific question. This information is not often made available to a central data evaluation and storage facility for dissemination to those needing the information for design applications. This procedure requires a large expenditure of funds and a great delay in time. A better knowledge not only of the techniques for measuring these properties, but also the actual values derived from these properties will be useful to the scientific and industrial communities in both the high-income countries and poorer countries.

We estimate that immediate benefits will result from this research and that by the end of five years substantial savings will be possible by utilizing the improved knowledge of physical and chemical properties of foods for food storage, processing, and handling.

Definition of standard evaluation procedures can be accomplished within a 10-year period. The actual measurements of these properties and their utilization is a long-term continuing project.

Several critical chemical and physical properties of foods can be measured by existing methods, yet for many properties no suitable methods have been developed. The probability of success in obtaining the desired measurements is largely dependent upon the availability of suitable methods. Success in every instance cannot be anticipated but sufficient progress to warrant undertaking this research is highly likely.

## Developing Foods for Emergencies and Disasters

Research on emergency and disaster foods will not only save costs, but will help save lives. In addition to its obvious humanitarian advantages, this research will aid food availability in less dire conditions and should be commercially applicable in the United States and in many poorer countries. Emergency food reserves will help counteract the effects of unpredictable shortfalls in world production of certain foods and thus will help stabilize world prices. A reduction in the uncertainty of meeting emergency food requirements will tend to reduce social and political anxieties in countries subject to sudden food shortages, and thus help to bring about more orderly economic development. And this research may provide a basis for developing public acceptance of products that have a commercial potential.

A good deal of the technology required for supplying emergency food is now available, e.g.,

military food rations. Research on the application of this technology and the economic assessment of alternative methods is required. Thus the probability of success of this research would be high, and the results would have a large impact on alleviating hunger caused by emergency conditions, and possibly for the longer run in those geographic areas and for those population groups most susceptible to severe food shortages.

## IMPLEMENTATION

Much research on processing and preservation is already underway and most of this research has been oriented toward the needs of the high-income countries. The thrust of this research profile is two-part: to maintain a progressive and efficient U.S. agribusiness industry and to develop and adapt this type of technology to meet the needs of the developing countries. Such an effort will require a substantial input of U.S. resources, and collaborative research must be initiated. The private sector will contribute resources to both efforts, but only modest resources into research in the developing countries. The recommendations below take the private sector input into account, but all recommendations are for public resources.

Resources necessary for the research on upgrading products are estimated at $5 million per year for 20 years. Food science and technology laboratories and food engineering laboratories also may be needed. This research must be well coordinated with a related research proposal by Study Team 2 for upgrading materials for animal feed.

The research on improved methods would be widespread throughout the research establishment. Hopefully, the private sector would be stimulated to increase its contribution to this area. Substantially increased support in public research is also necessary. Food science and food engineering laboratories (existing or new ones) may be needed. Funding of $4 million per year for 20 years is recommended. In general, public research should be contracted to the private companies under competitive grant programs.

The research on more efficient use of nonrenewable resources will largely be conducted in existing laboratories, and much will be carried out on a collaborative basis with private industry scientists using their plants essentially as laboratories. The results of comprehensive national programs now underway in the United States and other high-income countries on energy source development will assist in the energy

portions of this project. A funding level of $3 million per year for 20 years is anticipated, but a substantial amount of this may be included in general energy research programs and merely needs to be oriented toward food needs.

The research on water removal needs a central focus and a specialized food engineering laboratory with funding of $2 million per year for 20 years. Such a center could stimulate research, possibly by grants to private industry. Much of the research carried out in such a laboratory should be conducted jointly with researchers in the developing countries. Special facilities, particularly for new research on drying, will be needed in the developing countries.

Regarding research on designed and fabricated foods, additional food science and technology laboratories and food engineering laboratories may be needed. We estimate needed funding of $2 million per year for 20 years. U.S. companies should be encouraged to participate in this research. The main thrust of the new programs should meet poorer country needs.

This research should be coordinated closely with that proposed on emergency and disaster food production. The experience gained by the U.S. Army Natick Research and Development Command in designing and producing military field rations provides a data base for designing foods suited to emergency transport and feeding. Furthermore, foods that have been developed for civil defense purposes should be considered.

After the indicated research has provided product specifications, stockpiles must be built. These stockpiles will require storage depots and transportation facilities.

This type of research could require a commitment of 75 to 100 scientist-years and as much as $4 to $5 million over the next five years.

Research on fermentation is estimated to require an additional $500,000 annually and possibly the development of a food science and technology laboratory and a food engineering pilot plant. Private industry, through competitive grants, should be encouraged to explore this area. Some facilities may have to be constructed in the developing countries for special products. Although much of the related research on consumer acceptance of the fermented product will require leadership from the United States, most of the research must be done in the developing countries with their populations.

Research on developing the properties of foods will probably require specialized new facilities. There are few food engineering laboratories within private and governmental organizations. Funds will be needed to

create additional laboratories and to improve existing ones, as well as to provide necessary instrumentation. A food data bank capable of collecting, evaluating, sorting, and disseminating properties data (especially nutrient characteristics) should be established, preferably in conjunction with a facility already in existence. The initial funding should be $1.25 million per year for the first 10 years and approximately 80 percent of this level of support on a continuing basis.

Standard testing procedures and apparatus must be developed. Physical and chemical properties must be available to those who need them to design equipment and processing systems. Properties must be made available to engineers and scientists so that they can study and define the effects of various processes and events that allow or cause characteristics of foods to change. It will be possible to treat foods more like engineering materials are treated in the process of equipment design. The data will be useful as standards, such as data are now available to scientists and engineers in the American Society for Testing and Materials.

## Profile 3

## IMPROVING FOOD MARKETING AND DISTRIBUTION

The overall objective of the research described in this profile is to identify research needs that consider more efficient marketing and distribution a means of widening markets and lowering marketing costs (Table 3). This research is justified for many reasons. Insufficient research has been conducted on the problems of marketing, distribution, and postharvest food losses, and there is an urgent need for greater coordination as food moves through marketing and distribution channels. The private and public sectors particularly need to blend their competence and experience in this area. The potential of each nation to solve its own food problems depends upon its unique mix of natural, cultural, economic, and sociopolitical resources. Thus research must be tailored to fit these different resources. This adaptive process is complicated and such research must view the marketing system as part of the total development process:

> The economic development process involves the transformation of rural, agriculturally based economies into more urban, industrially based economies. Increased labor specialization, adoption of more scientific technologies, and the geographic separation of production and consumption require the development of a more complex marketing system....more of the urban consumer's food expenditures must go for marketing services, including transportation, storage, processing, and product grading. As incomes increase, more marketing services are demanded (Harrison et al. 1974).

Table 3. Improving food marketing and distribution—summary data

| Research needs | Study team priority: For next 15 years | Study team priority: After 15 years | Cost/year* ($ million) | Expected duration (years) |
|---|---|---|---|---|
| 1. Alternative marketing and pricing institutions | High, in some countries | High, in some countries | 1 | 3 |
| 2. Government incentives/ restraints | Lower, particu-larly in United States | Lower, in some countries | 5 | 15 |
| 3. Market access for small farmers | High, world-wide | | 5 | 20 |
| 4. Systems analysis of food marketing systems | Medium, in some countries | Medium, in some countries | 1 | 5-8 |
| 5. Trans-portation | High, in some countries | High, world-wide | 2 | 15 |

*Approximately one scientist-year for each $50,000.

| Probability of success | Impact: High-income countries | Impact: Developing countries |
|---|---|---|
| High | Better assistance to developing countries and possible commercial opportunities | Availability of farmer outlets and more, less expensive food available; better farmer incomes and improved trade |
| High | Much improved chance for private sector to aid other countries | More assurance of U.S. private sector involvement; better chance for trade |
| Medium | Better assistance to developing countries | Better farmer incomes, more and less expensive food available; improved economic development generally |
| Medium | Better assistance to developing countries; possibly improved trade | Better use of resources, improved economic development, and more food available at lower cost; better chance for trade |
| High | Reduced resource use and less expensive food; improved trade potential | Reduced food cost, much greater availability of food, and improved trade |

## RESEARCH NEEDS

### Alternative Marketing and Pricing Institutions

This research must first identify current market access and transfer pricing institutions and their successes and failures as measured by the criteria of the countries and private and public entities that use them, including enabling a subsistence producer to become part of the commercial food system (Goldberg 1974, Thor 1975). The following case examples[3] illustrate situations in which this research would apply:

-- The Amul Dairy Cooperative in India is a farmers' cooperative with a developed market orientation, including the establishment of high quality grades and packaging with incentives for small producers who are able to compete with the existing substandard milk system. The average size of each farmer's dairy herd is one and one-half buffalo. Success was dependent upon upgrading managers of the entire cooperative, including improvements in cattle and buffalo breeding.

-- The Raphan Seed Corn Project in Pakistan (also known as the CPC project) is a private firm that has developed the local market for corn and has supplied seed for both small and commercial corn producers. The project was so successful that the government asked the firm to provide similar development for other crops in Pakistan.

-- Tate & Lyle joint ventures in Belize. This British sugar company divested itself of land holdings and limited its size to encourage small producer ownership, but continued to provide domestic and international market opportunities.

-- C. Itoh and Thailand represents a Japanese corn agreement. Thai corn producers and exporters were guaranteed a market in the Japanese feed and import corn industry with the guarantee based on Chicago Board of Trade price quotations. Market availability provided rapid growth of the Thai corn industry, while penalty clauses and loss of export license by the Thailand Board of Trade helped to police the agreement. At the same time, the presence of the Japanese Free Trade Association provided similar fulfillment by Japanese corn buyers with appropriate penalties and safeguards.

-- Development of future local markets in Colombia and other developing countries. A public pricing mechanism provides an alternative to a closed "company store" price provided by a local "buyer-banker."

-- Southern Agricultural Association Case. Black U.S. producers have formed this federated cooperative to maintain small farms in the South, but it is organized to respond to large uniform quantity and quality markets in an efficient manner.
-- Long-term export agreements between the United States and importing countries. These agreements have led to policy choices which have an impact on U.S. domestic food prices. Studies of these long-term contracts and of their effects on the U.S. and world food system are essential. (For example, consider the Continential Grain Co./U.S.S.R. Wheat Agreement and the Continential Grain and Export Control Case.)
-- Joint venture and capital arrangements. Examples of such arrangements are those developed by LAAD (Latin American Agribusiness Development Cooperation) wherein the developing country, the financial institutions, and the high-income country share in each other's operations.
-- The PAK Dairy Project in Iran was initiated by a U.S. firm (Foremost Foods Company). This venture has become a self-sustaining business, vertically integrated from the farmer to the consumer. Technology transfer has been accomplished successfully at the production, marketing, and distribution levels. Increased employment and local ownership (initially 49 percent; now 69 percent) help make the project socially acceptable and politically attractive.

The proposed research must establish the transferability of such arrangements for coordinating production, marketing, and pricing from specific examples in one country to other commodities in other countries. We must evaluate the effectiveness of these institutions and arrangements in providing food more efficiently and in a manner that lessens waste and enhances nutrition. This analysis can be broken in subfields such as: standards and grades; processing and preservation techniques; packaging; inventory management; and development of transfer pricing through long-term price agreements, price formulas, future markets, and terminal price information.

The research must then evaluate whether these agreements can be made to fit the type of institutions and coordinating mechanisms of an individual country as affected by: respective government agencies, buying and selling trade association enforcements, the role of cooperatives in assuring that members comply with supply contracts, arbitration procedures for major changes in conditions that surround the contract or agreement, and risk-sharing procedures.[4]

The ability of public and private institutions to finance these food marketing arrangements must be evaluated. With terms of trade running against the developing countries, demand for renegotiations of loans for a "new economic order" will be present unless there is an orientation toward food programs that provide a market for production. The World Bank supports this approach and prefers that it be combined with the priority of utilizing both commercial producers and smaller subsistence producers who are entering the commercial food system.

This research must be coordinated with that recommended by Study Team 7.

## Government Incentives/Restraints for Developing and Operating Food Distribution Systems

The objective of this research must be to identify government programs that stimulate or restrain the creation or operation of national and international food distribution systems. Furthermore, remedial policies, practices, and regulations must be devised that (1) improve the focus, productivity, and cost-effectiveness of food production, processing, and marketing research, through a study of food distribution systems; (2) encourage greater participation of the private sector in the organization and operation of self-sustaining food production and marketing businesses in the developing countries; and (3) amend or remove those regulations that unnecessarily prohibit or delay the commercial use of new or nonconventional food product and process technology.

A separate effort by either the public or private sector alone is unlikely to provide workable answers to our global food distribution problems. A joint effort by government and industry is essential if the food distribution systems of developing nations are to be improved significantly and within a reasonable time frame (also see Study Team 10's report).

Research on implementing government policies, practices, and regulations should help develop more effective procedures for organizing and conducting research related to food production, processing, and distribution, both domestically and internationally.

Current U.S. practice places the majority of all federally funded research and development work in public institutions such as the U.S. Department of Agriculture (USDA) and the land-grant colleges and universities. This practice has proven to be highly successful when dealing with basic scientific problems but relatively less productive when the business-

oriented disciplines of market research and product development for either consumer or industrial markets are needed. The present process needs to employ more of the commercial skills and expertise needed to make food marketing efficient. The private sector now conducts considerable research on marketing and distribution, and has been involved in marketing in the poorer countries.

The effectiveness of both product- and market-oriented food research can be improved significantly by revising current policies and procedures so as to permit private business to participate in the research process through appropriate contractual practices now used by some federal agencies such as the Department of State, the Department of Defense, and the National Institutes of Health (see Study Team 14's recommendations).

Policies and programs should be devised to stimulate greater participation of the private sector in the planning, organization, and operation of permanent, self-sustaining food production and distribution businesses within host countries. Because of political and economic instability, private business is often reluctant to make the long-term investments and extended operating commitments essential for the meaningful improvement in food marketing in poorer countries. Several U.S. companies in other industries have lost their operations through expropriation. To remedy this problem, the risks of business involvement must somehow be reduced to an acceptable level. Invested capital, patents, trademarks, and earnings of private business must be given reasonable protection throughout the life span of the venture.

Research should evaluate the means of creating an international fund to be used to repay financial losses suffered by foreign and domestic firms as a result of a takeover by a foreign government or by shifts in government regulations which make attainment of original economic agreements no longer possible. Another research possibility would look at coverage of losses caused by a defaulting government through financial assistance from international monetary sources.

Another aspect of this research will be to develop the scientific evidence needed to realign those food regulations that now prohibit or impede commercial utilization in the United States and abroad of food additives (e.g., chemical preservatives) and processing techniques (e.g., irradiation) useful in expanding the global food supply. Particular attention should be given to developing a better understanding of the toxicological and epidemiological significance of (1) agricultural residues which tend to carry over in trace

amounts from food waste recovery operations into the food chain; (2) indirect additives from packaging materials and other food contact surfaces; and (3) direct additives useful in protecting the nutritive value and consumer acceptability of new, supply-stretching food products (Grisanti 1976). The regulatory prohibition of processed and fabricated foods containing toxicants at any detectable level versus the relative safety of unprocessed foods which contain a wide range of naturally occurring toxicants (NRC 1973) is a dichotomy that must be researched. Similarly, the newly suspected link between dietary imbalance and cancer (Anonymous 1976c) deserves attention. Obviously, a substantial scientific effort will be needed to prevent present and future inconsistencies in international regulatory standards which tend to block a free exchange of foods and technology among nations (Goldberg 1976).

This research will develop better information concerning all phases of intra- and international marketing systems to complement the production data already available through established international agencies. One approach would be the use of existing agencies to develop and maintain an information center on the natural, socioeconomic, and political resources that can be expected to influence food production, marketing, and distribution within each developing country. The development of the marketing system also depends upon the food information system (see Study Team 8's report).

## Market Access for Small Farmers

When farmers in the developing countries increase their production, the market must be sufficiently large to absorb the increased output. Moreover, farmers often must be assured of markets before they will adopt more expensive production inputs to increase yield. The expansion of markets can stimulate production as well as handle increased production once it occurs.

There are two approaches to expanding markets for smaller farmers: (1) increasing the purchasing power of the consumer, especially of the poor consumer who needs food; and (2) increasing the number of outlets for products by developing new uses or forms of products, new market areas, and new institutional arrangements (Kriesberg 1970a, 1970b, 1976; Kriesberg and Steele 1972).

Expanding markets can provide consumers with a wider variety of foods at lower cost, and can reduce the food losses that result when supplies that accumulate cannot reach markets. Research is needed to

reduce the physical impediments to the movement of food supplies and/or the lack of information that cause market imbalances.

Research needs to determine how to enhance the purchasing power of the consumer in the developing countries, especially that of the poor consumer. Some practices used to make food more available to the poor include: (1) food-for-work programs, with at least part of the wages paid in food, (2) price-controlled stores or depots for foods in low-income neighborhoods, and (3) government-subsidized foods. Thus far too little research has been done to assess the efficiency of such programs in the United States and worldwide, and more research is needed.

Studies of demand elasticity also are important. Most such studies in the developing countries have been carried out in urban areas and are limited in commodities covered. Studies of household consumption should be carried out in both urban and rural areas, and should cover all socioeconomic groups and major commodities. Most studies have been concerned with markets that are little used by the poor. Thus how the very poor respond to changes in prices and incomes is another problem that needs to be studied. Research also should be undertaken in the developing countries on how to shift consumption patterns to more nutritious foods (see Study Team 12's report).

Research to develop new products for the long run must be encouraged in the developing countries. Traditionally, those countries have marketed products that have had little processing. The processing techniques discussed earlier can provide needed employment, improve the product line for export to the high-income countries, and generally give smaller farmers access to more markets.

Markets that serve small holders frequently service areas no larger than the distance the farm family can walk to and from a local village. Extending the radius of the local market often is the best means of increasing the incomes of farmers and others in the food system. Linking local markets with regional, national, and international markets further extends the marketing radius.

Several factors limit the size of the market. The limitations of transportation are probably the single most important constraint, followed by food preservation and storage.

Research could provide better options for strengthening local and regional marketing institutions available to farmers. These institutions serve not only as centers for food exchange but also as service centers that provide the farmer with transportation, storage, and food preservation as well as farm inputs.

Marketing systems should be designed to synchronize food production and its inputs with handling, processing, and transportation facilities. Research on organizations in food marketing including government, private firms, and cooperatives can provide small farmers with market information and technical services and local processors with information on intermediate or possibly final processing. Government incentives can be important factors to consider in such research.

Research on intermediate marketing institutions should consider the role of women. Women are important in farm production and in marketing, and those who are to work with local programs will need technical and scientific training.

The place of the smaller farmer must be given consideration in systems research applying modern analytical techniques to the planning, organization, public incentives, and management of commodity flows in the developing countries. This work should identify bottlenecks in producer-to-consumer flows and improve communication in the system.

Research in this area also must: (1) obtain and objectively analyze descriptive information regarding the present importance of small farmers in the world food production system, and their degree of participation in the market or exchange mechanism; (2) provide a more complete understanding of production and marketing cost relationships under different conditions of factor availabilities and prices, and product prices; and (3) identify and evaluate alternative institutional arrangements for reducing small farmer input procurement and product marketing costs. (Also see the reports of Study Teams 4 and 7.)

Survey research, farm budgeting, or simulation analysis of small farmer production, input procurements, and product marketing costs must be used for the main parts of the study, but case studies will be made to evaluate success and failure of existing institutional arrangements and adaptability to other countries.

Much of the originality of this work will rest in descriptive-diagnostic research to identify new institutional approaches or to adapt old approaches to new circumstances to aid small farmers in market accessibility. The adaptive work in the developing countries will require closely monitored pilot projects to try out new approaches to effective food marketing with particular regard to small farmers.

A growing consensus holds that some type of institutional arrangement is needed to make it possible for small farmers to lower unit procurement and marketing costs. Research must assess the viable alternatives. Farmer cooperatives have been the

standard solution in most developing countries. Unfortunately, the lack of emphasis on economic incentives, poor management, the free-rider problem of nonmembers, individualism, dishonesty, and distrust have proven to be major obstacles to cooperative expansion in most developing countries.

More recently, communal farming partnerships, associations, or corporations, particularly devoted to production, have been in vogue in some countries, especially in land reform projects. But in most cases these eventually encounter the same problems that have plagued cooperatives. While cooperative and communal farming associations will continue to provide alternative solutions to the marketing problems of small farmers, there are alternative institutional arrangements which under certain circumstances could prove feasible. Some examples are contractual agreements with buyers, farmer-owned marketing companies, marketing boards, marketing orders, and other government-regulated bargaining arrangements.

## Systems Analysis of Food Marketing

We must identify and analyze food marketing problems on a systemwide basis. Local research must (1) determine the current organization and methods and costs of marketing food at each important stage from producer or importer to consumer; and (2) identify at each stage and for the system as a whole opportunities to increase economic efficiency including the development of new institutions and capital and public policies to encourage needed adjustments.

Research on marketing is frequently partial and fragmented, making it difficult to appraise the efficiency of whole systems. Furthermore, such research often concentrates only on the physical aspects without adequate attention to the economic aspects of exchange processes and public policies that affect incentives or disincentives for improved efficiency. The following approach is suggested:

-- Select one or two major commodity subsectors for intensive analysis, beginning with a thorough description of existing physical, economic, and policy institutions from producer or importer to consumer.
-- By use of simulation or other appropriate techniques, and drawing upon knowledge in the country and elsewhere, examine the implications of possible changes in the system, e.g., increased storage capacity, modification in transportation networks, improved information systems, improved

processing methods, and improved handling facilities.

-- Suggest public and/or private actions that would achieve higher levels of efficiency, indicating magnitude of savings and beneficiaries.
-- As researchers gain experience, include additional subsectors for study, linking them as appropriate to other subsectors and to the whole of the distribution system.

## Transporting Food

Transportation is a relatively large part of costs in any marketing system. It is energy-intensive, and renewed efforts must be made to reduce U.S. transportation costs. As the developing countries establish more elaborate marketing systems and more products must move among countries, research that directly attacks the transportation problems of the developing countries must be increased. This research must:

-- identify necessary future adjustments in the transportation infrastructure and location of processing and storage facilities in light of increasing energy shortages and costs;
-- evaluate alternative modes of transportation and determine how to stimulate the development of those that are most promising from the standpoint of reducing food marketing costs and/or expanding markets for food;
-- evaluate the benefits and costs of transport regulations on the efficient distribution of food;
-- consider the human constraints on transportation, such as work stoppages, particularly under emergency conditions.

Several factors give rise to transportation problems. Inflation has resulted in increased transportation costs, and regulatory policies have been self-defeating in many instances. The energy crisis has had varying impacts on different modes of transportation. Rate-making procedures such as demand-oriented pricing by transport firms and pressures from lobby groups have had substantial influences on the location of processing and production.

These factors bring on many problems, both in the high-income and developing countries. Insufficient returns on investment can result in difficulties in obtaining financing for new facilities and equipment, and deterioration in quality of services. Regulatory policies often hinder more efficient organization of

transportation services. These policies can cover a broad spectrum: transport rate regulations, entry and exit regulations, maximum weight and dimension regulations, and work rules. Different approaches to rate regulation among different modes of transportation add to the confusion. Labor problems in the form of work stoppages and uneconomic work rules add greatly to the cost and time involved in the distribution of food, and often are more critical in this industry than in others. Food losses during distribution add substantially to the cost of transporting the portions of food products that are not processed for food, such as the material removed by trimming meat and cleaning grain.

The transportation needs of a food marketing system must be put into the context of the total transportation system of a given country. Research must first assess transportation's role in the food production and marketing system; food transportation must then be related to the total transportation system.

The emerging energy crisis has raised many questions regarding the efficiency of current transport methods in the distribution of food. As a starting point, it is necessary to determine how much energy is presently being consumed for food distribution along with an analysis of whether this amount could be reduced by changes in the transport infrastructure, location of processing and storage facilities, and changes in the location of workers. Changes in the transport infrastructure would need to include more efficient use of existing facilities and equipment, new transport equipment, and construction of new roads, railroads, harbors, and airports.

The ecological and economic effects of limited fossil fuel supplies have already produced renewed interest in alternative modes of transportation. The proposed research should aid in choosing among these alternatives. For example, recent technological advances seem to justify renewed interest in developing lighter-than-air craft because of technical feasibilities, safety, the possibility of attaining lower fuel, and infrastructure costs. Pneumatic transport of nonfluid food products over long distances also merits some interest.

The development of packaging materials and methods to improve the efficiency of transport is still another dimension of the proposed research.

Finally, this research must identify transport regulations that impinge upon food distribution, and then assess their costs and benefits. Attention must also be focused upon variations in regulations with respect to different commodities, modes, human

constraints upon the transportation systems, and regions within a country and among countries.

## IMPACT

### Alternative Marketing and Pricing Institutions

The value added at the producer level, although critical to the food system, represents a rather small percent of the total delivered cost of food in most high-income countries. Even in many developing countries the value added at the farm may be low compared to that of the other parts of the system. The labor, credit, and input supplies, together with the farmers' added value, are dependent on the market mechanisms and incentives in the food system. The value of food at the consumer level must be reflected in economic and/or political incentives sufficient to reach back to the distributor, processor, farm producers, and farm suppliers involved in the food system. These relationships are true regardless of the political and economic system of a given country.

Adequate capital is critical for the food system both in the United States and abroad. The financing of food enterprises that have market access is critical to provide not only an efficient signal to the producer but a method of limiting risk and therefore encouraging capital to flow to the agribusiness sector (Goldberg 1974).

New institutional arrangements, such as the corn industry of Thailand in the Thailand-Japanese Corn Agreement case, have affected the entire crop production of the countries involved. As an example, historically in the United States, the transportation system has served as a catalyst in developing regional specialization of crops. Producers did not want to grow a crop without a market and the processor did not want to build a plant without a raw material supplier. The transportation firm (e.g., the railroads) brought them together. The world food system needs catalysts to bring the high-income and developing countries into one global food system. Research on market access and transfer pricing not only affects the development of total crop systems in major countries but also affects the availability and price level of food in the United States.

The production-oriented international research centers would benefit from the development of market access and transfer pricing arrangements and institutions that would enable scientific progress to expand even more rapidly while at the same time

providing market feedback to the production scientists and farmers.

We now have many successful market coordination arrangements as discussed above. We must build future research and apply that research to make maximum use of scientific breakthroughs. These new coordination arrangements require the farmers and agribusiness managers to look forward to changing market opportunities and arrangements while at the same time looking backward to scientific production breakthroughs. The progressive attitude of the International Rice Research Institute in working with public and private marketing institutions in the Philippines and Southeast Asia is an excellent example of the type of cooperative effort required.

Most of the institutions and arrangements suggested above have been analyzed separately, but their total impact on major food commodity systems has not been assessed. Thus the object of such research will be to determine the impact of such arrangements. This research should start immediately and would take no more than three years.

Over the past 15 years, U.S. efforts to bring about meaningful improvement in the food problems affecting developing regions of the world have for the most part been production oriented rather than market oriented. As a consequence, results have been disappointing largely because the solutions offered lacked consumer appeal, commercial orientation, or political incentive within the target community (Forman 1975:63-89).

By focusing the combined skills and resources of public institutions and private business on the full range of tasks to be done (from concept through product and market research to the realities of food production, processing, regulation, and distribution within host countries), the United States can expect to achieve a greatly improved measure of success over the next 15 years and beyond.

The critical importance of combined public and private effort is gaining recognition both domestically (Albright et al. 1976; Prinsky 1976a, 1976b, 1976c; Martin and Ricklefs 1975, Vicker 1975) and internationally (United Nations 1975). Significant examples of how and why the private sector must be encouraged to take a leading position in the development of economically productive food distribution systems are a matter of record (Thor 1975 and Schumacher 1975).

The major impact of the proposed research would be to focus future efforts on developing the potential of each nation to feed itself more completely using its own natural, social, economic, and political resources. The research would identify and target assistance

programs to the economic means and acceptance criteria of the consumer. It should achieve a permanent rather than a transient improvement in the availability, distribution, and cost of food in the target country. Also, it would provide workable solutions tailored to fit the wide range of unique and variable problems encountered. Finally, it would establish within the host country pilot commercial operations capable of demonstrating the political as well as the commercial advantages of an adequate food supply, higher employment, and an improved balance of payments. These results would each have short-term and long-term implications.

## Market Access for Small Farmers

Some evidence suggests that, given the factor endowments in most developing countries (scarce capital, land shortage, abundant labor), small independent farmers are more efficient than large farmers in physically transporting water and plant nutrients to food products. However, technological inputs and marketing for their agricultural products cost these small farmers more because of their geographic dispersion, low volumes of inputs and final products handled, poor management practices, and limited access to information. In addition to relatively higher physical handling costs, a system comprised of many small farmers implies relatively higher communication, transaction, and inventory management costs. Also, such a system of small farmers, each with limited information and limited inventories, produces high levels of market price fluctuations, uncertain demand conditions, and high degrees of price risk.

This research can assess the trade-offs among low physical transformation costs and higher input procurement and product marketing costs for small farmers. These results could provide guidance on public price and income policy and on optimum farm size under different conditions of factor endowments and price relationships.

Most of the world's food supply is produced by small, independent farmers. And, contrary to popular belief, the families of many of those small farmers depend upon the marketplace for much of the food they and their families consume and for the sale of their farm products. As an example, Colombian farmers produce an average of only 25 percent of their food needs on their own farms. Thus this research would result not only in new outlets for small farmers but

also in increased availability of food for more consumers.

Studies in selected countries have indicated that the marketing costs of foods produced by small farmers could be reduced by 10 to 20 percent through more effective marketing arrangements. In addition, the reduction of marketing risks and uncertainties could provide a significantly improved environment for the small farmers to adapt cost-reducing production and marketing technologies.

When building up some protection for a disaster year, subsistence farmers may do a host of inefficient things just to protect their families. Some market access may yield a chance to build up an asset base which will enable the families to store some products and thus protect themselves. Also it will enable the farmer to adopt more progressive production and marketing innovations.

The outcome of improving the access of small farmers to markets could in the long run reduce real food costs by an estimated 20 to 30 percent or more in relation to other costs in certain developing countries. The resulting impact on human nutrition would be substantial.

Effective alternative institutional arrangements could be developed in relatively few (5 to 10) years. The widespread application of such arrangements will be a continuing battle for a long time (15 to 30 years) and will depend heavily on political will and specific diffusion efforts in a given country.

## Systems Analysis of Food Marketing

This research would provide a framework in both the public and private sectors for systematic planning for future investment and development policies for marketing systems. Such an analysis would meet for the first time the unique needs and circumstances of the individual countries in question. Without a systems framework, improvements are likely to be highly fragmented and costly.

Some savings may result from increased efficiency of present marketing systems, but most benefits will likely result from major changes in the systems of transportation, storing, and processing of agricultural products. In many cases, these changes will require investments in transportation, storage, and processing facilities.

The benefits of improved and modernized marketing systems are diverse and complex. Benefits include: reductions in waste; higher quality products; greater variety of products; increased services to consumers;

availability of seasonal foods over longer time periods; and reduced costs of handling, transporting, storing, and processing agricultural products.

A major reorganization of marketing systems could reduce marketing costs and margins. Estimates of marketing margins in the developing countries differ greatly. For good grains, margin estimates range from 20 to 50 percent of retail price.

The proposed systems analyses would provide estimates of impacts and serve as a basis for implementing alternative policies and the required marketing infrastructure. Such research would yield important long-run payoffs to both public and private sectors.

## Transporting Food

The impact of the transportation research proposed rests on the fact that transportation plays a key role in the distribution of agricultural products (input materials as well as raw and processed foods), both in the developing and high-income countries. In addition, transport represents a significant portion of food marketing costs.

In the developing countries, the pervasive effects of improvements in transport infrastructure can be quite significant. For example, improved roads may aid greatly in increasing the efficiency of food distribution, as well as providing better transportation for both people and nonfood commodities (Owen 1968).

Much of the research in this profile will reduce energy consumption as a result of more efficient use of existing transportation technology, fewer regulatory constraints, and the development of new technology. As one example, ligher-than-air craft require only one-fifteenth the fuel required by airplanes, and are capable of traveling at speeds of 60 kilometers per hour with payloads of 500 to 1,000 tons (Society of Automotive Engineers 1976). The use of airships, especially by the developing countries, could lead to savings in transportation costs because these airships do not require expensive airports. Airships can provide food transport services into or out of remote areas, thus reducing costly expenditures on roads into such areas.

Much of this research can be undertaken fairly quickly without large sustained financial support, except in the case of developing new modes of transport. This research has a high probability of success and its impact on certain geographic regions in

terms of reducing hunger and malnutrition would range from moderate to high.

## IMPLEMENTATION

The cost of the proposed research on alternative marketing institutions would be minimal given the wide variety of knowledgeable people and institutions in agribusiness. An all-out effort would take three years and 20 to 40 scientist-years at a cost of approximately $1 million annually.

Resources are available to carry out the research on market access and transfer pricing institutions, including land-grant colleges and universities, overseas institutions such as Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA 1973), and other institutions such as the Stanford Research Institute and Harvard Business School. These institutions and many others are carrying out parts of this research in cooperation with industry, cooperatives, and governmental entities.

The implementation of research on government incentives/restraints on food marketing is difficult because it involves high-level, controversial public policy. Much of this policy is already embedded in existing legislation and will be difficult to change.

The first phase of the research proposed can be achieved by better utilization of existing domestic and international research facilities and institutions. Policies and practices will need to be adjusted to permit and encourage research involvement by the private sector. Additional funds, estimated at $5 million per year, will be required to finance market-oriented research not now provided for in either national or international budgets.

The research phase can be accomplished in concert with existing international institutions. Financial support should be provided by those high-income nations that expect to benefit from the resulting marketing programs.

The third phase will require a substantial increase in the level of effort devoted to research on the toxicological and epidemiological significance of food additives. Existing research institutions such as the National Institutes of Health could be used. An estimated budget of $3.5 to $5 million per year will be required.

The fourth phase can be achieved through existing international institutions such as the International Food Policy Research Institute. The level of funding will depend in large part on timetables set for the

attainment of food distribution goals. An annual budget of $1 to $1.5 million is proposed.

All of the proposed research on government incentives and restraints will require approximately 200 scientist-years of effort per year, with estimated funding of $10 million per year.

Implementation of the research on market access by small farmers must be closely coordinated with research already underway or planned. Much of the current research is oriented toward production and this proposed research may best be initiated as an expansion of current work.

Much of the success of this research will depend on the attitudes of both international agencies and the governments of the developing countries. If they adopt a positive attitude and genuinely recognize marketing problems of the small farmer, the probability of success will be high. If they slight the issue when allocating resources and when making key policy decisions, the probability of success is low.

To achieve the full potential impact on small farmers in major areas of the developing world, an estimated annual research budget of $5 million would be needed. It is also assumed that as research results become available, additional resources would be made available to begin implementing those results through educational, governmental, and private industry channels. Most developing countries lack researchers with the training necessary to serve as effective counterparts to marketing researchers from the high-income nations. The research will need to be paced by improved training or research personnel.

The systems research proposed should be closely coordinated with the research now underway by several projects funded by the U.S. Agency for International Development (AID), the World Bank, and others. A large amount of emphasis has been placed on this type of research in the United States such as a large swine subsector analysis conducted jointly by scientists from Purdue University, Michigan State University, the Economic Research Service of the U.S. Department of Agriculture, and others. The proposed research must build on this type of work which will facilitate collaborative research needs of the U.S. and foreign scientists.

Scientists in many of the developing countries could contribute to such research. Some assistance from experienced researchers in the high-income countries would be necessary in the design of the projects and during the critical synthesizing and analytical stages of the work. The scale of effort should be limited initially until some experience is accrued and the research has demonstrated its

usefulness to the public and private sector. Thereafter, tempo of the research could be increased.

It is recommended that this research be conducted over a five-year period. Costs on an annual basis for each commodity (including salaries, travel, data processing, etc.) on a country basis are estimated at $150,000 per year. If two commodities were studied in three countries, estimated annual costs would approximate $1 million.

The project would necessarily involve participants from the public and private sectors. The research team, most of whom would preferably be part of a university or government organization of the host country, would need to work closely with physical scientists and industry people to evaluate the present and alternative marketing systems. Joint participation could be extremely important in gaining acceptance of recommended structural changes in the marketing system.

Research on transportation is widespread and much of it is not marketing-specific. The proposed research must be coordinated with ongoing, more general transportation research. In countries where the marketing sector can be assured of equitable treatment, such research should be planned by the country planning unit responsible for planning the total system. However, in some countries special programs may be needed to give research on food transportation the emphasis it deserves.

An annual commitment of 75 to 100 professional scientist-years and $10 to $15 million over the next 15 years would make a significant contribution to removing some of the constraints mentioned in this profile.

## SOME GENERAL PROGRAM NEEDS

Research on food marketing generally must do many things if we are to improve the quantity and quality of foods consumed in the developing countries and increase the real incomes of producers and consumers. It must include: reduction of waste, reduction of costs, better maintenance of food quality, enhancement by fortification or other processing, wider and more even distribution of supplies over time and space, and better communication of consumer demands to producers.

This research can be carried out both in the developing countries and in U.S. research centers and laboratories (including the Defense Department's Natick Laboratory). AID can contract for increased ongoing U.S. research that could be adapted to the needs of the developing countries and could help to create research relationships between U.S. researchers and food science laboratories in those countries. The National Science

Foundation (NSF), USDA, and others should support fundamental research on the biochemical and physiological processes involved in the deterioration of animal and vegetable products.

This research will require additional funding. We recommend that the United States be prepared to give additional research funding of up to $55 million annually if it is to give leadership in this research. A rough allocation of this amount is $22.25 million for research on food losses (Profile 1), $18.75 million for research on improving food processing and preservation (Profile 2), and $14 million on improving marketing and distribution systems (Profile 3). Tentative cost estimates for the various lines of research are shown in Tables 1, 2, and 3. We do not vouch for the ultimate accuracy of these cost allocations, but we do feel that total expenditures for the entire area should approximate $55 million.

For several lines of research, we recommended additional capital expenditures, especially for new laboratories, but obviously we could not make an in-depth analysis of these needs. We recommend that a comprehensive study be conducted to assess the adequacy of facilities currently undertaking such research in the United States and elsehere. The feasibility for integrating some of this work with the ongoing production research in existing international centers would be part of that study.

Much of the adaptive research may best be accomplished by expanding the role of regional and international research institutes. These institutes are presently devoted primarily to production but could be expanded to include the responsibility for research in preservation, processing, marketing, and related technologies.

Before pursuing the approach of using the existing international centers, administrative arrangements and programming procedures need to be developed to assure that the appropriate efforts in processing, preservation, and marketing are incorporated. Previous experience in carrying out marketing research by production centers had led to criticism of some production-oriented groups (Shaffer 1968, Williams 1966). Without assurance that existing units will properly manage the programs, new institutes will be needed.

Industry, government, and university groups can participate in funded projects, based on their capabilities to work in the area. The five USDA Regional Utilization Laboratories are examples of existing research groups that could carry out basic research. This research could be funded from proposals for basic research and planned on the basis of five-

year grants with extensions based on satisfactory performance. Many countries should participate in the funding, but the major responsibility will rest with the high-income countries.

Applied and development programs require considerable education to extend knowledge of food and nutrition to producers, processors, and consumers. Each developing country will need to develop its own techniques for distributing information through educational activities, corporations, government programs, the press, and the news media.

Well-planned research on pertinent issues and problems will by itself do little to alleviate the world food and nutrition problem. The ultimate solution rests with the will of the people and their level of professional competence to carry out the research. The development of human resources with this competence will undoubtedly require some mix of formal education, extension education, on-the-job training, vocational training, and ongoing marketing experience (Meissner 1975:29-50). Little information is available to determine the characteristics of that education mix. With the cooperation of the governments involved, perhaps researchers from other fields could be encouraged to transfer to food research. Increased research resources will aid in this. The recent studies and subsequent development of scientific manpower in Brazil to meet its plan for development might serve as a guide, particularly for international donor agencies in planning assistance grants. The whole area of training must have emphasis if the proposed research is to be successful (see Study Team 14's report).

A missing ingredient for successful marketing programs in the developing countries is a sound management program to fit the marketing program into the overall development program. This is particularly important in marketplace development whether done by a government or a private concern. The proposed research will provide much new information on the many variables that make up a marketing system. But it is not possible nor practical to lay out the solution to a complete marketing system in a research sense and expect it to work in practice or in theory. Much of the research must be designed with feedback mechanisms to alter the research as management of the system gains new knowledge from implementing the research. Research is needed to establish the dimensions for this type of management capability. The skill of researchers and development personnel in identifying and building the management component as a bridge between research and the operating food marketing system will determine the

impact of this research on improved availability of food.

## Appendix A

## DEFINITIONS USED IN THIS REPORT

Many terms used in this report may merit definition, but only a few of the most widely used ones follow:

Loss--A loss is material not available for use in the food chain. This could result from the actual destruction of products (such as by microorganisms) or it might be a physical loss (from a leaking storage container, for example). Some losses are unavoidable; other losses can be prevented through appropriate control of destructive agents.

Waste--Wastes are secondary raw materials that originate from present food systems, as well as materials not currently recognized as food sources. And wastes are food materials that have been deliberately underutilized by diversions or disposal due to economic consideration or inadequate knowledge of the potential food value and the potential processing techniques. An example is the waste parts of animals and plants, often edible, which are lost to the food system.

Nutrition--Good nutrition refers to the state of being in which an individual enjoys normal growth, reproduction, performance, and longevity. Good nutrition results from ingesting a diet that provides all the nutrients required by the species of which the individual is a member. An individual having a state of good nutrition is free of any disease attributable to nutrient deficiencies and excesses. Diseases attributable to other causes, however, may affect the nutritional status of an individual.

Distribution (Harrison et al. 1974)--Distribution refers to the set of activities and institutions that is involved in handling a product or set of products from production to consumption. At one extreme, a completely integrated distribution channel could consist of one firm that produces, processes, transports, and distributes products from the farm to

the consumer. At the other extreme, a variety of independently owned firms could produce, process, assemble, transport, and distribute products from the farm to the consumer. Then independent firms may be bound together in a variety of institutional arrangements that coordinate this activity.

Marketing (Harrison et al. 1974)--Marketing, or marketing system, generally refers to the mechanism for coordinating production, distribution, and consumption activities. Viewed in this manner, it would include activities associated with exchange of ownership of commodities, physical handling of products, and institutional arrangements associated with these activities. In this report, the emphasis is placed on the exchange activities and institutional arrangements.

Fabricated foods--Fabricated foods are "items made from cottonseed, alfalfa protein, peanut flour, triticale and algae; dairy substitutes instead of dairy products, dehydrated potatoes instead of raw potatoes, and vegetable protein meat analogs instead of meat cuts (Anonymous 1976a:22)." We generally accept this definition as it refers to human consumption but question the inclusion of dehydrated potatoes as a fabricated food.

## Appendix B

## COTTON PEST CONTROL AND COTTONSEED PROTEINS

Cottonseed provides an untapped source of protein for direct human consumption. Of the many crops now indigent to the developing countries, the cotton plant, which is just as important in the United States, offers the greatest potential for meeting protein needs for food and feed. Because the cotton plant is also important in the high-income countries, considerable research has been done and documentation exists on its potential. Similar discussions could be given for other crops that have great potential, but with less documentation. The dual role of cotton for both fiber and food makes it particularly attractive.

One of the major barriers to the use of cotton as a food crop is the extensive complex of pests that attacks the plant, especially insects. Any attempts to develop cottonseed protein as a remedy for malnutrition must take these pests and their control into account.

### IMPORTANCE OF COTTON

Cotton produces enough protein, were it in suitable form for human consumption, to alleviate the present world protein deficiency. Cotton is already important as a source of clothing, food, and livestock feed. As a source of foreign exchange earnings, cotton is second only to petroleum for the developing countries. Cotton is grown on more than 34.4 million hectares of land in more than 70 countries. The United States generally produces more than 10 million bales (213.6 kg each) annually. The growing and processing of cotton involves more people than any other commodity (Harrar 1975).

Cotton is grown primarily for its lint, which is the world's most important fiber and accounts for almost 50 percent of the total weight of all apparent fibers used. Cottonseed is an important source of

cooking oil and is used in various human food products and livestock feed; it is, nevertheless, considered a secondary product of cotton. However, cottonseed could become much more important as an ingredient in human diets and in nonruminant livestock diets.

Cottonseed is the most widely grown oilseed in tropical and subtropical areas of the world where protein deficiencies most commonly occur. The cotton plant is well adapted to hot, dry areas and may be profitably grown where other oilseed crops such as soybeans, with high water demands and unique photoperiodic requirements, do not do well.

For each bale of lint, cotton produces 364 kilograms of seed. The seeds contain approximately 73 kilograms of protein and 73 liters of oil. In many areas of the world, the protein found in cotton compares favorably with other vegetable proteins in its nutritional adequacy for human consumption. Unfortunately, cottonseed contains pigment glands with a yellowish-brown substance, gossypol, and other toxic entities. Unless these substances are removed, the processed cottonseed meal or flour is not fit for consumption by humans, poultry, or nonruminant livestock.

About 72 percent of the world's production of cottonseed is processed for oil or meal. Even a smaller percentage is processed in the developing countries. The oil is used mostly for human consumption and the residual meal is fed to ruminant animals. However, practices vary from country to country. In China, where there are relatively few ruminant animals, much of the seed may be returned to the fields in the form of organic fertilizer even though the country produces millions of pigs, chickens, ducks, and geese that could be fed a high protein supplement.

The world protein shortage in 1975 was estimated at 2.2 million tons. Because 5 million tons of cottonseed protein are grown each year, the potential of cottonseed for correcting this deficiency is clear. For example, if half the oilseeds now being consumed as animal feed were converted directly into human food, this would produce an increase in the world food supply equal to approximately 50 percent of all the animal proteins now being consumed. If all the world's supply of cottonseed were converted directly into human food, the protein contribution would be nearly equal to all the protein provided by fish in the human diet. In simpler terms, the 25-county area of the Texas high plains produces each year cottonseed protein equal to the protein produced by 7 million head of feeder calves. Thus cottonseed should be more than a by-product of fiber production.

Cottonseed has a substantial short-term potential for alleviating the world food crisis. In addition, if the approximately 5 million tons each of edible cottonseed oil and good quality protein produced annually were made fit for human consumption either by genetic techniques (development of cotton varieties devoid of pigment glands) or physical-chemical processing of seed, then the value of cottonseed to the farmers might increase 25 to 50 percent or more (NRC 1975).

## NUTRITIONAL QUALITIES OF COTTONSEED PROTEIN

The quantity and quality of protein in cottonseed flour are high (Tables 4 and 5). Edible products now can be manufactured from cottonseed either by using glandless cotton varieties with little gossypol or by using special solvents or liquid cyclone processing (LCP) of seed of conventional glanded varieties to remove the gossypol. The cottonseed flour and isolates (90 percent protein) produced may be used as food additives in bread, pastries, meat products, fortified cereals, noodles and macaroni, dressings, sauces, gravies, puddings, beverages, and baby foods. Since the late 1950s, cottonseed protein has been a major ingredient in Incaparina, a low-cost, milk-like beverage used to combat malnutrition in Central and South America (Lyman 1966). It also has been used in the production of chapatis and other foods common in many developing countries with promising results. The protein in cottonseed flour is nutritionally equivalent to or better than other sources of nonanimal protein. The flour is more bland than soybean flour so its use in food manufacture may be greater than for soya products (Harrar 1975).

Cotton nuts, produced from the seed kernels of glandless varieties, also provide a source of protein for human consumption (Table 6). In May 1976, the U.S. Food and Drug Administration approved the use of glandless cottonseed in human food and permitted the sale of cotton nuts as a food additive for candies, snack foods, and bakery products.

Only one Texas supplier sold cotton nuts to major food companies in the United States in 1976. This supplier had 10,000 hectares of glandless cotton production contracted in West Texas in 1976 and hoped to produce 18,182 kilograms of cotton nuts per week the first year, then doubling production each year for the next five years. Peanut processing equipment will be used to sort, grade, and process the nuts according to procedures developed at the Texas A&M University Food Protein Research and Development Center (Piggs 1976;

Table 4. Chemical composition of glandless cottonseed flour*

| Substance | Percent |
|---|---|
| Moisture | 6.9 |
| Oil | 1.1 |
| Protein (Nx6.25) | 59.8 |
| Protein solution | 99.3 |
| Free gossypol | 0.017 |
| Total gossypol | 0.017 |
| Crude fiber | 2.2 |
| Total sugars | 13.2 |
| Color readings | 86.3 |

*Data provided by Food Protein Research and Development Center, Texas A&M University, College Station, Texas.

Table 5. Amino acid content of glandless cottonseed*

| Amino acid | Percent |
|---|---|
| Lysine | 4.0 |
| Histidine | 2.6 |
| Ammonia | 1.8 |
| Arginine | 11.7 |
| Tryptophan | 1.5 |
| Cystine | 2.4 |
| Aspartic acid | 9.1 |
| Threonine | 3.2 |
| Serine | 4.3 |
| Phenylalanine | 6.0 |
| Glutamic acid | 20.5 |
| Proline | 3.8 |
| Glycine | 4.2 |
| Alanine | 3.9 |
| Valine | 4.5 |
| Methionine | 1.4 |
| Isoleucine | 3.1 |
| Leucine | 6.0 |
| Tyrosine | 3.3 |

*Data provided by Food Protein Research and Development Center, Texas A&M University, College Station, Texas.

Table 6. Properties of glandless cotton nuts*

| Substance | Per 100 g (percent) |
|---|---|
| Protein | 40.0 |
| Oil | 39.0 |
| Moisture | 1.7 |
| Crude fiber | 1.7 |
| Sugar | 6.7 |
| Ash | 4.4 |
| Calories | 771 |

*Data provided by Food Protein Research and Development Center, Texas A&M University, College Station, Texas.

Carl Cox 1976, personal communication, Texas Natural Fibers and Protein Commission).

## Dietary Test Results

### United States

Chemical studies currently being conducted by nutrition specialists at Texas Woman's University show that cottonseed protein is adequate for protein maintenance purposes in adults; it can substitute for 50 percent of animal protein fed to children without loss of normal growth patterns. Further studies are underway on vitamin and mineral nutrition needs associated with the consumption of cottonseed protein (Alford 1975; R. M. Thomas 1977, personal communication, Department of Nutrition and Food Science, Human Nutrition Research Institute, Texas Woman's University).

### Africa

Nutritional studies involving food products made from glandless cottonseed have been conducted in several African countries (Roux 1975). In Senegal, tests proved the high nutritive value of glandless cottonseed flour for supplementing sorghum or manioc protein diets. Also, a study conducted with infants showed that glandless cottonseed flour could be used to produce high protein food comparable with the best commercially available baby foods. A sorghum meal/cottonseed meal food, supplemented with 10 percent milk powder, provided a very low-cost, high protein baby food of excellent quality and nutriment.

Tests in Mali showed that a mixture of 80 percent sorghum meal with 20 percent glandless cottonseed meal provided a highly nutritious product that would be acceptable for use in traditional foods.

In Chad, glandless cottonseed flour is being used to make a high protein food for children. The end product consists of sorghum flour mixed with 30 percent glandless cottonseed meal. Results have shown this mixture will more than meet the daily protein requirement of the children.

Tests in Africa show that cottonseed flour may be derived from locally produced seed and that food items can be manufactured to satisfy local tastes and customs.

## COTTONSEED SUITABLE FOR CONSUMPTION BY HUMANS AND NONRUMINANT ANIMALS

Presently there are two ways of making cottonseed products suitable for consumption by humans and nonruminant animals. One is by special processing of conventional glanded or glandless varieties using the liquid cyclone process. The other is to grow glandless varieties that are almost devoid of gossypol and process them with oil mill equipment designed and operated under the standards necessary for the production of human food.

### Liquid Cyclone Processing

The Southern Utilization Research and Development Division of the U.S. Department of Agriculture has developed a method involving the use of liquid cyclones in which more than 50 percent of the protein from conventional glanded cotton may be recovered as a protein concentrate with no more than 0.045 percent gossypol. This process separates the gossypol-containing pigment glands from finely ground cottonseed meats. The flour produced can be used as an additive to human foods or livestock feeds in the same way as soya flour or other vegetable proteins are utilized.

There is no doubt of the nutritional quality of the edible grade cottonseed flour produced by the liquid cyclone process. However, more research is needed on processing technology, mill design, and product development if the extraction of protein from glanded cottonseed is to meet its full potential.

### Glandless Cotton Varieties

Conventional glanded cotton varieties produce seed having small lysigenous glands that contain gossypol and other pigments, which impart a darkish-red color to the oil. Special refining and bleaching processes are required before the oil is suitable for use by humans. The meal produced is a yellowish-brown color and suitable for use only in rations of ruminant animals unless subject to special processing that removes the gossypol (Boatner 1948).

In the early 1950s, cotton geneticists of the U.S. Department of Agriculture Cotton Field Station, Shafter, California, discovered that the crosses and selections of the cotton, Gossypium hirsutum race punctatum, produced plants that had no pigment glands in the seed (McMichael 1959). These "glandless" cottons produce a seed from which the oil is light

yellow in color and requires a minimum of processing; the cottonseed protein is almost white.

The discovery of glandless cotton made it possible to reduce greatly the cost of seed processing and refining losses in making edible cottonseed oil. The glandless cottonseed protein also may be consumed with equal benefit by cattle, swine, poultry, and humans. Since the discovery of glandless cotton, plant geneticists have been able to incorporate the glandless characteristic into commercial varieties. Although a few commercial varieties of glandless cotton have been released and are being grown on a limited basis in the United States and parts of Africa, including Egypt, there are still problems of susceptibility to certain insects that must be resolved if these cottons are to ever be widely accepted by growers.

## Yield Potential

The backcross method was the first approach taken by cotton breeders in the development of glandless varieties. They believed they could use this method to incorporate the glandless genes into existing varieties and the U.S. cotton acreage might be converted to glandless production in a short time period. However, the transfer of glandless genes to conventional germ reduced yields in the resulting progeny approximately 10 percent (Hosfield et al. 1970, Kohel 1974, and Lee 1967).

Research has been underway for the past several years throughout the United States to improve the lint yield and quality characteristics of glandless cotton. Seeds of six glandless varieties are being sold in the Texas high plains. The yields and fiber properties of several of the glandless varieties presently being grown in Texas are equivalent to those of commercial glanded varieties (Ray et al. 1976). In New Mexico, a glandless Acala-type variety yielded 95 to 96 percent of the yields of the standard glanded Acala 1517V and 1517-70 varieties and the fiber length of the glanded variety was somewhat shorter. In California, yields of some glandless varieties over a four-year test period (1970 to 1974) were equal to commercial Acala types, but in some cases were reduced by attacks of Lygus sp. Roux (1975) reports from research conducted in Chad and Mali that yields, fiber properties, and gin turn-out of glandless varieties are as good as the commercially grown glanded varieties when both types are grown under suitable conditions. However, he reports that more research is needed in Chad, Mali, Upper Volta, Cameroon, and Senegal to further improve lint yields, hardiness, and adaptability of the glandless types to

various climatic conditions. In summary, the lint yields and fiber properties of glandless cottons have been improved in recent years. Many glandless varieties now have yields and fiber properties that are equivalent to conventional glanded varieties. More research is needed to maintain these properties and to improve adaptability to the various cotton growing areas of the world.

## Susceptibility to Pest Insects

Since the 1960s several reports have been issued in the United States that glandless cottons are more susceptible to attack by many insects than glanded varieties. In fact, most U.S. cotton researchers have taken it for granted that glandless cottons suffer more from pest insect attack than glanded varieties. This has been one of the major hindrances to their acceptance by commercial producers.

In the early 1960s, it was observed in tests at Tucson, Arizona, that the glandless experimental strain 30-8 was eaten in preference to either glanded Acala or Pima varieties by the beet armyworm, Spodoptera exigua; the bollworm, Heliothis zea; the black fleahopper, Spanogonicus albofasciatus; and the grape colapsis, Maecolaspis flavida. At Brownsville, Texas, an undetermined species of cutworm, beet armyworms, pillbus (Porcellio spp.), and rodents were observed to eat the glandless line before attacking glanded varieties (Bottger et al. 1964).

Later tests at Brownsville, Texas (Lukefahr et al. 1966) showed that larval growth of the bollworm and tobacco budworm, H. virescens, on glandless varieties was greater than on the glanded parental line. The glandless cottons also were attacked by the spotted cucumber beetle, Diabrotica undecimpunctata, while the glanded varieties were not. Infestation by the cotton fleahopper, Psuedomatecellus seriatus, was approximately the same on the glandless and glanded strains. There also was little difference between infestations of the boll weevil, Anthonomus grandis, on the two types of cotton. This has been confirmed by work in Georgia (Singh and Weaver 1972). It was interesting to note that oviposition by the Helicthis spp. was approximately the same on the glandless lines as on the glanded lines. Maxwell, et al. (1965) reported that the striped blister beetle, Epicauta vittata, stripped the lower leaves from certain glandless strains while not bothering the glanded lines. Leigh and Hyer (1971) reported that the western spotted cucumber beetle, Diabrotica undecimpunctata, damaged certain glandless lines in tests in California

while not bothering the "equivalent" glanded variety. Jenkins, et al. (1966) reported that the bollworm was no more serious on glandless Rex Smoothleaf and Deltapine Smooth Leaf varieties than on the glanded counterpart. However, damage was greater on glandless Acala than on the glanded Acala. Also, the glandless cottons suffered more damage from the cotton leafworm, Alabama argilacea. In 1975, field tests in West Texas, D. R. Rummel (1976, personal communication, Agricultural and Extension Center, Texas A&M University) was not able to measure any difference in bollworm infestations between glandless and glanded varieties. Tingey, et al. (1975) reported that Acala glandless was more susceptible to Lygus hesperus than glanded Acala. However, more recent results (Adkisson 1976) suggest that the incorporation of the nectariless character into glandless Acala may provide resistance to lygus.

Roux (1975) reports that in Chad the glandless varieties tested were very susceptible to flea beetles, Podagrica spp., which only infrequently attacked glanded cottons. However, this is an occasional problem that is localized and easily controlled. More importantly, the main pest insects of cotton in Chad, the lepidopteran bollworms, Diparopsis watersi (also a major pest of the Sudan Zone), and H. armigera were less serious on the glandless than on the glanded cottons. However, infestations of Erias insulana and E. biplaga were more severe on the glandless lines.

Roux (1975) also reports that in most cases in Chad and Mali insect problems have not been any more important for glandless than for glanded varieties when normal production practices have been followed. It is necessary, however, occasionally to treat for seedling pests such as flea beetles. He reports that the glandless varieties are being grown on a trial basis in Chad, Mali, Upper Volta, Cameroon, and Senegal, and that more research is needed concerning the status of insect pests and the measures needed for their control.

In summary, it has become almost axiomatic among cotton researchers in the United States that glandless cottons are more susceptible to insect attack than glanded varieties. However, careful examination of the available data shows that this may not always be true. It is true that glandless cottons may be attacked by various species of leaf-feeding beetles that are not pests on glanded varieties. Rodents also may be more serious pests on seeds of mature glandless cotton in the field than on glanded varieties. However, it does not appear true that major pest insects of cotton are always more serious on glandless than glanded varieties. This depends on the genetic background that is carrying the glandless character. For example,

bollworms may inflict more damage on glandless Acala 4-24-77 than the glanded counterpart, but incorporation of the glandless character into Rex and Deltapine Smooth Leaf varieties apparently has not affected their susceptibility to this pest. Lygus apparently prefer glandless Acala over glanded Acala but this may be overcome by breeding a glandless-nectariless line. In Africa, the major bollworm pests are no more serious on glandless lines than glanded strains. It is apparent that there is a great deal of variability among the genetic backgrounds of glandless cotton in terms of resistance (or susceptibility) to insect attack. This variability provides a good basis for selecting and breeding new glandless lines that are resistant (or at least neutral) to pest insects.

Glabrous, nectariless, high gossypol, and "X" factor are plant characteristics that confer some level of resistance to bollworms, lygus, fleahopper, and boll weevil. In addition, short season varieties that mature in about 140 days escape a great proportion of late season pest insect attack. These characteristics are being incorporated into glandless stocks in Texas, California, and Mississippi. This program could result in glandless cotton varieties that are resistant to most pest insects and no more susceptible to others than present glanded varieties. Such research should be accelerated so that entomologists and agronomists have enough glandless lines to develop the most profitable types for farmers to grow. Until that time, glandless cotton production in the United States will be confined to the low insect hazard areas of Texas and California.

## Economic Aspects

Under 1975 prices seed accounted for about 16 percent of the income farmers received for their cotton. For this reason, farmers are much more interested in yield and quality of the lint than of the seed. However, if producers are paid a sufficient amount for the seed, they will produce glandless cotton even if lint yields are less than for glanded varieties. If producers are given a $25 per ton premium for the seed, their income will be increased by less than $12 per acre. A $100 per ton premium will increase their income by $44 per acre. This is a 16 percent increase in the total value of the cotton. An increase in seed prices of $30 to $50 per ton probably would be sufficient to entice U.S. farmers to grow glandless cotton if they could be assured that they will not incur additional production expenses and if the value of the lint produced is the same as the

glanded varieties they are accustomed to growing. In the developing and centrally planned countries where the government exercises great control over cotton production, the conversion to glandless cotton might be made without any additional inducements to farmers.

## RESEARCH NEEDS

### Glanded Seed Processing

The liquid cyclone process is based on relatively simple procedures. However, the technical and engineering problems involved in the building and successful operation of such a mill are considerable. The difficulties experienced by the commercial-sized plant in Lubbock, Texas, are evidence that technical problems remain. Problems still exist in the sorting, grading, and handling of the seed; processing and handling of the meal; and in obtaining a uniform end-product that meets food standards. Present problems appear to be more technical than scientific. Still, small-scale testing and pilot plant facilities are needed for evaluating specific processing variables with indigenous seed produced in the different cotton-growing regions of the world.

Specific research needs in the United States are:

- Continue research on the effectiveness of the liquid cyclone and other processes for rendering glanded cottonseed fit for consumption by humans, nonruminant livestock, and poultry.
- Develop new processes and new products that enhance the usefulness of cottonseed flour and cottonseed products.
- Better utilize the cottonseed now being produced by incorporating it into economical food products that may be purchased by low-income and other families.
- Develop high protein food intermediates for export.
- Increase research on the fundamental physical and chemical properties of cottonseed and on those functional problems of interest in the development of food products.
- Develop pollution control procedures for cottonseed processing and food manufacturing facilities.
- Develop procedures and techniques for training scientists and engineers for the food processing industry and for governments interested in converting cottonseed protein for use in the diets of people.

Research should be continued for developing a liquid cyclone pilot plant suitable for the developing

countries. The plant could be used to evaluate processing variables, to adopt processing procedures to fit local needs, and to afford training for technicians and operators of commercial-scale plants. From local seed sources the plant also could provide cottonseed flour, kernels, or isolates for various human dietary tests and livestock feeding experiments. The market potential and acceptability of products also might be investigated.

## Glandless Cottonseed

Over the short term, glandless cotton varieties may offer the greatest promise to the developing ccuntries for increasing the amounts of cottonseed protein available and suitable for human consumption. This is primarily due to the fact that these seeds may be processed by existing oil mills, provided they meet human health standards. In addition, glandless seed may be processed in a new type of oil mill such as the one recently built in the Philippines to process coconut. However, in order for glandless varieties to be widely grown by farmers, lint yields and resistance to insects must be improved and the price received for seed must be increased.

Specific research needs are:

-- Expand existing research for varietal improvement, insect resistance, environmental adaptability, and improvement of yields and fiber properties.
-- Initiate new research to determine the basic mechanisms of insect resistance (or susceptibility) in glandless and glanded types, and to develop a reservoir of information for the development of new plant types.
-- Quantify with precision the levels of insect resistance (or susceptibility) present in existing varieties and identify areas where they may be grown with minimal pest problems.
-- Develop better integrated control procedures for combating the pests that attack present and new glandless varieties.
-- Incorporate into glandless lines early maturity and insect-resistant traits identified in glanded cottons, i.e., glabrous, nectariless, high leaf gossypol, "X" factor, and frego bract.
-- Improve present technology and equipment to process glandless cottonseed into products suitable for human consumption.
-- Continue nutritional, product development, and market acceptability tests required to establish glandless cottonseed products in the human diet.

-- Continue nutritional tests of glandless cottonseed with nonruminant animals in order to develop the best and most economical rations.

## NOTES

1. Although the word "food" is often used in this report without definition, caution is suggested in its interpretation. In examples of possible treatments of various food products, it would be cumbersome to list each time all the food sources such as cereals, fruits, vegetables, meat, nuts, fish, etc., or the processes used. The food or processes mentioned are intended to be illustrative rather than inclusive. Further, food is the mechanism by which proper nutrition can be provided.
2. Understanding of the research profiles may be improved by referring to a series of definitions discussed in Appendix A. Research profiles provide specific examples of each definition.
3. Detailed writings on these cases are available in Goldberg (1974); Harrison, et al. (1974); and various case studies compiled by the Harvard Business School in May 1976.
4. Some 1976 cases studies of Harvard Business School cover these in detail.
5. This appendix was prepared by Subgroup A of Study Team 1, but was included here since it directly supports research prepared in Profile 2 of this report. Contributions of Study Team 1A are acknowledged and appreciated by Study Team 6.

## REFERENCES


Adkisson, P. L. (1976) Development of Insect Resistance in Cotton to Minimize Use of Insecticides for Control of the Bollworm and Tobacco Budworm. The Rockefeller Foundation, New York, N.Y.

Albright, K., J. F. McClelland III, and W. H. Young (1976) A Case for Increased Cooperation Between Agroindustry Enterprises and Selected United Nations Agencies for Agricultural Development in Less Developed Countries. Harvard Graduate School of Business Administration, Cambridge, Mass.

Alford, B. (1975) Nutritional status of children consuming cottonseed protein. Oil Mill Gazateer 79:14-15.

American Society of Agricultural Engineers (1976) First International Congress on Engineering and Food: Digest of Papers. St. Joseph, Mich.: ASAE.

Anonymous (1975) Converting waste into food. Food Manufacture (United Kingdom) 50(6):17, 68.

Anonymous (1976a) Aids to Marketing--Food Product Development. Arlington Heights, Ill.: Arlington Publishing Co.

Anonymous (1976b) Oilseeds and Products. Foreign Agriculture Circular FOP 1-76:21.

Anonymous (1976c) Senate unit hears evidence of diet link to cancer. Food and Chemical News 18(20):29-36.

Boatner, C. H. (1948) Chemistry and Technology of Cottonseed Products. New York: Interscience Publishers.

Bottger, G. T., E. T. Sheechan, and M. J. Lukefahr (1964) Relation of gossypol content of cotton plants to insect resistance. Journal of Economic Entomology 57:283-285.

Canby, T. Y. (1977) The rat: lapdog of the devil. National Geographic 152(1):60-87.

Coursey, D. G. and P. H. Haynes (1970) Root crops and their potential as food in the tropics. World Food Crops 22(4):261-265.

Crosson, P. R. (1976) Relations Between Food Production and Processing and Distribution Alternatives and

Energy. Paper presented at the World Food Conference.
Food and Agriculture Organization of the U.N. (1969) Food Losses--The Tragedy and Some Solutions. Rome: FAO.
Food and Agriculture Organization of the U.N. (1976) Ceres 9(2):21.
Forman, M. (1975) Barriers to Initiating Food Delivery Systems. Proceedings of the International Food Delivery Systems Symposium, September 17-19, University of California, Berkeley.
Goldberg, R. A. (1974) Agribusiness Management for Developing Countries--Latin America. Cambridge, Mass.: Ballinger Publishing Co.
Goldberg, R. A. (1976) Multinational Agribusiness and Global Food Problems. Paper presented to the American Political Science Association, annual meeting, September 2, Chicago, Ill.
Grisanti, E. (1976) Food safety: fact or fiction? The need for a multidiscipline national safety program. Food Product Development 10(8):36-37.
Harrar, J. G., ed. (1975) Report and Recommendations for an Expanded Research and Development Program for Cotton. The Rockefeller Foundation, New York, N.Y.
Harrison, K., D. Henley, H. Riley, and J. Shaffer (1974) Improving Food Marketing Systems in Developing Countries: Experiences from Latin America. Research Report No. 6, Latin America Studies Center, Michigan State University, East Lansing.
Hosfield, G. L., J. A. Lee, and J. C. Rawlings (1970) Agronomic properties associated with the glandless alleles in two varieties of upland cotton. Crop Science 10:392-396.
Jenkins, J., F. G. Maxwell, and H. N. Lafeuer (1966) The comparative preference of insects for glanded and glandless cottons. Journal of Economic Entomology 59:352-356.
Kohel, R. J. (1974) Influence of certain morpholcgical characters on yield. Cotton Growing Review 51:281-292.
Kriesberg, M. (1970a) Food Distribution Research for Developing Countries, Paper presented to the Food Distribution Research Society, annual meeting, October 26, St. Louis, Mo.
Kriesberg, M., ed. (1970b) The Marketing Challenge: Distributing Increased Production in Developing Nations. Foreign Economic Development Report 7, Foreign Economic Development Service, U.S. Department of Agriculture (in cooperation with the U.S. Agency for International Development).

Kriesberg, M. (1976) Aid by International Organizations to Improve Food Marketing in Developing Countries. Paper presented to the FAO-OECD International Seminar on Food Marketing Systems in Developing Countries, October 18-22, Paris.

Kriesberg, M. and H. Steele (1972) Improving Marketing Systems in Developing Countries, An Approach to Identifying Problems and Strengthening Technical Assistance. Foreign Agricultural Economic Report No. 93, Economic Research Service, U.S. Department of Agriculture (in cooperation with the U.S. Agency for International Development).

Krochta, J. M., T. R. Rumsey, and D. F. Farkas (1975) Defining food R&D needs as a guide for the future. Food Technology, October:74-84.

League for International Food Education (1973) Resource recovery from food waste. Newsletter, November.

Lee, J. A. (1967) Some problems in altering the gossypol content of cottonseed through breeding. Journal of American Oil Chemists Society 46:124-125.

Leigh, T. F. and A. H. Hyer (1971) Susceptibility of glandless cotton to attack by Diabrotica beetles. Journal of Economic Entomology 64:319.

Lukefahr, M. J., I. W. Noble, and J. E. Houghtaling (1966) Growth and infestation of bollworms and other insects on glanded and glandless strains of cotton. Journal of Economic Entomology 59:817-820.

Lyman, C. M. (1966) Another Serving Anyone? Cottonseed Protein May Become Human Food. Texas Agricultural Progress, Texas Agricultural Experiment Station Extension Service, College Station, Texas.

Martin, E. G. and R. Ricklefs (1975) "Third world" presses to stabilize the prices of its raw materials. Wall Street Journal, July 3.

Massachusetts Institute of Technology (1975) Protein Resources and Technology: Status and Research Needs. MIT Department of Nutrition and Food Science, Cambridge, Mass., December.

Maxwell, G. G., H. N. Lefever, and J. N. Jenkins (1965) Blister beetles on glandless cotton. Journal of Economic Entomology 58:792-793.

McMichael, S. C. (1959) Hopi cotton, a source of cottonseed free of gossypol pigments. Agronomy Journal 51:630.

Meissner, F. (1975) Role of Development Banks in Structuring and Implementing Agricultural Products. Proceedings of the International Food Delivery Systems Symposium, September 17-19, University of California, Berkeley.

National Association of State Universities and Land Grant Colleges and the U.S. Department of Agriculture (1976) A National Program of

Agricultural Energy Research and Development. A report to the National Planning Committee of the Agricultural Research Policy Advisory Committee.
National Research Council (1973) Toxicants Occurring Naturally in Foods. Washington, D.C.: National Academy of Sciences.
National Research Council (1975) Pest Control: An Assessment of Present and Alternative Technologies. Volume III. Washington, D.C.: National Academy of Sciences.
National Research Council (1977) World Food and Nutrition Study: The Potential Contributions of Research. Washington, D.C.: National Academy of Sciences.
Owen, W. (1968) Distance and Development: Transport and Communications in India. Washington, D.C.: The Brookings Institution.
Parker, D. (1976) AID and agribusiness: the challenge before us. War on Hunger, U.S. Agency for International Development, September.
Piggs, C. (1976) Cotten protein approval opens food markets. Southwest Farm Press, Dallas, May 27.
Popking, B. M. (1971) Economic Benefits from the Elimination of Hunger in America. Discussion paper 102-71, Institute for Research on Poverty, University of Wisconsin, Madison.
Prinsky, R. (1976a) A tale of two nations. Wall Street Journal, May 10.
Prinsky, R. (1976b) One-crop economy. Wall Street Journal, May 14.
Prinsky, R. (1976c) Two edged sword. Wall Street Journal, April 7.
Ray, L. J., D. Bilbro, J. Supak, N. W. Wuthrich, and J. L. Davis (1976) Cotton Variety Test in the Texas High Plains, 1975. Technical Report No. 9, Texas A & M University Agricultural and Extension Center, Lubbock, Texas.
Roux, J. B. (1975) Glandless cotton growing in central and west Africa. Cotton et Fibres Tropicales 30:223-229.
Schumacher, A. (1975) Pakistan--Corn Products. Proceedings of the International Food Delivery Systems Symposium, September 17-19, University of California, Berkeley.
Scrimshaw, N. W., D. I. C. Wang, and M. Milner (1975) Protein Resources and Technology: Status and Research Needs. Report prepared for the National Science Foundation. Washington, D.C.: U.S. Government Printing Office.
Shaffer, J. D. (1968) A Working Paper Concerning Publicly Supported Economic Research in Agricultural Marketing. Economic Research Service, U.S. Department of Agriculture, March.

Singh, I. D. and J. B. Weaver (1972) Growth and infestation of boll weevils on normal-glanded, glandless, and high gossypol strains of cotton. Journal of Economic Entomology 65:821-824.

Society of Automotive Engineers (1976) Energy and Transportation. Publication No. SP-406. 69.

Southeast Asian Center for Graduate Study and Research in Agriculture (1973) The SEARCA Diary. Vol. II, No. 4, April.

Steinkraus, K. H. (1977) Enhancement of food quality by fermentation. International Agriculture (New York State College of Agriculture and Life Sciences) Vol. 4, No. 2.

Thor, E. (1975) Iran--PAK Dairy. Proceedings of the International Food Delivery Systems Symposium, September 17-19, University of California, Berkeley.

Tingey, W. M., T. F. Leigh, and A. H. Hyer (1975) Glandless cotton: susceptibility to Lygus hesperus. Crop science 15:251-253.

United Nations (1975) Food marketing. PAG Bulletin. Vol. 4 (Protein-Calorie Advisory Group).

U.S. Department of Agriculture (1968) Dietary Levels of Households in the U.S. Agricultural Research Service.

U.S. Department of Agriculture and National Association of State Universities and Land Grant Colleges (1976) Task Force Report on Quality of Food. Western Region Planning Committee, Research Program Group 5, Berkeley, California.

Vicker, R. (1975) New partners. Wall Street Journal, March 18.

Williams, W. F. (1966) Toward improved performance in agricultural marketing research. Journal of Farm Economics 48(3):Part 2, 37-72.

Report of Study Team 7

# RURAL INSTITUTIONS, POLICIES, AND SOCIAL SCIENCE RESEARCH

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## INTRODUCTION

Study Team 7 was asked to analyze how U.S. research and development could help strengthen the performance of the principal public and private institutions serving agriculture in the developing countries. And we were asked to give specific attention to research and development that would improve the performance of these institutions at the local level.

Our study team was divided into three subgroups. Subgroup A, "Policies and Program Planning," considered research and development that would strengthen continuing organizational arrangements for doing the socioeconomic analysis needed to support government and private policymaking and program planning. Subgroup B, "Research, Education and Training, and Extension," concentrated on research and development needed to improve the performance of research and educational institutions. And Subgroup C, "Finance, Input Supplies, and Farmers' Organizations," dealt with research and development to strengthen intermediate organizations[1] that facilitate food production, assist equitable participation in development, and promote rural health, nutrition, and family planning.

Research on institutions and policy tends to be in the domain of social scientists. Thus this study team is comprised predominantly, although not exclusively, of social scientists. Although the composition of the study team has undoubtedly given a social science bias to its report, no claims are made for the preeminence of social scientists or of social science research and development in solving the problems at hand. The joint efforts of engineers, biophysical scientists, economists, and other social scientists are required to solve many of the problems needing attention.

We also took the liberty of enlarging our assignment. In the first place, it was a general consensus of our group that, while research on institutions and policies per se is important, substantive research by social and other scientists in

certain of these institutions is of equal or perhaps of more importance. Therefore, we developed our own suggestions for research we judged to be important, although the other study teams already deal with some of the priority areas needing attention.

We also felt that a useful distinction could be made among the various kinds of research needed, and that recognition of this distinction would be of assistance to policymakers and others allocating research and development resources. Hence we will discuss these different kinds of research and will make suggestions which often emphasize how the means of allocating research and development resources can strengthen institutions and their capability for doing such research.

In our view, increasing the social science capabilities of the developing countries may be more important than specifically delineating the research upon which social scientists might work. Although the research capability of the low-income countries to solve agricultural problems is generally quite limited, the lack of social science capability is especially serious.

## THE PROBLEM

Most of the food and nutrition problems of the low-income countries will have to be solved in those countries. Recent projections suggest that it is most unlikely that the high-income countries can produce and transfer the amount of food necessary to meet the needs of the developing countries by 1985. Moreover, although measures can and should be taken to reduce the population growth rates that are an important cause of these projected deficits, balance between demand and supply will be attained in the next decade or two only by increasing agricultural output in the low-income countries.

To avoid stunted economic development, extensive hunger, and malnutrition, the low-income countries will have to strengthen their own institutional capability to identify and solve their food and nutrition problems and to increase the productivity of outside assistance in the form of research, capital, and training. The United States can help develop this problem-solving capability, and that is the subject of this report.

The policy environment in which biological and physical research take place is an important determinant of how effective such research can be in solving food and nutrition problems. A policy environment includes governmental investments, governmental price and trade policies, governmental

policies on research and education and training, and governmental policies related to income distribution and employment.

But good economic and social policies are inadequate as the sole basis of development, just as is biological and physical research. The low-income countries need to develop a diversified and for the most part decentralized set of institutions that can produce a larger agricultural output and distribute it equitably.

## Policies, Programs, and Projects

To increase their agricultural output and improve their nutritional status, countries must have the analytical and research capability to establish: appropriate policies, the means of translating these policies into effective programs, and the means of implementing the programs in the form of specific projects.

We want to emphasize the complementarity of economic and social policy with research and development activities designed to produce and distribute new production technology. Such policy plays an important role in determining whether biophysical research will be supported within a country, whether the results of such research will be imported from other countries, and whether the new knowledge will be adopted at the farm level. The analytical capability at the policy level will determine whether or not public resources will be allocated to support agricultural research and development efforts. But furthermore, it will determine whether the incentives exist to adopt new technology. Such incentives are determined by price and trade policies and by policies that determine how the benefits of technical changes are distributed among consumer and producer groups, among the owners of resources, and among the various sized groups of farms, ranging from pure subsistence farms to large commercial and corporate operations.

At a somewhat different level, social and economic policies determine what institutions evolve in a society, how the food produced by improved biotechnologies will be distributed and used, and what the nutritional impact of the distributed food will be. Similarly, policy, program, and project decisions redistribute the ownership of the means of production and thus the distribution of the income used to buy the food.

Effective social and economic policies require an analytical and research capability in institutions

organized to provide and analyze information relevant to food production and use. Also, decisions are required on institutions that control and monitor the performance of farms and households.

## Research and Educational Institutions

The return to research on new production technology is high. Likewise, the return to education and training is also high, emphasizing the complementarity between education and the introduction of new production technology. This complementarity arises in part because education helps people deal with disequilibria within their households, their firms, and their labor markets. Of course, such disequilibria frequently result from the introduction of technical change.

Much less research has been done on how research and educational institutions should be organized and on what kinds of such institutions are needed at particular stages of development than has been done on food production itself. Clearly, how these institutions are organized makes a difference. For example, the organization of a plant breeding institute influences the amount, quality, and perhaps the relevance of the new plant materials it produces. Similarly, a school's organizational arrangements and educational philosophy influence the type of students it produces and their capabilities of dealing with problems in both the farm and nonfarm sector. Thus we need to know more about optimal size, effect of linkages with correlate institutions, and means of control of educational and research institutions.

The educational and research infrastructure can absorb a sizable amount of resources, usually those that tend to be in critically short supply. Given these considerations, research on institutions, and how they can be more effectively organized and administered, was singled out for special attention.

## Intermediate Organizations

Forming and reforming intermediate organizations (IOs), which link individuals, families, and small rural firms with regional or national organizations, are difficult rural development tasks. Successful IOs play a valuable role in facilitating development. However, the limited number of successful IOs and the large number of feeble or defunct cooperatives, farmers' associations, community development organizations, family planning institutions, and rural

labor unions in the low-income countries are evidence of how difficult it is to develop and maintain effective organizations of this type.

Accelerated rural development is traditionally associated with an increase in the use of purchased inputs, larger commercial sales of output, and the need for more information to coordinate activities in rural firms and households. In some cases, traditional organizations can adjust, or small private firms may emerge, to provide additional services to reinforce this movement toward specialization. In many cases, however, new and more complex organizational forms will have to be tied into regional or national agencies to furnish developmental services. These new organizations may capture some economies of scale, allow higher levels of government to control or influence participants in the organization, provide the means by which members of the organization can exert pressure on higher levels of government, coordinate a number of closely related services, or introduce completely new services into rural areas. All of these are key elements in increasing the output of food and using it to improve nutrition.

## PRIORITY RESEARCH ON RURAL INSTITUTIONS, POLICIES, AND THE SOCIAL SCIENCES

This section is divided into five parts. The first part gives a generic classification of the kinds of research that might be done on food and nutrition. This is followed by a brief discussion of the organizations conducting the different kinds of research, and then by a discussion of the research needs themselves, divided according to (1) subject matter and problem-solving research, (2) disciplinary research, and (3) institutional research.

### A Generic Classification of the Kinds of Research

Scientists participate in three kinds of research on food and nutrition: (1) problem-solving research, in direct support of decision-making and action-taking entities; (2) subject matter research, designed to accumulate information from several disciplines that could be useful in solving the set of problems that requires that information; and (3) purely disciplinary research, to improve and expand the knowledge and techniques of concern to a particular discipline. Disciplinary research can be broken down into that

which is relevant and that which is of unknown relevance where relevance is defined with respect to a known problem or set of problems. Hence disciplinary research can be relevant to both problem-solving and subject matter research. In using the term problem-solving research, we refer to practical problems faced by private and/or public decision-making and action-taking persons or agencies, as contrasted to the problems solved in intellectual and academic circles to improve disciplinary and subject matter knowledge.

Confusion among problem-solving, subject matter, and disciplinary research results in administrative problems, improper evaluation, and inappropriate specialization on disciplines and techniques in doing problem-solving research. In addition, it results in inappropriate mixes of positive, normative, and prescriptive knowledge in problem-solving and subject matter research, and in the lack of disciplinary progress.

## Problem-solving Research

This kind of research is problem-specific and the problems are institutionally specific to decision-making units with power to execute. Typically, each practical problem involves knowledge from a mix of disciplines unique to that problem. Moreover, such problems are time-, place-, and institution-specific.

Individual academic disciplines make their own special contributions to understanding the technological, institutional, and humanistic aspects of the specific problems involving food and nutrition. The physical and life sciences, for example, contribute technological knowledge and information. The social sciences, on the other hand, contribute knowledge of both monetary and nonmonetary costs and benefits and of the institutional and human opportunities and constraints on improvements in these problems.

When disciplinarians participate in problem-solving efforts, they operate in a far different arena than when doing subject matter or disciplinary research. For the former, the objective is to help prescribe a solution to the problem. If the problem is at the public level, interaction is required with decision makers and affected persons (if they possess market, political, and/or military power). Even at the farm firm level, interaction among family members is essential.

## Subject Matter Research

Subject matter research is carried out in a vast array of research institutes and organizations. Some of these organizations are para-societal, others are para-academic, and still others are quite independent of governments and universities. These organizations are scattered along a continuum between problem-solving and disciplinary research. Those near the disciplinary end tend to be more specialized with respect to groups of, or even specific, disciplines. Of course, the organizations vary in their relevance to solving food and nutrition problems.

Subject matter research, like research on a specific problem, is multidisciplinary in nature. In the case of subject matter research on food, nutritionists, plant breeders, soil specialists, and irrigation engineers often contribute information useful in solving a set of problems. Economists provide information on monetary costs, prices, incomes, and expenditures as well as nonmonetary costs and benefits. Other social scientists study the motivational and humanistic aspects of food and nutrition problems.

Subject matter research on food problems can be extremely valuable, even if the work is not done directly on a specific problem of a specific public or private agency. Similarly, institutes of human nutrition play useful roles in society. Such institutes are typically multidisciplinary--food and nutrition involve the physical and life sciences as well as the social sciences.

One of the first steps in subject matter research is to define the set of problems for which a specific kind of information is being accumulated and analyzed. Although subject matter research has some of the characteristics of problem-solving research, its immediate objective is not a prescription for a specific problem.

In connection with subject matter research, disciplinarians are expected to contribute disciplinary excellence with respect to the theories, empirical information, and quantitative techniques of their discipline, and to cooperate with other disciplines in organizing and interpreting this information. It should be stressed, however, that the multidisciplinary nature of subject matter research does not make disciplinary excellence unimportant.

## Disciplinary Research

Social science disciplinary research relevant to problems involving food and nutrition includes theoretical and empirical work as well as work on quantitative techniques. An example of disciplinary economic research is that on improving theories of public and private decision making under risk and uncertainty. Each social science discipline needs to develop its basic theory, data, and techniques. Support of fundamental disciplinary research in the social as well as the physical and life sciences is necessary if we are to solve the world's food and nutrition problems.

## Organizations Conducting this Research

An examination of the organizations doing food and nutrition research reveals many examples of the three kinds of research currently being conducted in the developing countries in international organizations, and in the United States (see Appendix A). A study of these organizations demonstrates their extreme heterogeneity with respect to (1) systems of organizational control; (2) centralization and decentralization; (3) powers of execution; (4) resources available and devoted to the three kinds of research; and (5) interactions among the organizations doing the problem-solving, subject matter, and disciplinary research.

The major systems of organizational control are public and private, between which is a continuum of intermediate forms. In terms of problem-solving and subject matter research, the developing countries seem to be turning to semipublic forms of control (e.g., the Brazilian Public Corporation for Agricultural Research). The shift to this kind of organization seems to occur when entrenched governmental and academic organizations are unable or unwilling to respond to important problems, and the existence of social benefits limits exclusive private involvement.

Differences among the developing countries with respect to centralization, decentralization, and powers of execution are common. These differences often reflect the political and economic philosophies of the ruling class and may change abruptly as individual governments rise and fall (e.g., Chile). Insecurity and instability of research organizations, particularly at the problem-solving and subject matter levels, are common in many developing countries. Social science departments in some developing countries are also highly unstable due to political reasons.

The quantity and quality of resources devoted to the three kinds of research vary greatly among developing countries and international organizations. Social science research on food and nutrition problems is virtually nonexistent in many developing countries.

Lack of interaction among organizations conducting the three kinds of research is common not only in the developing countries but also in the United States and in international organizations. What interaction that does occur often involves disciplinary and subject matter groups and excludes problem-solving agencies. Interactions among developing country, U.S., and international research organizations tend to be among individuals doing similar kinds of research, e.g., U.S. disciplinarians with developing country disciplinarians, international subject matter specialists with developing country subject matter specialists, etc.

## Subject Matter and Problem-solving Research Priorities

Food and nutrition are more subjects than they are problems to be researched. Generally, to speak of the food and nutrition problem or even of the food problem is to be ambiguous in a decision-making, action-oriented sense. Decision makers face an almost infinite number of problems involving food and/or nutrition. Each one requires information not only about food and/or nutrition, but also about many other things.

The selection of specific social science research problems involving food and nutrition is difficult, since the problems are time- and space-specific. They are conditioned by the particular circumstances in which a country or region finds itself, and can change rapidly from one year to the next. For instance, just a short time ago the United States had surplus disposal problems and export promotion was widely practiced. This quickly turned to food shortages and the need to impose export embargoes in order to channel available supplies to the domestic economy. And now the United States may soon engage once again in export promotion to reduce its agricultural surpluses.

Fortunately, there is more stability with respect to sets of problems than with respect to individual problems. This stability makes it relatively easy to make long-term plans for subject matter research of international significance. At the disciplinary level, it is even easier to make long-term research plans of interspatial significance.

In the following sections, we illustrate country-, time-, and institution-specific subject matter research of high priority. This is followed by an example of problem-solving research. The next section then gives suggestions of high priority disciplinary research.

We start with subject matter research because it is more relevant to problems than is disciplinary research. Also, it has more stability in time and space than problem-solving research and is less specific to particular institutions. The presumption is that all three kinds of research are important in solving problems involving food and nutrition, even though they are quite different with respect to objectives, resource requirements, timing, administrative needs, and evaluative procedures. Thus none of the three is denigrated by listing them separately, nor does their order indicate a sense of priority. Instead, we seek a constructive clarification of research needs and implementation.

## Developing and Adopting New Agricultural Technologies

Subject Matter Research. Research on adoption processes, the economics of new technology, and associated investment decisions should have high priority.

Such research can contribute to the resolution of food and nutrition problems in two ways. Evaluation at the firm level can indicate what the firm will gain by adopting new practices or inputs, which may stimulate the adoption at a more rapid rate. Evaluation at the aggregate level can show policymakers what is to be gained from extension programs that take new practices to the farmer, and the potential contribution of the production and distribution of new and improved inputs. These in turn can provide a guide to obtaining the maximum output from scarce development sources and, perhaps more importantly, provide a basis for obtaining additional development resources for the agricultural sector.

More analyses of farming systems and management at the firm level are needed to guide the adoption of biophysical technologies. Specific attention should be given to:

-- Researching the designs of farming systems, including systems analysis of farming and cropping systems and the management of soils and water (see Study Team 4's report).

-- Studying the investment and disinvestment decisions involved in adopting new and disinvesting in old technologies.
-- Researching managerial processes whereby farmers (1) learn about new technologies, institutional changes, and changes in people; make decisions; execute decisions; and bear responsibility for actions taken; and (2) bear and take risks, both formally and informally.

Research in this area is inherently multidisciplinary. Knowledge is required from the biophysical sciences and disciplines as well as from engineering, the social sciences, and the administrative-management sciences.

Problem-solving Research Example. Improved varieties of sorghum have been developed for northeast Brazil but introducing them will not be an easy task. In the first place, under "normal" weather conditions corn will yield more grain per hectare. However, sorghum will produce more under the stress of periodic droughts in the region.

In addition, corn is produced in the region in a complex system of crops and livestock and with intertwining tenure arrangements. A combination of perennial cotton, corn, and edible beans dominates the cropping pattern. The cotton is produced primarily for the landlord and is the main cash crop in the area. The corn and edible beans are primarily the tenant's. Landowners also own cattle, which normally graze the stubble and remains of the crops in the dry season.

The tenure system is complicated, with the tenant required to work a certain number of days for the landlord at lower wages than the prevailing rate. On the other hand, the tenant receives milk and medical care from the landlord. Clearly, the tenure arrangement is such that the landlord pays the tenant in kind with land in exchange for labor services for his own plot.

This cropping-livestock system strongly resembles an informal insurance scheme to protect against the highly variable weather. Similarly, the complicated tenure arrangements provide a means of sharing the risk, as well as of dividing up the output from the interdependent production process.

Given such a complicated system it is obvious that just producing an improved variety of sorghum is not sufficient to assure its adoption by the producers. The variety and crop have to fit into the system. Questions of timing, weed and pest control, and fertilizer response are important. And the new crop may have implications for the tenure arrangement as well, since its adoption may influence the distribution of risk-bearing and the distribution of income. Unless

the new crop is compatible with the existing production system and tenure arrangement, new arrangements for both will have to be worked out. Hence biophysical and social scientists will have to work together.

How does one evaluate the impact of research on this problem? Northeast Brazil, the largest poverty area in the western hemisphere, has a high level of malnutrition. Some 30 million people live in the region, with 60 percent of the population classified as rural. Not all of them use this same production system, of course, nor is the sorghum yet adapted to the whole region. But tenure and cropping patterns such as these are common in the region. Clearly, the quantitative impact of solving this problem could be large, measured either in terms of output, well-being of the population, or nutrition.

The difficulty is in attributing the impact of a solution to the problem to any of the disciplines involved. Clearly, without the appropriate social science research, it is less likely that the improved varieties will be adopted. If one takes the limiting factor argument seriously, then all or most of the benefits could be attributed to the social science research. By the same token, without the improved variety, or without the other technical knowledge required, the institutional and economic research would be largely academic. In this sense, and again using the limiting factor argument, all of the expected benefits could be attributed to the biophysical research. Clearly, neither approach is valid; both types of research are required, and the impacts cannot be imputed to one or the other of the two kinds of research.

Problems similar to the one described for improved sorghums arise quite frequently when new crops or improved varieties are introduced into a traditional production system. Problem-solving research is highly time- and location-specific, however, which points up the difficulties of establishing generalizable research priorities. But in the individual instance, knowledge generated by the research would be valuable to farm operators, to the director of the agricultural research station who could use it in shaping a biological and physical research program, and to government planners and policymakers who would use it to bring about changes in the tenure arrangements between landowners and sharecroppers.

The subject matter research, on the other hand, would add to a body of knowledge that would backstop analysis of the problem when it arose in an individual instance. This should contribute to a more rapid solution to the problem when it does arise.

Agricultural Marketing

Subject Matter Research. Improved production and distribution depend on improved markets for agricultural inputs, including land, credit, and labor, as well as product markets (see Study Team 6's report). This research would include work on regional marketing problems and customs unions (e.g., European Economic Community, Latin American Common Market, etc.) and other factors which change comparative advantage within countries and on a world scale, such as transportation, port facilities, storage, and communications.

Of immediate concern is research on marketing systems to improve the delivery of high quality inputs such as fertilizers, pesticides, herbicides, seeds, and tools. This research is particularly important in cases where new technologies are being introduced. Research also needs to be directed toward price elasticity of demand for fertilizer, especially in countries with limited land.

The performance of input and product markets under differing conditions of competition is not well understood, especially under conditions characteristic of the developing countries. The economic models of imperfect competition need to be expanded to include more noneconomic variables such as status and coercion. This implies multidisciplinary research with economists, sociologists, anthropologists, and political scientists cooperating in an effort to specify and quantify such variables.

Problem-solving Research Example. Argentina has a constraint on its port capacity, which limits its capability to respond to market opportunities abroad, especially in rapidly changing international markets. Research that analyzes this problem and designs a solution, when combined with appropriate government investments, can have far-reaching consequences.

The consequences of this marketing barrier to Argentine grain producers can be measured in terms of income foregone. A $10 per ton differential on a million tons of grain is a sizable amount of income lost, with a consequent loss of incentives to produce at efficient levels.

The consequences go beyond this, however. Market barriers and inefficiencies such as these are the source of instability in international markets. They cause poor people to pay higher prices for grain than they would otherwise pay, and create risk and uncertainty for producers in other countries.

The solution to a market barrier problem such as Argentina's limited port capacity would be of value to public planners responsible for investment decisions. It would guide them in knowing how to improve the port,

and, if complemented with estimates of the income foregone as a result of the bottleneck, would indicate how much the government could afford to pay to eliminate it.

## Income Distribution

Subject Matter Research. Equity in the distribution of assets, rights, and privileges, and access to sources of power is as important to improving the world food and nutrition situation as are the more direct measures taken to increase output (see Study Team 12's report). Although it is difficult to measure the superiority of one distribution of assets, income, or privileges over another, it is recognized increasingly that broad-based participation in the development process is imperative. Extreme inequities in the distribution of income are unlikely to be tolerated, either within a country or among countries. And this suggests that particular attention needs to be given to the distribution of ownership of property used to produce income. Important subtopics include: labor markets and employment opportunities; access to education and training; land tenure; water rights; fishing rights; grazing privileges; the productivity, rights, and roles of women and children; access to political processes and public presses; and access to new technology and to other public services such as credit, health, and police protection.

Each of these subtopics has an influence on the distribution of income within a society. Tenure arrangements influence how income streams are distributed among resource owners. Access to employment opportunities and to public goods such as education, new production technology, and health services is often precluded from low-income groups. This results in an underinvestment in human capital and the failure to adopt readily available technical knowledge. It also limits the accumulation of both human and nonhuman capital, which is important in light of the fact that the bulk of capital accumulation for output expansion occurs at the farm-household level.

Problem-solving Research Example. Chile's land reform in the Allende period was a combination of group farming and private small plots (Valdes 1974). Recipients of the land were given the right to till the small parcels on their own, but the rest of the land was farmed on a group basis. Modern inputs were supplied to the beneficiaries of the land at low cost with the idea that they would be used on the group plots. Unfortunately, it appears that the bulk of these subsidized inputs and the bulk of the labor input

were allocated to the small privately held plots. The result was inefficient in that the bulk of the land received only a small proportion of the other inputs.

Although the recipients of these inputs undoubtedly had their income position improved, the distortion in factor proportions, together with other problems, caused agricultural output to decline dramatically. The deleterious consequences did not stop there, however. Food imports increased substantially and scarce foreign exchange that could have been used for developmental purposes, including fertilizer, was used to import food.

Perhaps as important as either of these factors is the fact that the reform did not benefit the poorest sector of Chilean agriculture, about 50 percent of the campesinos. Rather, it benefited the higher income wage earners who were better organized.

Other than these descriptive figures, there is little that one could say about impact. Clearly, the reform did not attain its avowed goals. Whether appropriate analyses could have prevented Chile's tragedy is unanswerable. However, well-executed, problem-solving research at the appropriate time and available to the right decision makers should have provided a correct prediction of the outcomes of the land reform policy.

## Health, Nutrition, and Population

Subject Matter Research. Family size has an important influence on per capita income, the amount of savings accumulated in the family, and the form in which that capital is invested among human and nonhuman forms. Upgrading human capital through adequate health and nutrition is as important as upgrading human capital through improved education and training, although both are rather badly neglected subject matter areas.

Important research needs relative to these problems include:

-- Studying the relationship between health, nutrition, and individual performance in such things as work, learning, disease resistance, lactation, and fertility (see Study Team 9's report).
-- Determining how agricultural development patterns and strategies influence individual and family nutrition. For example, does the shift from diversified to specialized cropping systems result in short-run declines in the nutritional status of some rural workers and their families?

-- Investigating the cost-effectiveness of alternative arrangements for the delivery of nutrition, health, and family planning services to rural people. The emphasis should be on assessing the feasibility and cost advantages of a composite package approach to the delivery of these three services.
-- Determining effective methods of reorienting health services away from simply curative care, and toward emphasis on nutrition education and other preventative activities.

Problem-solving Research Example. In Chile, as in many other countries, many children are malnourished. Research has shown that at an early age this malnutrition affects the future productivity of the individual. A recent study (Selowsky and Taylcr 1973) using survey data from Chile shows that the investment in a two-year free milk program for malnourished children would yield a social rate of return in the range of 19 to 25 percent. This compares favorably to a social rate of return of 17 percent for investments in primary schooling, 15 percent for secondary schooling, and 15 percent for ordinary physical capital.

This example shows that investments such as these could increase the future output by raising productivity. Research that could identify such investment opportunities and that could design the systems by which such malnutrition problems can be alleviated obviously has a high payoff to society. The knowledge would be useful to government decision makers in allocating their scarce development resources, as well as to private decision makers in showing the importance of improved nutrition.

## International Trade Policy

Subject Matter Research. Special attention should be given to tariff and nontariff barriers to trade, their consequences, and the means to change them, and to exchange rates, capital flows, foreign aid, and food aid (see Study Team 10's report). Many countries seriously discriminate against their agricultural sectors by means of trade policies. Exchange rates are overvalued, export quotas are imposed, and capital flows are impeded, often as a by-product of import-substituting industrialization policies. Food aid often causes prices to farmers in the recipient country to decline, thereby providing a disincentive to invest and produce in the agricultural sector. Equally as important, food aid enables the government of the recipient country to avoid making the public

investments and establishing the price and trade policies that would culminate in a productive agricultural sector.

Problem-solving Research Example. Brazil was discriminating against its agricultural sector by a policy of overvaluing its exchange rate and imposing quotas on exports of selected products such as corn. The consequence was lower market incentives to produce and therefore a reduction in agricultural output. Fewer exports also resulted, thereby creating balance-of-payments problems, and in turn stifling development projects dependent on foreign exchange. Still further, by changing the price of corn relative to the price of fertilizer, this policy made the use of fertilizer unprofitable. This in turn reduced the incentive to use hybrid corn, with the result that the country failed to capitalize on its considerable capability to produce improved hybrid lines. The result was a low rate of return on private and public sector investments in agricultural research.

Not all of these impacts of this policy can be readily evaluated. But a recent study (R. L. Thompson and G. E. Schuh, "Trade Policy and Exports: The Case of Corn in Brazil," mimeo, Purdue University) showed that the elasticity of excess (export) supply for corn was approximately 15. At an overvaluation of 20 percent--a reasonable figure during the post-World War II period--exports would have increased 475 percent if an equilibrium exchange rate had prevailed. This represents a potential increase in exchange earnings of approximately $60 million a year for a crop that was relatively unimportant as an exchange earner. When this figure is applied to an export multiplier, the impact on the economy is indeed large.

The dead-weight welfare loss to the economy as a result of this policy was on the order of 1 to 2 percent of the value of the output of the sector, and corn is a relatively important component of the Brazilian agricultural sector. The policy also redistributed income from the relatively low-income farm sector to the upper income urban consumers. At the same time, it annulled the effect of rather sizable investments in research designed to produce improved varieties.

The Minister of Agriculture could have used the knowledge gained from such research in negotiating with the Minister of Finance to change this policy. Alternatively, by means of such research, the Minister of Finance might have changed the policy of his own volition. The Planning Minister, on the other hand, could have decided that as long as such policies continued, biological research on corn would have a low social rate of return, and therefore would have decided

to allocate the country's scarce development resources elsewhere. Similarly, private companies doing biological research on hybrid lines may have decided to allocate their resources elsewhere.

## Water Management

Subject Matter Research. Water is a high payoff input once improved varieties and cheap fertilizer become available. Efficient use of water requires that its flow be controlled, that it be priced according to its marginal opportunity cost, and that it be husbanded with care. However, once water is used on an expanded scale many drainage problems arise. Water management for both irrigation and drainage often involves intercountry river basins and access to lakes--problems that cannot be solved without collaboration among countries and the development of multicountry institutions.

Technical knowledge about soils, water, and plant response to water is required to devise solutions to these problems. Similarly, knowledge of water rights and legal rules--both nationally and internationally--is needed, as is knowledge of the economic and social costs of water, the investments required to make it available and to control it. Political scientists can make an important contribution to establishing appropriate institutions, as can sociologists and representatives of the administrative sciences.

Problem-solving Research Example. In many areas of India water for irrigation is charged at a flat fee per hectare. This gives the producer no incentive to economize on the use of water, nor to allocate it to its highest use. The result is wastage of a critical input, inequitable distribution of the water among individual producers, and the sacrifice of considerable output.

We know of no estimates of the impact of this policy. However, it should be noted that with an unstable monsoon, water management is critically important to the development of Indian agriculture. The availability of improved, fertilizer-responsive varieties of wheat and rice has increased considerably the private and social value of water, and thereby made its efficient use ever more important. The failure to use efficiently the available water reduces the payoff from the breeding program that produced the improved varieties.

## Forestry

Subject Matter Research. Forestry and wood products compete with food products for the use of land. Forests and wooded areas are often destroyed to supply fuel for encroaching populations and to make land available for growing crops. In many cases, this is an inappropriate use of the land, leading to erosion; problems of water control; silting up of rivers, lakes, and reservoirs; and the permanent loss of land to productive use. We need to learn more about the ecological systems that describe the interaction among forests, climate, and water systems, and about the trade-offs among uses of land for forests and for agricultural products.

Problem-solving Research Example. The growing population in the hill country of India has resulted in the denuding of terrain that can only be described as mountainous. Extensive soil erosion has resulted from the use of the forests for firewood. The consequences of this situation are twofold: (1) the permanent loss of a productive asset in the form of land that could support a forest resource if well managed; and (2) the silting up of a large reservoir, constructed at considerable public cost, at approximately three times the expected rate.

## Price Policy

Subject Matter Research. Price policy has been a rather neglected aspect of policy research, but it should receive special attention as it affects both the price of agricultural products and the price of modern inputs, credit, and other factors of production. Farmers are motivated by price incentives, and their level of output will be determined in part by relative price ratios. Moreover, whether or not they adopt new innovations is also partly determined by whether they have adequate price incentives (see Study Team 6's report).

To illustrate the importance of such research, it should be noted that political pressures from urban groups often cause prices to be set below their equilibrium or optimal levels. The consequences are lower agricultural output, reduced payoff to biological and physical research, and a flow of resources (including labor) from agriculture to other sectors--often prematurely or nonoptimally. Again, multidisciplinary research is required to devise solutions to this problem, including collaboration between political scientists and economists to

understand the forces shaping economic policy (see Study Team 10's report).

Problem-solving Research Example. The Nigerian government has used marketing boards as a means of taxing the agriculture sector. The marketing board served both as a monopsony purchaser of palm oil from producers and as the single Nigerian seller of the product in the international marketplace. It paid the farmers a lower price than it received on the foreign market, keeping the difference as a tax.

Although obviously an effective means of extracting resources from the agricultural sector, this policy was inefficient in that it undervalued domestic resources and income opportunities in relation to their international opportunity costs. In addition, this form of taxation acted as a strong disincentive since it affected the marginal incentive price of the product to the farmer. If the supply curve of the product has an elasticity of 1.0, a 10 percent "tax" would have a 10 percent effect on output. However, not all of this would be a dead-weight loss, since the resources would presumably have some alternative use in the domestic economy. But the loss could be sizable for a sector as large as the Nigerian palm oil sector.

An additional loss arose because the government was spending research money on new varieties to promote an increase in output at the same time that it was making the production of palm oil unprofitable with the marketing board policy. In a real sense the output of critical research and development resources was being cancelled as a result of a contradictory government policy.

## Systems Modeling

Subject Matter Research. Modeling skills are required at all levels, from enterprise to farm to subsector to sector to economy to global systems. In addition, there is a need for biophysical modeling of plant and livestock biological processes, and for work on pesticide problems, energy, and hydrologic processes.

The development of sectoral models (and components) of general value in solving problems involving food and nutrition is of high priority. Among components of particular importance are those on demography (including migration), investment, disinvestment, income distribution, social indicators, behavioral components based on more realistic decision-making assumptions, and environmental impacts. Particularly needed are short-run models and components dealing with the management of food grain systems at the national

level, and components linking national aspects of the agricultural sector to regional subdivisions, to nonfarm sectors, and to international markets.

Also needed are global models capable of dealing with the world's diversity vis-a-vis human/land ratios, population pressure on food supplies, income levels, technical skill, political power, military power, ability and willingness to control birth, and likely rates of starvation and disease. Also, the positive relationship between global heterogeneity and stability (freedom from large nutrition, disease, and military disasters) needs to be researched.

What is envisaged under this item is an eclectic, unspecialized approach to modeling which includes information from any relevant source or discipline, and technique, free of epistemological bias. It is not specialized on Forrester's dynamics, linear programming, input-output, benefit-cost, or any other technique, although, of course, none is excluded from consideration.

These components need to be tested in problem-solving situations. A software library organization is needed to store this important form of social capital, along with the necessary advisers and consultants. Past investments in developing modeling skills and software will not be fully utilized until the institutional means for pooling and sharing the knowledge acquired are provided.

Problem-solving Research Example. The U.S. government now finds itself at an impasse in agreeing upon an international reserve policy for grains. This impasse arises in part because of disagreement over, and lack of knowledge about, who will receive the benefits of such reserves and who will pay the costs. The results are rather unstable grain markets, fluctuations in prices which give false signals to producers and consumers, and redistribution of income between producers and consumers, both within and among countries. The increased risk and uncertainty probably acts to lower the output of grains.

The appropriate modeling of international grain markets could provide insights into what size reserves are required, and into the distribution of costs and benefits both among countries and among producer and consumer groups. Such knowledge would be the first step on the path to obtaining a rational policy. It is difficult to say what the value of such an improved policy would be other than to say that it would be large, since it would affect the allocation of an important share of the world's agricultural resources, and the income of great numbers of people.

## Disciplinary Research Priorities

Disciplinary research in the social sciences has essential contributions to make to the solutions of food and nutrition problems. Research on theory and quantitative methods of analysis will be emphasized as the priority areas in this section.

The social sciences that appear to have the most potential for food and nutrition research are economics, political science, sociology, anthropology (cultural and physical), and demography. Study Team 7 was comprised largely of economists; consequently, the disciplinary research areas listed below do not adequately represent the needs of the other social sciences. The needs of political scientists, sociologists, anthropologists, and demographers should be given consideration as total research programs are expanded in the social sciences. Each discipline must define its specific research needs. Thus the research proposed here is much more illustrative than implicit with regard to the needs of other disciplines.

### Theories of Decision Making

Improved theories of decision making under risk and uncertainty are needed for both public and private decision makers. Economists, sociologists, psychologists, and anthropologists should contribute to this work. Much of this research will involve improved quantitative models including successful research developed in industrial management decision making.

### Behavioral Research

Knowledge gaps still exist in the theoretical development of such topics as adoption behavior, the formation of human capital, migration decisions, and the social determinants of food preferences and food preparation practices. Contributions by sociologists, economists, anthropologists, and psychologists are needed. As an example of the importance of this area of research, it does little good to develop new inputs and products if producers and consumers will not accept them for social and/or cultural reasons.

### Theories of Investment and Disinvestment

"User-cost theory" needs to be more fully developed in order to increase our understanding of when it pays to invest or disinvest in durables rather than to

change the rate at which services are extracted from existing durables. Growth in capacity to produce food takes place when investment exceeds disinvestment, but changes in food production take place by changing the rate at which services are extracted from such food-producing durables as land, tractors, family and operator laborers, equipment, livestock, irrigation equipment, and buildings.

In agriculture most of the capital is accumulated at the farm-household level. Such accumulation by the family is the key to the personal distribution of income and the productivity of the household's resources, but our ignorance is vast in this area. Family size often influences the choice between human and nonhuman forms of such capital, as does what access disadvantaged groups have to public services and available labor markets.

## Organizational Theory

Advances in organizational theory have been considerable in recent decades. Yet systematized knowledge about such things as how to do multidisciplinary research is sorely lacking. Lack of such knowledge is critical, especially in light of the fact that multidisciplinary research is a frequent recommendation of this report as well as of others dealing with the organization of research. Successful examples of multidisciplinary research in the United States and abroad often exist on an ad hoc basis and are not institutionalized as part of a regular research operation.

Similarly, organizational theories are sorely lacking for the study of institutions critical to development. We only have the rudiments of a theory of institutional change. Until such a theory is available, institutions can be analyzed only in a descriptive fashion. Similarly, prescriptive knowledge will be available only on an ad hoc basis, and nct from a systematized body of theory or knowledge.

## Nonmonetary Objectives

The development of a measurement of nonmonetary objectives and values requires contributions from economists, ethicians, psychologists, and sociologists, among others. Such measures are needed in evaluating technological, institutional, and human changes to solve food and nutrition problems. Such changes have distributive effects, even when they increase food production and consumption. However, the solution for

many food and nutrition problems will inevitably involve either (1) deliberate redistribution of resources to produce income for the poor, or (2) malnutrition and starvation. Making correct decisions on such distributions requires interpersonally valid measures of nonmonetary values.

People tax each other, starve, go to war, or die over redistributive questions involving access to food. Yet there is little that one can say about a redistribution of income that makes one person better off at the expense of another, even though most shifts in income distribution are of this kind. Until knowledge is available that will permit the treatment of such questions, policies will be determined by the weight of political forces and not by rationality.

## Theoretical Relationships between Employment and Inflation

Although recent events in the United States have led some economists to write about the "unique" problem of unemployment and inflation, it is a common and far more serious problem in most developing countries. The continual controversy among economic theorists suggests that further research is needed. Advances in theory could have impressive impacts on such pressing problems as poverty, income distribution, and international trade.

## Theoretical Relationships between Commodity Price Changes and Inflation

More research is needed on the theoretical relationships between changes in the prices of individual commodities or groups of commodities (e.g., wheat, petroleum, food, and energy) and general inflation. Although the "accepted wisdom" of the press, intellectuals, agricultural and nutrition research administrators, labor leaders, and politicians is disastrously inadequate in view of what is known about these relationships, more disciplinary research is still needed. Mistakes in dealing with such relationships can adversely affect food production, make it necessary to ration food, unduly concentrate incomes and access to food, and inflate economies while attempting to hold down food prices. While the need for research on this relationship becomes apparent when solving problems and doing subject matter research, theoretical research on the relationship is disciplinary and of great practical importance.

## Use of Time in the Household

Recent theoretical breakthroughs in economics have put the value of time on an equal footing with the cost of goods and services in determining the price of final commodities in consumption. This breakthrough requires a revision of currently received demand theory. By focusing on the value of time in the household, it also provides important insights into the supply of labor a household offers to nonhousehold activities, into the demand for children as influenced by the trade-offs between quantity and quality of children, and into the investment in human capital. Extensions of the theory provide a means of explaining marriage and other social actions heretofore treated largely on an ad hoc basis.

Substantial progress has been made in this theory in recent years, and it shows great promise for explaining population growth rates, investments in human capital, and other activities pertinent to the development process. High priority should be given to further work in this area as an input into the subject matter areas discussed earlier.

## Institutional Research Priorities

Because our initial charge stressed research on improving organizations and institutions, this research is presented separately from the previous discussion of priority social science policy research. Research on institutions serving agriculture is largely in our subject matter research category. However, disciplinary developments and "action-cum-research" activities with respect to organizations and institutions are needed. The pertinent disciplinary research appears in the previous section.

The proposed research is designed to improve public and private decision making and action relative to problems involving food and nutrition in the developing countries. Although the stress is on organizations in the developing countries, research on international organizations in the high-income countries is recognized and encouraged as important in improving the capability of all organizations serving agriculture in the developing countries.

Some observations relative to research on organizational function and behavior are: (1) organizational change is possible; (2) organizational change is often the result of implementing a prior decision; (3) such decisions are based on existing knowledge about the expected impacts of the proposed changes; and (4) expanding the knowledge of organizational behavior should result in better

decisions and hence improved organizational performance. The research topics proposed in this section are designed to expand the base of multidisciplinary knowledge.

Our discussions of potential impacts under the following research topics on the problems of food and nutrition are purposefully brief and lack specific numerical estimates. We felt such estimates are impossible when only one item in a complementary set of items is being considered (see "General Observations on Impact").

Appendix B contains a statement on theoretical and methodological approaches suitable for research on institutional performance.

## Linking U.S. Research and Development with Developing Country Organizations

Organizational precepts have evolved for the international agricultural research centers. Research conducted at these centers on such problems as increasing the production of rice or wheat generally results in savings over more scattered programs. A nucleus of highly skilled scientific talent is concentrated in such centers allowing both forward linkages to research and development institutions in the developing countries and linkages back to sources of new fundamental knowledge in the high-income countries.

Rather different patterns of linkages have emerged in other institutional development activities. For instance, U.S. research and development have been linked to institutions in the developing countries through institution-building programs and through problem-solving research contracts. In institution-building programs, U.S. universities provide technical assistance to strengthen developing country universities, while for problem-solving contracts, U.S. and developing country operational programs are staffed by U.S. universities, research firms, and related institutions. Of course, the United States has not been alone in providing research and development assistance. Major countries of Western Europe, including Great Britain, France, Germany, and Sweden, as well as Japan and the U.S.S.R., have supported research and development programs designed to assist the developing countries. International and regional banks and other multilateral organizations also have played a role.

A number of important limitations have characterized these efforts. Perhaps foremost is the frequent inability to provide the sustained support

needed to assemble and maintain experienced researchers and to obtain commitments from institutions that are basically oriented to their own state. In addition, other problems have to do with organizations and how to link the various institutions together.

Four factors suggest the need for and possibilities of research on problems associated with linking U.S. research and development with organizations in the developing countries:

-- The number of scientific personnel and research organizations in the developing countries has increased significantly during the past decade.
-- A major new set of research institutions, the international centers, has been introduced into the worldwide agricultural system.
-- U.S. institutions have a continuing interest in collaborating with research organizations in the developing countries.
-- There are several instances in which industrialized nations have lent assistance that has been relatively unexplored and unanalyzed, and that can provide insights into how to link more effectively research organizations across national boundaries.

Decision makers in U.S. research and development institutions, in research-sponsoring organizations, and in developing country institutions are confronted with a number of different problems when they decide to support or to participate in research efforts involving linkages between U.S. and developing country institutions. For example, is there a division of labor between the two kinds of institutions that can maximize their combined output? How can efforts be most effectively coordinated and managed? Is there a limit to the number of institutions that can be linked together effectively? How can the financial resources be most effectively managed and allocated among the participating institutions? Are such linkages more effective with certain kinds of research than with others? And what are the logistical barriers to effectively carrying out such research?

Research Possibilities. The following are important research tasks:

-- Assess by drawing on past experience what impact the linking of developing country research organizations with high-income country (U.S.) and international institutions has had on the effectiveness of the former.
-- Compare the performance of such linkages under various management systems and forms of control in order to identify what will and will not work.

-- Compare the costs and effectiveness of research undertaken through a linkage of developing country institutions and those in the high-income countries with research done by expatriate institutions implanted in the developing countries.
-- Compare the effectiveness of such linkages for various kinds of research and for dealing with various kinds of problems to identify whether there are differences and the sources of such differences.
-- Examine the experience of past and existing international organizations to identify problems they have encountered in collaborating with both developing country and high-income country institutions, to identify how those linkages might be made more effective, and to identify new sets of problems for which linkages might be established.
-- Identify the kind of backstopping skills required from institutions in the high-income countries to reinforce and complement developing country institutions, with emphasis on identifying the skills required for different levels in the developing countries.

Potential Impact. Individual countries as well as international funding agencies have invested considerable sums of scarce developmental resources to train people in the developing countries and to develop institutions in which they can use their skills. Often these trainees are ineffective when they return to their home countries because they are unable to adapt their newly acquired skills to their home environment, because they lack professional peers with whom to interact in analyzing and solving their research problems, and because they do not have specialized skills available to them which would help in correctly identifying their problems or in solving particular problems that might arise. Linking such researchers to professionals in high-income or other countries is one means of solving the problem. Unless the problem is solved, past investments in training may be lost. Equally important are the gains foregone when the researchers are not effective. The potential impact of such research, therefore, is in increasing the payoff from past investments by funding institutions, in realizing the potential gains from the research the professionals might do, and in making current research expenditures for these professionals more productive.

Similarly, many developing countries do not have enough trained people (or have gaps in critical skill areas) to have an effective program. Often, a link with an institution or institutions in an advanced country can provide the critical mass or provide the

critical input to make the limited number of people more effective. Again, research designed to make such linkages more effective would raise the productivity of expenditures made on such researchers, and would provide the research output from their more effective mobilization.

## Optimal Organizational Mixes

Decision makers in the developing countries face many questions having to do with the combination of organizations. For example the Minister of Education needs to know what is the optimal mix of primary, secondary, undergraduate, graduate, and continuing education programs for the given stage of development of the country and the particular problems and potentials the country faces. Similarly, the Planning Minister needs to know what mix of regional, state or province, and local agencies are needed to carry out central government policies, programs, and projects. Decision makers at all levels in the public sector need to know what nongovernmental intermediate and participatory organizations are needed to integrate the rural poor into the development process. And decision makers responsible for research need to know what specialization of research organizations is needed, what kind of research organizations are needed, and the optimal mix of the various kinds that might be developed.

It is recognized that the optimal mix for a given developing country may be unique, reflecting its political philosophy and its particular set of problems and resources (human, physical, and capital). Consequently, research on this question should concentrate on the principles and techniques suitable for determining the organizational needs of the developing countries. We believe that the enormous diversity of developing country organizations serving agriculture can be profitably examined to identify viable combinations and arrangements, and to identify the various combinations and arrangements that might be most effective. Moreover, we believe that information attained in this way can be used to design more effective organizations and organizational relationships.

Research Possibilities. Examples of questions to be answered by research in this area are:

-- How should developing country resources for agricultural education be allocated among primary, secondary, undergraduate, graduate, and continuing

education programs? What is the optimal mix of such programs under various conditions?

-- What regional, state or province, or local agencies are needed to execute, monitor, and receive feedback on central government agricultural policies, programs, and projects? How can these various agencies be most effectively integrated, and what is the optimal proportion in which to combine them under different conditions?
-- What types of nongovernmental intermediate and participatory organizations are needed to serve agriculture, particularly the rural poor? How do these needs vary with the extent of use of the market system and with the extent of the public sector?
-- What subject matter research institutes are needed and how is this need determined?
-- What problem-solving and disciplinary research organizations are needed and how are these needs determined?
-- What is the optimal combination of problem-solving, subject matter, and disciplinary research organizations for countries at different stages of development and facing different kinds of problems?

Potential Impacts. One of the largest expenditures of public funds in most countries is on education. Such resources can be badly misused in terms of stated development goals. For example, scarce resources can be invested in expensive graduate programs where there are no effective research organizations to absorb the students, and vice versa. Similarly, resources can be spent at the elementary and university levels, with little or nothing spent at the secondary level. In the first case, there will be little payoff from the large investment at the upper levels, and the resources so used will be wasted. In the latter case, resources invested at the upper level may be underutilized, since there will not be enough students to use them. Such wastages through inappropriate combinations of educational institutions can be sizable.

There are other dimensions to the optimal mix of educational institutions. For example, the educational system can be an important influence on the distribution of income, and anomalies in the educational system can influence the distribution of income. As an example, many countries have only a private secondary school system, but a public system at the advanced level. Poor people tend to be precluded from moving through such a system, while the more well-to-do receive a subsidy at the very level that tends to have larger private returns. These distribution implications need to be taken into account in

determining an optimal educational mix. Research that helps define educational systems that improve the distribution of income and broaden the access to more productive employment can therefore have a major impact on a country's growth and development.

Education is highly complementary to research and development at a number of different levels. In the first place, education can be a limiting factor in the sense that if well-trained people at the appropriate levels are not produced, no amount of expenditure on research and development will produce any results. Both the Minister of Education and the Minister of Agriculture will have an interest in research that prevents such situations.

At a somewhat different level, education has been shown to be highly complementary to research and development at the farm level in the sense that some level of schooling is required to use the knowledge generated by the researchers. It is difficult to quantify such effects, but clearly education without technical change in agriculture has a low payoff, as does technical change without education.

Education also influences the distribution of income by facilitating the outmigration from agriculture. If new production technology is to be fully adopted, labor has to be transferred out of agriculture in most countries. Hence an improved educational system can both improve the distribution of income and accelerate the adoption of new production technology. Research that facilitates the design of educational systems to attain these goals again has a very high payoff.

At a somewhat different level, the policies of a central government tend to be pervasive in a society and affect decisions at all levels. The consequences of wrong decisions can therefore be enormous. With optimal control and feedback the chances of wrong decisions are reduced.

Intermediate and participatory organizations bridge the individual and government organizations. They can be the key to releasing and mobilizing human energy, or their absence can mean that government policy is ineffective. The potential for such organizations depends importantly on whether alternative means of doing the tasks expected of these organizations are available.

The mix of problem-solving, subject matter, and disciplinary research can determine whether research expenditures have any payoff. If only problem-solving skills are available, but the solution to a problem requires disciplinary skills, no amounts of expenditure on the first will provide a breakthrough. Such complementarities are real; hence research that

improves the mix of kinds of research can improve the productivity of the resources committed.

## Functional Integration of Critical Organizations

Many institutions and organizations within a country have to be integrated if developmental resources are to be effective. Such needs exist at various levels and dimensions within a society. A common example is the importance of integrating teaching, research, and extension. Research programs cannot be effective in most instances without a connection to extension organizations. These organizations extend the knowledge generated by the research program and provide the researcher with a means of feedback and problem identification. Similarly, the extension service cannot be effective without access to a source of new production know-how. And research and teaching are highly complementary, particularly at the higher levels of education.

Such organizations can be integrated in various ways. The research task is to identify and evaluate the alternative means of attaining such integration under various conditions. Such knowledge will be useful at various levels, ranging from the Minister of Agriculture who is designing a new system, to the experiment station or extension service directors who are trying to determine how they can make their organization more effective.

In a somewhat different dimension, there is a problem of integrating decision makers with problem-solving researchers, subject matter specialists, and disciplinarians. When decision makers encounter a felt difficulty, obtaining its solution will often require inputs from each of these three groups. If the groups are integrated in some way, at least with the decision maker, the decision maker will be more likely to find the solution to his or her problems. Similar problems of integration exist between national nutritional programs and village-level health organizations, and between both of these and family-planning agencies. Intermediate organizations also need to be integrated with the public and private institutions with which they must work.

Functional integration of institutions can lead to a more effective use of scarce skills, talents, and physical resources. The developing countries often have fragmented institutions serving agriculture, with many of them working at cross purposes. Reportedly the State of Ceara in Brazil at one time had 76 organizations serving agriculture. The scarce human talent fragmented their efforts to such an extent that

they were ineffective. Similarly, the small amounts of public resources scattered among this multitude of institutions had little effect because critical masses were not attained and because the activities of the various institutions were not coordinated.

Research Possibilities. Several critical questions, each dealing with somewhat different components of the total set of institutions serving agriculture, need research. Important examples are:

-- What alternative forms of integration are possible to coordinate knowledge-generating, knowledge-disseminating, decision-making, and decision-executing institutions in agriculture?
-- What organizational patterns and mechanisms can be used to relate satisfactorily the following groups: decision makers, problem-solving researchers, subject matter specialists, and disciplinarians?
-- What alternative patterns can be used to coordinate various intermediate organizations with the relevant local groups with which they must deal?
-- In the United States, the market mechanism, the political and educational systems, and the press are used as a means of integrating institutions in the agricultural sector. Since these processes may be absent, or only incipient, in some developing countries it is important to investigate the impact of such an absence on the degree of integration and subsequent performance of agricultural institutions.

Potential Impact. Research, extension, and teaching institutions absorb large quantities of public resources. Working independently, their productivity may be quite low. Research that designs more effective integration can reduce the wastage of public resources now giving virtually no output. This research also can increase output from breakthroughs in research and effective teaching.

Countries often create regional development organizations as a means of integrating the institutions in one region. Because of a lack of knowledge on how to integrate effectively the existing and new institutions, the result is often little more than the creation of one more organization. The costs of the frustrations, broken hopes, and sacrificed output and nutritional improvement that could have been attained with effective integration are immeasurable. Reducing those costs can be an important contribution of such research.

## Issues of Institutional Control

The problems of institutional control are found at two quite different levels. In the first place, individual countries make decisions about the degree of centralization-decentralization they will have in their socioeconomic-political systems. At one extreme is the centrally planned economy with a high degree of political control, while at the other extreme is the decentralized economy in which individuals and firms make their own decisions and their activities are coordinated by a presumably impersonal market. Between these two extremes is a continuum in which activities are organized with varying degrees of centralization and control. Clearly, certain activities are better organized under central control, while others are better organized under a decentralized system.

Numerous experiments are being conducted worldwide on degrees of centralization and decentralization (see Study Team 12's report). Particular industries are nationalized in a given country, while others are left to a decentralized form of organization. Some farming activities are organized into centrally directed state farms, while others are left to individual decision makers. And still other activities are organized as mixtures of state and private activities, with the degree of centralized authority changed over time in pursuit of the optimal arrangements.

While many observers believe the degree of centralization is a critical institutional issue, relatively little systematic attention has been given to the problem. Country efforts tend to be location-specific and focused on the requirements for short-term successes, as indeed they should be. What appears to be missing is a significant research and development effort that would examine these cases comparatively over time.

At a rather different level there are problems of internal control within existing private and public institutions. Our interest here is concentrated on the public sector. Within that sector organizational questions concern the optimal size of organizations, effective means of reward and punishment, effective sources and means of feedback, and effective execution and coordination of decisions once they are made. Although knowledge of decentralization would be of the most use to political leaders at high levels, knowledge of internal control within existing institutions would be of value to decision makers at almost all levels in public institutions.

Research Possibilities. The following questions must be answered:

-- What kinds of activities are best organized under centralized controls and what kinds can be organized by decentralized means?
-- What is the optimal size for organizations with authoritarian control under various conditions and for various tasks?
-- What is the optimal degree of decentralization for particular types of decisions in various situations?
-- What are the impacts of various degrees of decentralization in agriculture on the performance of the agricultural sector in terms of productivity, income distribution, nutrition, employment, etc.?
-- What types of evaluation and reward systems should be used (peer groups, user, public interest, industry, etc.) in the different kinds of organizations?
-- What organizational arrangements give the most effective execution and control in centralized organizations?

Potential Impacts. Exaggerated degrees of centralization lead to wrong decisions, poor execution, and a general loss of efficiency. Probably no organizational question is more important than this one. Anecdotes abound of the industry that is stopped for lack of a particular kind of pin. Perhaps somewhat more relevant, data are often cited on the small proportion of output derived from the large collective farms in the Soviet Union and the large share of output derived from small farms in private hands. Yet we really do not know to what extent the difference is due to institutional considerations.

The contribution of research designed to answer questions of decentralization and institutional control depends importantly on the resources at risk. If the question posed is at the national level, obviously the losses from faulty organizations can be large--as the recent experience of Chile indicates. If the organizational question is on a smaller scale, the gains or losses will be relatively smaller.

The public sector in most developing countries absorbs a sizable amount of resources. Efficiency and effectiveness in that sector can save large amounts of resources, while enabling policymakers and decision makers to attain their goals. Often the difference between effective and ineffective organizations is the difference between success and failure in policy and policy implementation.

## Participatory Organizations

Participatory organizations are designed to capture some of the benefits of a bureaucratic organization while avoiding its disadvantages. Such organizations arise naturally when there is some externality that can be internalized, as in the case of producers' cooperatives or associations. Others arise as a means of pooling resources, realizing economies of scale, and amassing critical human and physical resources. And still others are created by public agencies in an attempt to increase the involvement of the clients and users of an agency's services in the operation and evaluation of that agency. This often occurs when there is a desire to more closely integrate the agency and its clients through new mechanisms. Examples of such participatory organizations are numerous: Taiwanese farmers' associations and irrigation associations, Peruvian labor-managed agricultural units, Sri Lankan agricultural productivity committees, Chinese commune organizations, and joint farming experiments in Japan and parts of Europe.

Much controversy exists as to the effectiveness of such organizations and the role they might play in promoting agricultural development. Some believe they are the key to mobilizing talent and resources at the local level, and to providing a source of feedback. Others believe they can be effective only with strong leadership, and since such leadership is often lacking, the potential for participatory organizations is limited unless they are imposed from above.

It should be noted, however, that most strategies for increasing food production depend upon large-scale public research and extension institutions. Given the tendency of large-scale agencies to arrange goals and priorities based on their internal dynamics and the expectations of various professional groups, some external to the nation or state, there is the need to design agricultural agencies that will be more client oriented and thus will produce information and technology relevant to specific habitats and socioeconomic conditions as well as gather information and experience from farm producers for incorporation into the research, extension, and policymaking processes.

Research Possibilities. The following questions must be answered:

-- For what kinds of activities and to attain what objectives can participatory organizations be effective?

-- How can they most effectively be organized, i.e., what form of organization works best for them under various conditions?
-- How can leadership be identified and developed?
-- How can they be most effectively linked to existing public institutions?
-- What are the effects of such organizations on incentives and effort?
-- What is the optimal size for such groups to attain particular goals?

Potential Impacts. The contribution of such research can probably be seen most directly by noting that there are many paths technical change can take to economizing on specific resources or to easing specific constraints on output expansion. The key to obtaining efficient output expansion is in keeping technical progress on an efficient resource path. Participatory agencies which are effectively linked to public institutions and which provide feedback information to their decision makers are an important means of keeping research efforts relevant. That is, they are an important means of concentrating research and development on the solution of whatever institutional, biophysical, or resource constraint is limiting output expansion.

Such organizations also could contribute to improving the distribution of income and in opening access to both public and private sources of inputs and services. Broader participation and wider access to key inputs can broaden the distribution of the benefits from development, as well as increase the rate of output growth.

## Innovative Staffing Patterns

Decision makers in developing countries who are forming and reforming public institutions to serve a developing agriculture face a number of important staffing problems. First, people with specialized talent tend to be scarce. If the staffing patterns of parallel agencies in the high-income countries are followed, the result may be an excessive dependence upon foreign training to educate staff, long time lags in assembling staff members, and selection and recruitment from among those least familiar with and/or interested in agriculture and rural communities.

Over the past several years, there have been a number of important staffing experiments that have used individuals with a less formal education but selected from among the intended program audience and given the minimal training, usually locally, required to perform

program-specific tasks. U.S. experiments have resulted in the addition of nutrition aides to the extension service and teacher aides in our public schools, and Chinese experiments have resulted in the famous barefoot doctors who are included in China's rural health delivery system.

Another class of staffing problems has to do with how to break out of the traditional system in which promotion and position are determined by nepotism, political connections, and cronyism. Such systems of staff selection work well when highly specialized skills are not required, or when such skills are readily acquired through experience and on-the-job training. But institutions to service modern agriculture require scientific and technological skills--skills that for the most part depend on conditions other than family and political connections. Moreover, a specialized skill needs to be placed at an appropriate place in the system.

Problems such as these arise in most institutions and organizations serving agriculture. The problem becomes increasingly severe as the development process becomes increasingly based on science and technology.

Research Possibilities. The following questions must be answered:

-- What staffing patterns can most effectively make use of limited scientific and professional personnel?
-- What is the optimum mix of lower level aides and assistants to highly specialized personnel? What is the substitution rate between highly trained people and people trained at a lower level? And what skills are needed to complement the highly trained person?
-- To what extent can systems be designed that permit people with specialized skills to be shared among several institutions?
-- How can existing structures be opened so that people with the appropriate skills can move into the appropriate leadership positions?
-- What staffing patterns provide the maximum on-the-job training and internal development?
-- What supervisory and administrative skills and systems are required to use effectively various mixes of technical skills?

Potential Impacts. To the extent that the problem is one of overstaffing with highly skilled, expensive people, research that will design more efficient staffing patterns and will design ways in which less skilled people can be more effectively used can reduce the budget costs of agencies or institutions. Such

contributions can be relevant to teaching, research, and extension organizations, and to other public institutions.

Equally important, more efficient staffing patterns could release scarce staff to deal with other more important problems, and to participate in other agencies. For example, such staffing may mean a limited number of highly trained people dispersed throughout a bureaucracy rather than highly concentrated in one or a few institutions. If effectively linked, the given staff may therefore make a larger contribution.

Breaking out of the traditional systems and the traditional criteria for staffing promotion may be the key to developing a system based on science and technology. The significance may well be the difference between having a highly productive infrastructure and having one with a very low payoff in terms of scientific and technological payout. It also should be noted that unless the people with newly acquired skills are able to penetrate the system, to do effective work in it, and to rise upward, they may well become frustrated and either leave the country or turn to other activities. In either case, the consequence is a waste of the previous investment.

## Training Needs

The development of a modern, progressive agriculture requires the development of a cadre of people trained in science and technology and other professional skills. Some of the most important decisions policymakers face in modernizing their agriculture concern how much and what kind of human capital to form. Similarly, one of the largest investments a country will make is in infusing the appropriate skills through the system.

Decisions are made at all levels, and knowledge generated from the proposed research should be as helpful to high levels of government as to administrators of specific institutions. Top policymakers often make decisions to send X people abroad, or to spend X dollars on training abroad, or to develop graduate programs within the countries in fields X, Y, and Z. At the other extreme, the dean of a school of agriculture decides to launch a graduate program in plant sciences, and needs to know in what fields the staff needs advanced training, and where they should be sent for such training. Similarly, the director of an extension service needs to know what mix of skills is required for an effective program, and in what fields. Directors of problem-solving, subject

matter, and disciplinary research organizations have similar problems. And finally, society at large faces important decisions on training and educational needs. When the flow of new production technology entering the system is limited, educational needs may be small. If the research capability is large and the flow of new technical knowledge is large, educational needs will be much larger.

Institutions in the high-income countries, in attempting to provide educational services to developing country professionals, have not always adapted their training programs to the needs of those countries. More often than not the training reflects the particular level of development of the home country or the particular development problems it faces.

Personnel studies are not lacking in many developing countries. What is lacking is careful research on specific institutional problems, on how the appropriate training can be provided and where, and on how the training capability of the high-income countries can be most effectively used to provide the skills required in the developing countries.

Research Possibilities. The following questions should be addressed:

-- What types of training and capabilities are needed by the people staffing the different kinds of organizations? Academic or nonacademic? Degree or nondegree? On-the-job training? Leadership training? Administrative training? This research should address the needs of developing country personnel as well as the needs of technicians from the high-income countries serving in the developing countries.
-- How many women and men with the different types of training should be forthcoming during a given time period?
-- How will the needed training be provided? In the developing countries, high-income countries, or both? What specializations in the provision of training should occur? What new training organizations will be needed?
-- Specifically, what changes are needed in U.S. universities to improve the training of developing country students? For example, how can multidisciplinary approaches to problem solving be incorporated into U.S. graduate programs?
-- What mix of out-of-country and in-country training will make most effective use of scarce educational resources?
-- To what extent can informal educational training programs substitute for more formal programs? And how much on-the-job training can be provided by

means of visiting specialists in periodic intensive short courses? What other educational innovations are possible?

This research should recognize that important differences exist among the organizations serving developing country agriculture, and that training needs are quite different at various stages of development.

Potential Impacts. It is generally recognized that the performance of the organizations serving agriculture in the developing countries is significantly influenced by the training and capability of the individuals staffing those organizations. At risk, therefore, are the sizable investments a country may be making in its infrastructure to develop a more modern agriculture.

However, this general statement fails to recognize the complementarity involved with highly specialized skills and training, or the complementarity of education and training with other expenditures made on research and extension. An inappropriate skill mix in developing a graduate program can result in ineffective training for the new generation. And lack of the appropriate skills can prevent a research organization from solving the key problem or releasing the key constraint that is impeding the development process.

Other important complementarities exist at a somewhat different level. Investments in research will have a very low payoff if the country does not have the skilled people to use the money appropriated. Similarly, if the masses do not have the skills to decode the information being generated by the research program, the new technology will not be adopted and research investments will be wasted.

## Institutional Change Strategies

In each of the prior research topics we have argued the need for additional information related to the improvement of institutional performance. The existence of this new information in conjunction with the already existing principles related to institutional performance still leaves an important knowledge gap: how does one change institutions in directions that will enhance their performance? We view this research topic as a set of "action-cum-research" activities in that we believe major progress could be made on this topic if research activities are conducted in close coordination with actual efforts to implement institutional changes.

Institutional change is a sensitive issue since it frequently requires some reassignment of power,

influence, and other resources. Thus the opportunities for conducting experiments on institutional change will be out of the hands of the researcher and dependent upon the commitment and decisions of others. Since such commitments and decisions occur irregularly, and often on short notice, an element of uncertainty is attached to this research activity. However, there are good opportunities for careful analysis of past institutional changes, especially where needed data are available or participants in the change can be contacted.

Research Possibilities. The following questions must be addressed:

-- What strategies are appropriate for the modification of existing agricultural institutions and organizations?
-- What strategies can be used to create new institutions? Here attention should be given to the existing work on the institution-building model.
-- What strategies can be used to modify existing institutional configurations and mixes?
-- What strategies can be used to build flexibility into organizations serving agriculture so they can respond more quickly to changing conditions?
-- Under what conditions is it better to develop a new institution rather than to reform an existing one?
-- What means can be used to alleviate the tension and conflict that arises when institutional change alters the distribution of income, assets, and power, and threatens vested interests?

Potential Impacts. Problems of institutional change occur at all levels. The dean of a school of agriculture faces it when sending staff abroad for advanced training, or when deciding to add graduate training to the program. Similarly, the Minister of Agriculture faces it when implanting a policy analysis group in the Ministry of Agriculture that threatens vested interest groups in the Ministry, and which alters the influence of vested interest groups outside the Ministry. Changes in tenure arrangements and in access to rights, privileges, and power may be the result of more general political decisions at a high level within government.

Identifying desirable institutional arrangements for improved performance is a necessary but not sufficient condition for enhancing institutional activities. To this must be added an improved ability to implement such findings and actually modify existing or create new institutions. Research on institutional change strategies is intended to develop this

capability. Without this additional capability, the gaps and lags between known principles of institutional performance and actual performance will remain large.

The availability of appropriate institutional change strategies can permit a smooth transition from existing institutional arrangements to the new situation. The absence of such strategies, or mistakes in working out the appropriate strategy, can lead to conflict, wasted effort, frustration, and social disruption in the form of civil war and other forms of social conflict.

## Assessing the Impacts of Institutional Change

The prior research topic dealt with institutional change strategies, but here we deal with determining the impacts of institutional change. Such knowledge is valuable to decision makers in deciding how much effort and resources to allocate to institutional change, in determining what institutions to modify and in what order, and in identifying the key problems that will arise as change takes place.

Impacts can be measured and evaluated both ex post and ex ante. To be of value to decision makers involved in changing organizations and institutions, ex ante assessment is clearly preferred.

The capacity to model the impacts of institutional change is increasing as part of our improving capacity to model systems in general. However, specific research is needed to develop components dealing with institutional control mechanisms, decision-making behavior, feedback, loops, executive capacity, etc.

Research Possibilities. The following research efforts should be undertaken:

-- Model the rather simple institutional changes required to solve well-defined problems. Grain management and institutional changes to handle crop disasters in specific countries should be modeled because (1) such models are badly needed and are useful as demonstrated by the present Korean grain management model, and (2) such experiences are valuable in developing the capability to model more complex institutional changes.
-- Develop generally useful components for dealing with various phenomena encountered in making institutional changes.
-- Identify the role of institutions in output, in the distribution of income and power, and in the allocation of resources and the adoption of new technology. Unless such knowledge is generated, useful systems models cannot be developed.

-- Explore the dynamics of particular institutional changes within a system, and how they interact with the larger social system of which they are a part.
-- Develop measurable criteria for evaluating the performance of organizations and for determining coefficients that relate specific institutional changes to performance.

As experience is gained and as tested components and data accumulate in software libraries and in data banks, it will be possible to model increasingly complex institutional changes concerned with controlling and expanding food production, storage, utilization, etc.

Potential Impacts. The impacts of such research are known to be great. Understanding the potential impact of institutional change is the key to devising a strategy for obtaining that change. And obtaining change is the key to obtaining more rapid growth, improvements in nutrition, and improvements in the distribution of income.

Of equal importance is the frustration encountered when making institutional changes at various levels from a lack of knowledge of potential impact. Land reform efforts have been frustrated in various countries because policymakers did not fully understand the redistribution of income, power, and influence that would be associated with them. Governments have been trapped into long and wasteful struggles with the bureaucracy as they have attempted to implant a scientific and technological capability into a traditional system. And schools of agriculture have lost valuable skilled people to other institutions and to other countries because administrators did not fully understand the consequences of particular reforms they were proposing.

* * * * *

Any consideration of the resources and strategies needed to obtain high payoffs from research and development on organizational and institutional constraints must begin with recognition of three important facts: (1) the pool of relevant researchers in the developing nations tends to be small relative to the tasks to be performed; (2) none of the existing international centers is concentrating on these problems, although some centers do have social scientists on their staffs; and (3) only a few U.S. scientists have been able to work on these issues in a sustained manner, and most of those have been able to devote only a small portion of their total efforts to

this topic. Enhanced research efforts in this area will need to recognize this state of affairs.

Steps are being taken to enlarge the pool of relevant social scientists in the developing countries. Perhaps most significant is the increased capability for training scholars locally or in regional institutions (such as the University of the Philippines at Los Banos). Equally important is the emergence of research organizations to support these young scholars (such as the Chulalongkorn University Social Science Research Institute in Bangkok).

There are a number of problems associated with creating international centers for the study of agricultural institutions which would be similar to those created for the biological sciences, and we are not advocating the establishment of such centers. However, if the comparative phase of institutional research is to proceed as suggested above, there will be a need for well-staffed research institutes, active research networks, or other mechanisms that can draw together disparate data from many cases for synthesis and integration. Since different nations of the industrial world will have contact with different portions of the developing worlds, it is important that arrangements be made to exchange information and otherwise foster collaboration among scholars from many different countries.

We believe that U.S. social scientists can perform a useful role in assisting and collaborating with developing country researchers in the description, analysis, and comparison of organizational and institutional arrangements for the three kinds of research and for disseminating agricultural knowledge. However, to do so adequately, they will need support arrangements that encourage sustained rather than sporadic and short-term involvements. As an example, the creation of the Land Tenure Center at the University of Wisconsin has allowed scientists to maintain a sustained research program on land tenure topics that has produced a significant body of knowledge. Sustained support for researchers investigating equally significant agricultural institutions and institutional issues should be provided.

The experiences of U.S. and developing country subject matter institutes can give us some indication of the cost of doing the above research. The annual operating budget of the Land Tenure Center has been about $350,000. The cost of establishing and operating the Economic Development Institute in Nigeria for 18 months with heavy use of expensive U.S. expatriates was about $600,000. The Agricultural Development Council (ADC) has assisted in the development of a research

network among rural social scientists in Southeast Asia. ADC's contribution to this effort has been about $1.8 million in recent years.

## GENERAL OBSERVATIONS ON IMPACTS

Attempts have been made in this report to assess the potential impact of policy changes, of improved institutions, and of certain kinds of investments. This section discusses the difficulty of making impact assessments of public policy.

Assessing the impact of research and development expenditures on food and nutrition is difficult for any discipline or subject matter. The multidisciplinary nature of the problems means that subject matter or disciplinary research pertaining to the production, marketing, distribution, or consumption of food typically produces necessary but insufficient knowledge for the solution of a specific problem. If any essential information is not available, an entire policy, program, or project fails. On the other hand, the mere presence of that kind of information does not guarantee success unless all other essential components are in place. Agronomists recognize similar situations at the production level and, as a consequence, devise "package programs" to include all the essential components in the required proportions. Yet such production packages still fail to make the necessary changes in markets, incomes with which to buy the output, etc. Thus even larger packages of essential ingredients are needed.

Because of the nature of the different kinds of research, it is easier to isolate the costs of failures to provide an essential component than it is to prove the contribution that any particular essential component makes to the results obtained with the overall package. For instance, excellent biophysical research and good extension work on oil palm varieties failed to pay off in Nigeria even though palm oil schemes have attained large payoffs in south Asia. In Nigeria, the missing component was a pricing policy to provide adequate incentives to farmers to use the new technology, such as was done in south Asia. As a consequence, Nigeria has gone from a leading to a minor exporter of palm oil, while Malaysian production and exports have expanded rapidly.

If one were to accept the limiting factor argument, all of the increase in output from an improved policy could be attributed to the research that produced such a policy, or to the institution doing the research. Given the complementarity between socioeconomic policy and science and technology, the impact of research that

led to improved policy could generally be expected to be quite high.

On the opposite side, many planning agencies have generated agricultural development plans as a part of national planning efforts, but have neglected physical and life science research on needed technological advances with respect to varieties, disease and pest protection, soil amenities, mechanical equipment, etc. The results have been disappointing, for peasant producers have generally already exploited their advantageous opportunities. This means that planned improvements in the use of their resources are generally rather fruitless unless substantially improved technologies or other changes open up new, advantageous opportunities.

Similarly, central planning agencies have often made decisions without paying enough attention to the managerial units that are going to execute the changes. As a result of the failures that have occurred, it has now become fashionable for these same planners to "discover agriculture," and for agricultural planners to "rediscover farm management." The costs of failing to attend to the skills and to the capacities of individual producing units to learn about and to adjust to changes are great.

An undesirable amount of faddishness is present in both national and international agencies, which has resulted in concentration on first one and then another "essential" ingredient of development while ignoring other ingredients. Earlier there was a heavy emphasis on community development. This fad passed. There was also a heavy emphasis on central planning while ignoring communities and farm management and, indeed, even agriculture. Now we emphasize farm management and are reemphasizing community development, but we are calling it "rural development."

Recognition that these are all essential but insufficient ingredients for development leads to the conclusion that it would be better if the multilateral and unilateral donors and grantors learned to balance these various emphases. Obviously, central planning is required, as is attention to the problem of local communities. And, the producing units of a society cannot be ignored, whether those units be individual peasant proprietors or administrators of state farms and cooperatives.

Despite the "essential ingredient problem" it is clear that there are enormous gains to be made from improving technologies, institutions, and human capacities in seeking solutions to problems involving food and nutrition. Johnson (1973) has shown that trade policy restrictions may cost world consumers as much as $40 billion annually. This figure is probably

underestimated by a rather wide margin, since it does not take into account all impacts on the total system, i.e., impacts of the failure to use new technology and of the generation and use of nonmonetized agricultural capital.

In more global terms, there is enormous variation among countries in terms of performance of the agricultural sector. For the period 1963-1974, data from the Food and Agriculture Organization (FAO) of the U.N. indicate changes in per capita food production across countries that range from about -5 to +5 percent annually. These differences partly concern technology and endowments of human and natural resources, but part is also due to the types of policy being pursued and the institutions that execute policies. To believe that better policies in association with other factors might alter the growth rate of agriculture by 1 percent in most countries is certainly not unreasonable. We estimate that such an improvement would mean the difference of 10 million tons of grain annually.

In addition to the "essential ingredient" difficulty, there are the distributive impacts of alternative solutions to policy, program, and project problems. Although not all problems involving food and nutrition originate from the distribution of income, many of these problems are problems of the poor.[2] The technological, institutional, and human components of different solutions to problems involving food and nutrition have varying impacts both on the distribution of income and on the ownership of resources with which to produce income. It is often charged, for instance, that the new miracle varieties of grains have concentrated ownership of wealth and hence incomes in the hands of larger farmers. Similar charges are leveled with respect to mechanization which, it is often asserted, deprives "landless laborers" of employment. In Nigeria, the imposition of marketing board taxes deprived small holder producers of export crops of the income badly needed to buy food and other necessities, while the expenditure of these monies increased the income of the "new elite" in government and in the universities.

Such distributional impacts of different policies, programs, and projects are difficult to evaluate. The meaning and value of production is a function of income distribution; hence the distributive impacts and output effects cannot really be examined separately.

However, there is much to be gained by projecting the consequences of alternative policy, program, and project decisions. How do we assess the costs and benefits of research on the distribution of income? The benefits are in terms of justice and equality of the distribution of real income with which to buy food.

The costs include taxes and reforms imposed on those who are relatively better-off. The potential costs of not redistributing income are also great; they include starvation, disease, unrest, war, and revolution, all of which are destructive and costly.

Both the "essential ingredient" and the distributive aspect of assessing research and development efforts suggest measuring impacts in terms of how packages or total systems work. The overall need is to know how complex systems react to technological, institutional, and human changes that result from deliberate decisions and actions, both public and private. The consequences of such structural changes need to be known in terms of how societies, economies, and people behave and manage their affairs, and in terms of consequences or performance (per capita calorie and protein consumption by income and demographic groups, income distributions, etc.). Marketing economists talk about structure, conduct, and performance. Systems scientists study state, behavioral, and performance variables. The performance variables tell us who gets what, where, when, and how and under what circumstances.

Overall assessment of impacts would be greatly facilitated by an interpersonally valid measure, or common denominator, of the returns sought and the costs avoided. In economics, the difficulty of obtaining such a measurement is referred to as the problem of finding an "interpersonally valid welfare measure." In practice, impact assessment is carried out by first projecting the consequences of alternative actions to solve problems in terms of performance variables. Then interaction among decision makers, executors, affected persons, and investigators on the basis of these projections leads to assessment and decision.

In any event, assessment is never entirely objective, and power (market, political, military, police, intellectual, etc.) is necessary if decisions are to be made. The distribution of power is reflected in data and bears consequences in any decision process. Projections of the consequences of decisions involving systems are necessary before an impact assessment can be made interactively among decision makers, executors, affected persons, and investigators.

The above arguments indicate that it would be foolish to claim that social science research alone would have impacts of certain magnitude in solving problems involving food and nutrition. Such unwise claims are often advanced by nonsocial scientists as well as by social scientists in drumming up public support for social science and/or biophysical research. Our position is that both biophysical and social science research are necessary for solving food and

nutrition problems, but that it is not honest to claim the output of packages for any essential ingredients going into the package. Clearly, population and food production growth rates indicate that astronomical costs will be encountered if we fail to assemble the necessary packages of institutional, technological, and human change necessary to bring population and food production into balance.

## INCREASING THE CAPABILITY FOR SOCIAL SCIENCE RESEARCH

### Properly Locating Social Science Capability

U.S. research and development funds inevitably influence the temporal, spatial, and institutional location of problem-solving, subject matter, and disciplinary research, as well as the ability to execute programs and projects. Thus the question is not one of whether those influences will exist, but one of whether they will be rationally guided in the high-income countries, the developing countries, and international agencies. In this respect, the following points are relevant:

-- Problem-solving research should be located where the problem exists.
-- Because problems are time-specific, research and development expenditures on problem-solving research should be administered to provide for timely initiation, execution, and termination. Current procedures for funding research by the U.S. Agency for International Development (AID) and other donor agencies preclude timeliness in terms of specific problem-solving research. One- to two-year delays between the initiation of a funding request and approval, are not uncommon.
-- Durable resources such as computers and other capital goods devoted to problem-solving research should be kept flexible to permit their reallocation as problems change through time.
-- Institutionally, research and development expenditures on problem-solving research should be located near the decision makers facing the problems. Some administrative control of decision makers over researchers can be established by the terms of research and development grants and contracts.
-- Subject matter research normally is much less time-, place-, and institution-specific than problem-solving research, and is typically more so than disciplinary research. Thus the above

recommendations apply less specifically to subject matter than to problem-solving research. There is more opportunity to separate subject matter research both spatially and institutionally from decision makers. Furthermore, since sets of problems are less ephemeral than individual problems, timing, initiation, and completion of research on such problems are less important. Thus institutes with some longevity can be established.

-- Disciplinary research is much less space- and time-specific than problem-solving and subject matter research. Even when relevant to time- and space-specific problems or sets of problems, it is ordinarily less crucial or, if crucial, can be made part of problem-solving or subject matter research. Thus disciplinary research can often be carried out in universities in the developing countries. Developing country universities are an important source of trained disciplinarians for work in the problem-solving and subject matter agencies of the developing countries, which is one reason for supporting disciplinary research in those universities. U.S. research and development monies can be used to provide research experiences for both disciplinarians and their students in the developing countries. The result can be both relevant disciplinary research and better trained disciplinarians more inclined to work in a country's problem-solving and subject matter agencies.

-- A general strategy for attaining the desired results is to channel some research and development monies through the problem-solving and subject matter research agencies to the disciplinary departments. Such an arrangement has the advantage of keeping researchers at all levels in contact with one another and with policymakers, planners, and executors. Increasing the amount of U.S. research and development money that reaches the social science departments via this route seems warranted given the above arguments and the fact that our institution-building programs have created a resource that is not being effectively used in many cases.

## Improving the Capabilities and Infrastructure for Social Science Research

One of the most important uses of U.S. research and development funds is to provide training and experience. These funds can give young disciplinarians training and meaningful experiences on problem-solving

and subject matter research teams. Without these funds, the disciplinary training of universities in both the high-income and the developing countries is likely to lack this important component. Research and development grants and loans also can provide assistantships and in-service training for both students and staff personnel. This training can be disciplinary, subject matter, or problem-solving in nature, and research and development monies can be provided in such a way as to facilitate an understanding of the differences in doing these kinds of research. In addition, loans and grants can be made for the development of specific skills and capabilities needed by researchers in their various roles. The needs here parallel those presented earlier with respect to improvements in theory, data systems, sector and global models, and methodologies for handling nonmonetary values.

Research and development monies also can be used to establish communications among researchers in the developing countries, the high-income countries, and between the developing and high-income countries, including international organizations. In the case of problem-solving research, it is important to use research and development monies to facilitate exchanges of ideas among members of different disciplines who may be working on similar problems. In the case of subject matter research, communication should be encouraged among the disciplines involved in a subject matter area. Communication among subject matter workers in different countries is also important. Communication among researchers in the more developed and less developed countries is probably most important in the case of disciplinary work because many of the disciplinary advances take place in the more developed countries.

Among the techniques for improving communications are conferences and seminars, research networks, travel grants, and special training programs. A close connection with the problems and with the decision-making agencies that solve them is essential for a successful communication program.

U.S. research and development monies can provide substantial opportunities for establishing and maintaining productive interactions among decision makers, on the one hand, and subject matter research and disciplinary research personnel, on the other hand. They also can serve as a vehicle for improving the physical facilities available in both the United States and abroad to do the three kinds of research. And finally, U.S. research and development money can be used to develop the institutional infrastructure of

both the more and the less developed countries as well as that of the international agencies.

Productive interactions among decision makers, on the one hand, and disciplinary and subject matter researchers, on the other, can be furthered by skillful administration. Contracts and grants can be written to motivate and, indeed, to purchase cooperation between the two groups. This can be done domestically as well as abroad. If the contracting or granting agency knows the more specific problems, it can require that subject matter or disciplinary researchers do some of the research necessary to solve the problems. If these problems are not known to the grantor and/or lending agencies, grants and loans can be made which will provide for the interaction between decision makers and the subject matter and disciplinarian researchers. These grants can give decision makers enough control over grants and loans to require the subject matter and disciplinary agencies to participate in defining the problem and to perform certain kinds of research. Grants and loans can require subject matter and disciplinary researchers to interact cooperatively with decision makers in reaching mutual agreements on the research to be done.

The agencies involved are, of course, both public and private and range from individual farms through multinational corporations, national ministries of agriculture and planning, the International Board on Research and Development and regional development banks, and FAO. Unless a connection is maintained with decision-making agencies and problems, communications do little to facilitate the solution of problems involving food and nutrition.

U.S. research and development grant and loan money also can be used to improve facilities available for doing problem-solving, subject matter, and relevant disciplinary research. Grants to all three kinds of agencies and personnel can provide for libraries, computers, data banks, and software libraries. Where these things have substantial durability, provisions can be included in grants and loans to lodge such facilities in structures where they will be available to support subsequent research.

U.S. research and development loans and grants also can be used in the direct establishment of the institutional infrastructure necessary to do the three kinds of research. Long-term grants can be extended to universities in both the more developed and the developing countries for the purpose of improving disciplinary departments to do relevant disciplinary research. Similarly, grants can be extended to national and international subject matter research institutes. In addition, grants and loans can be used

to establish research units or investigative units in decision making agencies to give greater attention to the solution of problems involving food and nutrition.

Important in the above recommendations is the underlying belief that the productivity of U.S. research and development monies can be increased substantially by careful attention to how they are allocated.

## Appendix A

## RESEARCH ORGANIZATIONS

This appendix examines the organizations dcing problem-solving, subject matter, and disciplinary research with respect to food and nutrition in the developing countries, within international organizations, and in the United States. In lieu of a massive inventory, we classify and illustrate the types of organizations and the kinds of research they conduct.

### DEVELOPING COUNTRIES

The three kinds of research related to food and nutrition can be combined with systems of organizational control to form a simple tableau (Table 1). The major systems of control are public and private between which is a continuum of intermediate forms. Generic and/or specific examples of the kinds of organizations are indicated for each cell in the tableau. Some organizations perform all three kinds of research.

Another dimension of these organizations is their level of responsibility and action. Because of the need to involve local populations, geographic distinctions are often made, i.e., national, regional, and local. This concern is most frequently expressed when discussing problem solving for action agencies. Thus a national planning organization or extension system without effective two-way communication with regional or local interests may find its impact severely constrained. Similar concern may exist for the location of subject matter and disciplinary research. For example, it can be argued that much of the research and disciplinary studies related to drought should be undertaken within or near the regions of the country subject to drought. The tableau in Table 1 accommodates this distinction; thus a cell, such as the public problem-solving cell, contains a

Table 1. Developing country organizations that deal with food and nutrition problems (illustrative)

| Kind of research | System of control: Public (central, regional, and local) | Semipublic | Private |
|---|---|---|---|
| Problem-solving and action | Planning groups within the ministry of agriculture, interior, planning; marketing boards; extension organizations | Agricultural or industrial development commissions; banks; credit associations; irrigation districts | Farm firms and households; fertilizer production and marketing firms; food processing firms; research and consulting firms dealing with marketing strategies, plant location, new products, etc. |
| Subject matter | Rural development institutes (e.g., National Agricultural Economic Research Institute--Korea; research departments in banks; organizations responsible for national accounts and data on population, health employment, prices, etc. | Agricultural research organizations (e.g., EMBRAPA--Brazil); research departments in banks (e.g., ENTENE--Bank of N.E. Brazil); commodity organizations; foundations (e.g., Getulio Vargas Foundation--Brazil) | Food processing firms; commodity associations |
| Disciplinary | Universities and disciplinary institutes; departments of economics, political science, sociology, etc. | Agricultural research organizations; commodity organizations (little or no disciplinary research being done by these organizations) | Private universities; private firms (relatively few and of varying quality) |

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classification by geographic location of responsibility and action.

The type of political regime and control also is important in examining policymaking and program planning agencies and their research support. Comparisons are made between systems with powers of coercion and systems with little control over individual decisions. All economic and social systems involve power and control, as complete objectivity and consensus are prohibitively expensive. Thus the relationship between research and the exercise of power is important to the capability and performance of organizations serving society. To a limited extent, the classification system in Table 1 accommodates differences in this respect. Thus socioeconomic research organizations in a country that has centralized police and military power with little private control through market, press, and dispersed political power would be classified under the "public" column of the table. However the distinctions within "public" organizations among different political regimes are not immediately recognizable from the table.

A number of other factors impinge upon the ability of a given developing country to perform policy, program, and project planning research. One factor is the quantity and quality of that country's resources, including the available human, physical, and capital resources, as well as the problem-solving agencies, the subject matter institutes, and the disciplinary departments. Country size, although important, does not seem to be a determining factor. A large country such as India is unable, given the administrative system, to employ all of its scientists, whereas another large country such as Brazil faces a shortage of trained scientists. Nevertheless, small, resource-poor countries typically have inadequate research bases for policymaking and program planning.

Another factor possibly more important than country size is variation in the problems faced by the decision makers. The sheer weight and immediacy of the problems are related to the other factors such as political and economic instability, resources, external pressures, equality in ownership of resources, rights and privileges, and population pressures. Another factor is the degree of a country's dependency on agriculture, which may be measured in terms of the level of self-sufficiency in food crops, for example. Food shortages influence the nature of the problems faced by the developing country, but this factor does not obviate the need for improved social science input into policymaking and program planning with respect to food and nutrition.

## INTERNATIONAL ORGANIZATIONS

The international organizations that conduct research on food and nutrition problems are similarly portrayed in Table 2. A study of these organizations reveals several points related to the kinds of research they conduct and systems of control used.

First, the international organizations tend to do either problem-solving or subject matter research. Few private or public international organizations are devoted to disciplinary research relevant to problems involving food and nutrition. In the physical and life sciences, some of the research conducted by the international organizations (e.g., the World Health Organization [WHO] and the International Rice Research Institute [IRRI]) approximate our definition of relevant disciplinary research and much of the social science research done by the subject matter institutes has disciplinary impacts. Although research contracts between international organizations and disciplinary departments may be for disciplinary research of known relevance, these contracts are typically part of subject matter or problem-solving efforts.

A second point is that the international organizations tend to be either public or private. The international agricultural research institutes (International Maize and Wheat Improvement Center [CIMMYT], IRRI, etc.) are the major exceptions in that they are funded by both quasi-private foundations and public agencies and are governed privately by boards of trustees concerned with sets of both private and public problems.

The third point is that a large number of regional and international subject matter research organizations exists, many of which are short on social scientists relative to the social science dimensions of the subjects with which they deal.

## U.S. ORGANIZATIONS

Some of the U.S. organizations doing research on food and nutrition problems are illustrated in Table 3. Although many U.S. organizations deal primarily with domestic problems involving food and nutrition, several include a significant international dimension in their research activities. In general, the international orientation is toward problems and knowledge gaps that are or are expected to be important to the United States as well as genuine concerns about the nutritional and general welfare of the world's disadvantaged.

Table 2. International organizations that deal with food and nutrition problems (illustrative

| Kind of research | System of control: Public | Semipublic | Private |
|---|---|---|---|
| Problem-solving and action | World Bank; regional banks (e.g., African Development Bank); AID; GATT; WHO | | Multinational corporations, mainly related to extraction, production, and marketing activities; international banks |
| Subject matter | Development Economics Department of the World Bank; FAO; Organization for Economic Cooperation and Development; Development Planning Advisory Society of the U.N.; Technical Assistance Bureau of AID; Economic Commission for Latin America and other regional commissions of the U.N.; WHO | International research institutes (e.g., CIMMYT, IRRI); the foundations; Agricultural Development Council | Multinational corporations, particularly international consulting firms |
| Disciplinary | No examples | | No examples |

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Table 3. U. S. organizations that deal with food and nutrition problems (illustrative)

| Kind of research | System of control: Public (central, regional, and local) | Semipublic | Private |
|---|---|---|---|
| Problem-solving and action | Commodity Credit Corporation; Farm Credit Administration; Office of Management and Budget; Commodity Exchange Authority; agricultural committees in Congress; Bureau of Land Management; Bureau of Land Reclamation; National Forest Service; state economic development and planning organizations; Soil Conservation Service; Council of Economic Advisers; HEW; Extension Service | | Food and fiber producing, processing, and marketing firms; input manufacturing and distribution firms; farm organizations; commodity organizations; banks |
| Subject matter | Economic Research Service and Statistical Reporting Service of the USDA; university institutes such as the land tenure center, area study programs, arid land studies, etc.; Department of Agricultural Economics; Bureau of the Census; special commissions (e.g., Food and Fiber Commission and this study); Cooperative State Research Service; CIA | Food research institute; Brookings Institution; National Institutes of Health; IFPRI; etc.* | Rand Corporation; research organizations; consulting firms; the foundations |
| Disciplinary | University departments of economics, political science, sociology, etc. | | University departments of economics, political science, sociology, etc. |

*Tax exempt agencies are classed as semipublic.

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The interactions between subject matter and disciplinary research organizations tend to be extensive. Cooperation, collaboration, and the exchange of scientists is common. Within the agricultural sciences, including agricultural economics and rural sociology, this interaction can be traced to the applied orientation of the U.S. college of agriculture. Recent "discoveries of agriculture" by U.S. organizations and agencies not used to working with agriculture have sometimes been humorous and can sometimes even border on the disastrous in their naivete, yet are important in bringing to bear a body of research resources on the problems of agriculture, food, and nutrition. The same can be said of recent discoveries of farm management and firm/household interrelationships in farming.

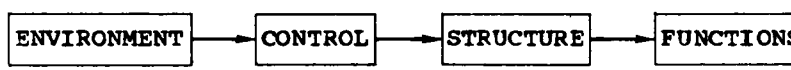
Relationships between problem-solving agencies and the organizations doing subject matter and disciplinary research in the United States are not as good. Decision-making agencies often fail to use the subject matter research organizations within their agency. Several possible reasons exist for the separation of the problem-solving, action-taking activities from the subject matter research organizations: (1) the decision makers do not listen to the subject matter specialists; (2) the subject matter research specialists neither listen to nor produce accurate research results useful for decision makers; or (3) disciplinarians tend to view decision making and action taking as unscholarly and, therefore, avoid interaction with decision makers.

## Appendix B

## THEORETICAL AND METHODOLOGICAL APPROACHES FOR RESEARCH ON INSTITUTIONAL PERFORMANCE

### A THEORETICAL FRAMEWORK

The performance of any organization will be strongly influenced by the socio-political-economic environment in which it operates, the way the organization is controlled and administered, and the functions or services it is called upon to carry out. These four areas of concern are depicted schematically:




The environment incorporates the resources, constraints, and norms that society relates to the organization. The environment most immediately influences the way organizations are controlled. The control patterns include leadership structure (rotating or career), the lines of responsibility for leadership (upward, lateral, or downward), and the extent to which various control techniques such as bureaucratic or market forces are used in making decisions in the organizations.

The form of control affects organizational performance by working through structural arrangements. Organizations may be structured vertically or horizontally in the transmissions of authority. Additional structural features include the management of resources, funding sources, staffing patterns, and relationships to other organizations serving agriculture. The structure of an organization, in turn, largely determines the functions, tasks, or services that it can perform effectively. These functions may include creating new resources, transmission of information, or using resources to provide services.

The interaction among environment, control, structure, and function of organizations can be studied as a comprehensive system only when the experience with variations in each of the four elements is known. Most research on organizational change has focused on variations in structure, especially in resource utilization. Varieties of patterns used in staffing and funding program operations constitute the richest source of data available to organization theorists. Collating these experiences in agricultural organizations thus offers the best prospects for quick research payoffs. The impact of such structural changes on immediate organization outputs can be studied on the basis of existing records in many countries.

Other forms of structural changes also can be evaluated in the short run, since variations in vertical and horizontal authority relationships are fairly common. The consequences of these variations have been less systematically studied than have changes in staffing and funding patterns, but it also should be possible to develop data on the associated output variables from existing records, and reasonably quick research payoffs can be expected for such endeavors.

There has been somewhat less systematic attention devoted to the consequences of changes in the control structures of organizations. However, there are enough variations in use in different settings to permit some comparison of outputs without having to engage in administrative experimentation for this purpose. The results of such comparisons can be acquired after productivity measures have been developed and applied cross-sectionally. Similar appproaches can be applied in studying variations in leadership, also with medium-term payoffs.

Carefully structured, long-term research will be required to discover the systematic consequences of environmental variations on organizational performance. Longitudinal studies will be needed to isolate the impact of changes in resources, constraints, and norms, since such changes as exist "naturally" were usually introduced haphazardly and for extraneous reasons. Such studies will probably be of greatest utility in the long run. However, they may show the way to introducing large-scale variations in resource allocations while holding constant output measures, organizational control, and operating structures.

## DATA COLLECTION AND ANALYSIS

The critical research laboratory for the study of organizations serving agriculture is comprised of the

numerous existing institutions throughout the world as well as selected historical cases of the development of similar institutions. These existing institutions have two important features that make them useful for analysis: they vary in the organizational arrangements that have been created to implement agriculturally related functions, and they vary in their performance and impact on agricultural development. Some institutional arrangements have produced very useful policies, programs, and technologies; some have had an excellent record of distributing needed information to farm operators; and some have provided training programs that improved needed farmer skills. Likewise, other arrangements have failed to achieve these and other results.

The variation in both institutional arrangements and institutional performance provides an opportunity for researchers to analyze these cases for the purpose of identifying patterns of association that can be applied to the design of more effective institutions for agriculture. In general, the analysis of this variation can be organized in five cumulative modes: description, analysis, comparison, field experimentation, and modeling.

A first step in institutional research is the careful description of specific institutional cases. Often we only have the idealized projection of what the institution should be, but little reliable information about what its actual structure, operating rules, and performance outcomes are. Without these basic data, analytical work is impossible or inaccurate.

Since organizations often perform differently than they are intended, it can be difficult to obtain the access to individuals and information needed for achieving this phase of the research. In some instances, foreign researchers may be able to obtain access, while in others such access will be possible only for national researchers.

The "raw" data provided in careful and detailed case studies can be used for the purpose of institutional analysis. Examples include: (1) a research activity in which the institutional case is examined to identify the basic interrelationships that explain the dynamics of the institution, (2) an analysis of the relationship between size and specialization, and (3) an analysis of the impact of accountability on job performance. While analysis cannot be done completely out of context, once the basic descriptive data have been produced it is possible for that information to be used by a larger community of analysts. In this sense, descriptive data can be transferred from the setting in which they are produced to other critical research centers that may

have the resources and other capabilities for extensive analysis.

As numerous cases are described and analyzed it is possible to move the institutional research into a third phase, that of comparative studies. In this phase the researcher is able to move beyond the data of the single case to test and explain further the critical dynamics of institutions. The relationship tentatively identified in a specific case can be subjected to scrutiny with the data from several cases, and in the process be abandoned, modified, or substantiated. It should be emphasized that this sophisticated level of analysis, which promises to yield significant information about institutional dynamics, can be achieved only if the prior activities of description and analysis have been performed adequately.

In the fourth phase, opportunities also may arise for applying (and, therefore, further testing) these emerging principles of organization through the development of new, or the modification of existing, institutions in selected national settings. Since the successful creation of new institutions is highly dependent upon the support of national and local leaders, such institutional testing can only proceed in situations in which a particular nation or state is prepared for this activity. While these opportunities may be few in number at any given time, they do represent an important aspect of institutional research and development and should be pursued when they arise.

Currently, several countries are reorganizing their agricultural research systems; Brazil, Korea, Pakistan, and the Philippines are specific examples. In these situations, policymakers may be open to reviewing several institutional alternatives for improving the performance of research organizations. Situations such as these may provide important opportunities for institutional design and testing.

The detailed data available from the first three types of research, and utilized for the purposes of field testing, also can be utilized for various modeling techniques. These modeling exercises would allow the researcher to evaluate quantitatively the effects of various alterations in institutional arrangements on a range of specified variables. They also would provide another means for policymakers to consider systematically alternative organizational arrangements for serving agriculture.

While the range of current institutions represents an important pool of cases for research as described above, we also would like to emphasize the importance of selected historical cases. Our thinking about strategies of agricultural development has been

positively influenced by the historical perspectives that have been developed regarding such cases as Japan and the United States. Historical treatments of additional cases are likely to produce important information.

## NOTES

1. Intermediate organizations are those that link individuals, families, and individual firms with regional or national organizations and institutions.
2. Even the inadequately nourished rich suffer informational or motivational poverty in the sense that they either do not know what constitutes good nutrition or are inadequately motivated to procure good nutrition.

## REFERENCES


Johnson, D. G. (1973) World Agriculture in Disarray. London: Macmillan in association with the Trade Policy Research Center.

Selowsky, M. and L. Taylor (1973) The economics for malnourished children: an example of disinvestment in human capital. Economic Development and Cultural Change. October. (Published by the University of Chicago.)

Valdes, A. E. (1974) The transition to socialism: observations on the Chilean agrarian reform. Employment in Developing Nations, edited by E. O. Edwards. Boulder: Colorado Associated University Press.

Report of Study Team 8

# INFORMATION SYSTEMS

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## HISTORICAL PERSPECTIVE

All countries need information about food and nutrition to conduct domestic and international affairs, to provide for human needs, and to manage natural resources. Information on any season's crop production affects the expectations of the food production and distribution systems. From this information, large inventory movements may result and food prices may adjust accordingly. These prices are key signals for food producers. Unless the signals indicate that a profit can be expected from production, the production process slows down. The more accurate the information, the more efficiently the resources of farmers, storage facilities, food processing enterprises, and investors can be allocated.

Information gathering is as old as civilization, e.g., census-taking by the Egyptian pharaohs and the Roman emperors. The use of scientific statistical methods and the institution of formal statistical analysis groups within major government agencies date back to the second part of the nineteenth century. Early methods--still in wide use today--consisted of sampling events, enumerating economic units, and taking censuses.

As demands for more accurate information grew and the costs of acquiring data increased, statistical methodology was developed and applied to the collection and tabulation of data for producing useful information. (Appendix A documents several existing information systems.) Hence a distinction must be made between data and information, the latter having a degree of decision making value (observations or measurements of economic, physical, or social behavior in and of themselves are useless unless given purpose). In spite of these technological advances, many countries still do not have adequate systems to gather the data needed to support decision making about food and nutrition.

Historically, in most developing countries agricultural statistics have not been adequate in terms of quantity or quality. The principal source of data in many of these countries is an agricultural census attempted at 10-year intervals with reference data on or close to the year ending in zero. Some countries are not able to complete their scheduled census. Often during years between censuses, there is a complete void of nationwide data collection activities. The chief reasons for this are: (1) lack of resources for acquiring and tabulating data, (2) inadequate technical capability to formulate sound data gathering and processing procedures, and (3) lack of a suitable sampling or data collection frame.

The collection of agricultural data in many developing countries generally has been limited to a few one-time surveys using a sample from the list of census respondents. However, census respondents provide a poor quality sampling frame when an appreciable period has elapsed between the time of the census and the time of the follow-up survey.

The timeliness of data acquisition becomes more important as world agriculture becomes more complex and the interdependence of countries for basic foods and fibers expands. The number one concern for world agriculture has become monitoring the demand for existing food supplies. Commodity markets exhibit great instability as worldwide information on crop and livestock production becomes available. The detrimental effects of misrepresented situations on the movements of markets as a result of crisis lead to misallocated resources and social turmoil. The turbulence of the early 1970s is a case in point.

## STUDY TEAM MISSION

Study Team 8 was asked to identify key areas of research and development that would lead to the establishment of a worldwide information system (or systems) for improved world food production and nutrition.

Information systems can vary in complexity and structure, and individuals from different disciplinary backgrounds can vary in their concepts of them. Thus in this report we provide a wide range of supportive analyses and descriptions. We also define the world food and nutrition system and the theory and concept of an information system, and we review existing information systems and information needs of the primary producer. Finally, we present a range of proposals, covering the informational needs of the primary producer in the developing world and of small-

scale nutritional surveys, to a satellite-based agricultural crop monitoring system with an extensive computer network for distribution and analysis.

The use of relatively uncomplicated information systems in the developing countries could promote a number of beneficial side effects because the logical organization of the system helps to improve the individual farmer's or the national planner's general decision making process. This achievement has been overlooked by many who analyze research and development for information systems (see Appendix B). Moreover, the logic of the information systems approach provides an all-encompassing set of guidelines for analyzing the effects of new agricultural technologies in the developing and higher-income worlds. The information systems approach to analyzing research and development proposals is essential to fully analyze economic, biological, social, and political impacts.

The costs of establishing information systems are high in the short run but diminish in the long run. On the other hand, benefits tend to be modest in the short run but increase in the long run. These characteristics do not make the establishment of information systems attractive to those in pragmatic politics where the short-run payoff is obviously desirable if not necessary.

## RECOMMENDATIONS

It was not difficult to produce a long list of research and development areas needing further attention and work. To reduce this list, we used the following criteria:

-- Relevance. If successfully completed, would the proposed research and development permit more intelligent judgments about the allocation of resources for food production, storage, distribution, and improved nutrition by the individual or firm concerned with utilizing available resources and by the planner or policymaker concerned with modifying the availability and allocation of resources?
-- Scope of applicability. Would the research and development, if successfully completed, be applicable in the developing countries, the high-income countries, or both?
-- Researchability. Could the proposed research and development be successfully completed within a reasonable period of time (i.e., 10 to 15 years)?
-- Long-term needs. Is the research and development proposal a significant long-range development that

needs to be initiated within the next several years but not necessarily completed?

-- Duplication. Is the same type of research and development already being done to a significant degree?

These criteria prevented us from preparing recommendations on a number of aspects of information systems, although these aspects are fully worthy of consideration and further development. For instance, we discussed the need for a rationalization of U.S. and international efforts to build a comprehensive world bibliographic inventory of agricultural information. This inventory is exemplified by the Cataloging and Indexing (CAIN) system of the U.S. National Agricultural Library and the International Information System for the Agricultural Sciences and Technology (AGRIS) program of the Food and Agriculture Organization (FAO) of the United Nations. Such a rationalization could halt the waste of resources in libraries and information centers where the work of bibliographic description and indexing is now duplicated extensively. However, we refrained from making a specific recommendation in this area as we are aware of the efforts already underway. We do recommend accelerating studies of available alternatives leading to an early crystallization of U.S. policy--both nationally and in defining the position to be taken by the United States in FAO. This work should require no more than a few months. We urge that any work still needed to arrive at the necessary decisions be completed as soon as possible. These decisions revolve around whether the United States will fully support AGRIS and apply its diplomatic, financial, and technical resources to this end or, alternatively, whether the United States will concentrate domestically on CAIN and make the products of this system and other existing systems as widely available as possible. The National Agricultural Library will make recommendations on the course of U.S. action following an evaluation of AGRIS to be made in 1977.

Other information systems and needs discussed related to market news, weather forecasts, genetic data bases, research networks, etc. All of these "information systems" need improvement and expansion. However, either because these systems were judged to be closer to the "applications stage" or because the relative level of activity and accomplishment was assessed to be already high, these information systems were not addressed in the same manner as those discussed under "Specific Recommendations."

Our recommendations for research and development on information systems to increase world food production

and improve nutrition fall into three categories: (1) information systems that would ensure that existing information and knowledge are more widely used to increase food production and to improve nutrition, (2) information systems that would provide knowledge not now available for increased food production and improved nutrition, and (3) information systems that are not designed to increase food production or to improve nutrition but are essential for efficiently managing an existing food supply.

## Priorities of Recommendations

Recommendations are presented below in what we view to be their most logical order. We begin with a recommendation relating to the concepts and methodologies of information systems, proceed to issues of data collection and storage, and conclude with recommendations designed to increase the effectiveness of data. Recommendations 1, 2, 3, and 4 are closely related and could be woven into one broad recommendation. A total system is desirable but realistic research priorities call for some choices. Recognizing the importance of each priority should strengthen planning so that the total system is considered as an information system is developed.

The view taken of a world food and nutrition system is that of a holistic system. This suggests that all components of the system should receive simultaneous attention (see Appendix C). This view is appealing but unrealistic, at least in the short run, since the resources and knowledge we have do not permit treating all of the components of food information systems simultaneously. Thus the above criteria along with other considerations were relied upon to assign priorities (see Table 1).

## Specific Recommendations

### Recommendation 1. Information Systems Approach

Problem. The planned or realized consequences of substantive biological or physical changes in any part of the food and nutrition system are often large relative to the environment affected. Conventional techniques for evaluating change (e.g., benefit-cost calculations) are applicable only when the change is so small that it does not alter the structure of the system. Failure to evaluate large, nonmarginal changes in a total information system context often allows the unanticipated consequences of change not only to exceed

Table 1. Priority ranking of Study Team 8 recommendations

| Priority ranking | Brief description of recommendation | Recommendation number* |
|---|---|---|
| 1 | Agricultural crop monitoring | 3 |
| 2 | Sampling and survey systems | 2 |
| 3 | Information systems approach | 1 |
| 4 | Data bases | 4 |
| 5 | Analysis centers | 7 |
| 6 | Producers' information needs | 5 |
| 7 | Capacity of information users | 6 |

*Order of presentation in the following discussion.

the intended, but on occasion to overwhelm the food system and even the society.

The transfer of advanced technologies to the developing countries or to the less-developed part of a nation frequently has had unanticipated and sometimes undesired consequences. In one example, building a bridge across an African river to reduce transportation time and cost allowed movement between the modernized portion of the society and an isolated tribal society. The unanticipated consequence was that the market economy flooded into and absorbed the physical resources of the tribal society, eventually destroying the tribal culture without providing any real means for continued subsistence of the human population. This kind of experience has been repeated many times.

An information system attempts to represent reality by describing specific phenomena in some system of categories usually in quantified form (see Appendix D). Data are the result of measurement or counting, but when one sets out to quantify anything, the first question that must be answered is: What is to be counted or measured and why? If the data produced are to be internally consistent and realistic, the ideas quantified must bear a meaningful relationship to each other and to the reality of the world being described. Reality is nearly infinite in its variation and

configuration and must be simplified or categorized if it is to be handled systematically. Thus in producing accurate data one either implicitly or explicitly develops concepts that are capable of portraying the complexity of the real world in a manner that can be grasped by the human mind. Data are a symbolic representation of those concepts. If the concepts are not reasonably accurate reflections of the real world, then no amount of sophisticated statistical technique or dollars invested in data will produce useful numbers (Bonnen 1975:727).

Data alone are not information. They acquire meaning only in the context of some information process. An information system produces, analyzes, and interprets data in the context of a policy decision or problem solution. In social decision making, this context is nothing less than the social system affected by and within which the decision is made (Bonnen 1975:758). Thus the scope of the information system specified could be as large as the worldwide social systems which are affected, or as small as the subsystems of a country's food system, such as the feed-livestock or potato sector.

It is worth noting that the idea of "information" as well as the idea of "systems" both involve purpose. Also, both are multidisciplinary in knowledge base and concepts. Finally, problem solving is an inherent characteristic of each, and, in this sense, both are processes.

Any information system with even the most limited adaptive capability can be considered dynamic. If there are feedback loops in the system there is some potential for learning in the processing of information. Thus the functioning parts of the system can be altered.

The purpose of the planning system and the underlying information system in most countries is to create some specified change in the system's environment. However, the learning that occurs during the planning process may lead to a change in the objectives of the planning system. This creates a different kind of information processing and information design problem. One purpose of the information system in this case is to assist the decision maker in specifying the goals of the system in a progressively more complete form. This has been described as information processing in a developmental mode.

There is no real need to redesign data and the information system when an information system is tracking phenomena that have an unchanging structure and thus behave in some consistent pattern over time. However, when the object being tracked rapidly changes

in nature in large steps, the conceptual base of the information system must be progressively modified so that the system is accurately representing the phenomena it is tracking. In this case, the information system must be capable of redesigning its own conceptual base and thus the nature of the information system itself. In an increasingly complicated, interdependent, and rapidly changing world, agricultural information systems should have these internal dynamic capabilities.

- We recommend that a conceptual and methodological foundation be developed for an information systems approach to the conscious design, implementation, and evaluation of major technological changes in world food and nutrition.

Objectives. Theoretic concepts have been widely ignored in the development of world food and nutrition information systems. Existing systems are partial systems, not dynamic, and permit little feedback within and between systems. It is therefore recommended that research be undertaken to:

-- Develop a conceptual (information theoretic) framework that will guide the orderly development of complementary information systems on world food and nutrition. Such a framework should be comprehensive enough not only to accommodate hardware and procedural questions, but also, more importantly, to address the institutional, cultural, and political aspects of information processing. Furthermore, it should address the trade-offs between timeliness, accuracy, and value of information inherent in the decision making process.
-- Develop new statistical techniques to collect and analyze data so that they might be used for multiple purposes in a dynamic setting.
-- Identify the technology or procedures needed to implement the system.

Approach. The "hungry countries" have the right and obligation to determine and implement changes in their food and nutrition systems.

Procedures for implementation in themselves involve changes that are frequently nonmarginal in impact. Therefore, the method of implementation must be viewed in the context of the whole system. For example, improving the collection of food and nutrition data requires investment in human and institutional capabilities. This investment must be done in the

context of the broader developmental goals of the society.

There will be a food information system by default if not by conscious design. While it is not possible to specify all parts of such a system equally, the attempt to include all the subsystems, such as the sample and survey system frame and background data (Recommendation 2) and the agricultural and crop monitoring data (Recommendation 3), avoids major decision errors that might result from misspecifying problems and alternatives within the system.

This project has a high probability of success and can be accomplished within 10 years. The cost of such a project is estimated to be $1 million per year and would most appropriately be sponsored and overseen by a research institution such as the National Science Foundation (NSF). Empirical test points should be built into the research process so that this research effort does not result in the development of highly abstract, narrow, and perhaps irrelevant models. Also, scientists from abroad should participate to ensure that a wide range of real world situations are considered.

Impact. The primary benefit of a systems approach is being able to avoid a wrong decision by identifying more completely the consequences (costs) of nonmarginal alternative decisions. Most benefits of a systems approach result from decades of well-directed development and an orderly self-adjustment of the society. In the short run, the chief benefit results from imposing a logical system of thought by which all decision makers, from the social planner to the individual farmer, can approach the issues produced by the technological changes in agriculture and the cultural changes in nutrition. This logical system of thought ideally is a consensual outcome and not a centrally derived outcome.

It is socially irresponsible to plan, implement, or evaluate major physical and biological changes in society as if the only consequences were physical and biological. Frequently, the most significant consequence lies in the effects on the viability and stability of the society's values and social organization and on the physical well-being of individuals.

"Muddling through" will work well as a problem-solving approach only in the case of small, marginal technological or cultural changes. Only in the context of the whole do we see the relevance of the parts and understand the significance of transforming any major part.

Recommendation 2. Sampling and Survey Systems

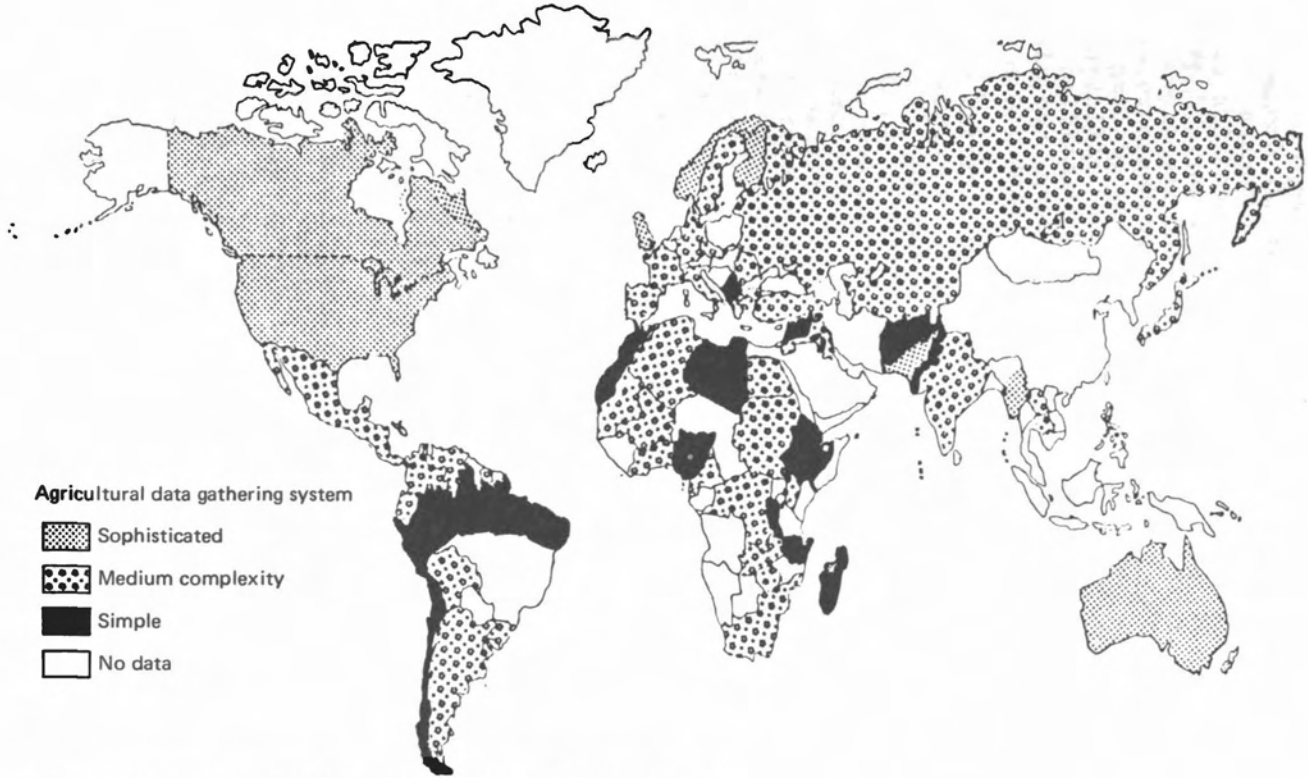
Problem. Periodic data on the production and supply of food, agricultural prices, food consumption and nutritional value, characteristics of farm firms, and agricultural practices and inputs are critically important in analyzing the world food situation and in formulating policy to respond to emerging needs. Likewise, data on the economic and social characteristics of rural households are important for economic planning. Data for food and nutrition information systems must be based on sound statistical sampling designs that provide estimates (data) in such a manner that statistical measures can be used to describe the quality of the data. A sound sampling design requires a complete sampling frame for the broadest range of interest. This sampling frame provides the basis for sample selection.

Agricultural production, food consumption, and nutritional and rural statistics are not adequate in terms of either quantity or quality for most of the developing countries. Several important agricultural countries have no agricultural food consumption, nutritional, or rural data gathering systems. Figure 1 shows a classification of the world's agricultural and rural data gathering systems. The principal data source in countries with "simple" or "no data" systems is the census of agriculture conducted at 10-year intervals with a reference date on or close to the year ending in zero.

To provide an efficient and effective agricultural, nutritional, and rural data collection system, the developing countries need to develop a general purpose sampling frame and a basic agricultural, nutritional, and rural survey system.

The most widely used sampling frame for agricultural surveys is an area frame which divides a country into homogeneous, mutually exclusive units. These units can be grouped into strata for efficient sampling in both commodity and household surveys. Frames of this type are in use in a few countries (e.g., United States, Canada, India, Tunisia, Dominican Republic, and Colombia) and have proven very efficient in responding to changing data needs. The theoretical principles have been developed for using sampling frames.

However, before developing such a frame for individual countries, a large research effort concentrating on major regions of the world must be performed to (1) determine the size of land holdings and characteristics of rural households, for various commodity or rural household surveys for optimizing frame units; (2) test potential stratifications for




SOURCE: Statistical Reporting Service, U.S. Department of Agriculture, 1976.

FIGURE 1 Distribution of crop forecasting activities.

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various commodity or rural household surveys based on current or desired land-use categories; (3) document the availability of aerial photos, maps, census household data, and related materials needed for frame construction in commodity household surveys; and (4) develop information on costs and related resources needed for such a project. An even more basic research item is whether an area or some other type of sampling frame would offer the most flexibility and efficiency in the long run. Samples are generally stratified according to age, sex, income, ethnic group, and place of residence for studies of food consumption and nutritional status of the population.

Establishing an agricultural and nutritional survey system in a developing country requires technicians trained in sampling, survey techniques, data collection, and data processing. Activities in these areas by the U.S. Agency for International Development (AID) and FAO presently reach about 35 participants annually through the U.S. Census Bureau International Training Center in Washington, D.C. Because of the small number of participants, limited resources are devoted to developing training materials and addressing the unique problems that exist in individual countries.

- We recommend that research and development be undertaken to develop a statistically sound, worldwide sampling and survey system. This system would periodically generate data on food production and supplies, food consumption and nutritional value, characteristics of farm firms and rural households, and inputs used in the production of food.

Objectives. The objectives of such research would be:

-- to construct a framework that meets basic sampling frame requirements for an agricultural, nutritional, and rural household data collection system;
-- to provide a methodology for data collection that ensures high quality data based on efficient sampling procedures;
-- to establish a foundation for a generalized data collection system that would acquire data on crop and livestock production, agricultural prices, farm credit, socioeconomic characteristics, rural household characteristics and food consumption patterns, and agricultural inputs used in production;

-- to test research findings in selected countries under a variety of agricultural and population conditions and to refine procedures and materials;
-- to develop training materials (in several languages) that describe essential features of such a system;
-- to enhance the existing 10-year agricultural census activities by providing a procedure that would subdivide the country into geographic units for enumeration;
-- to provide a method for evaluating the effect of development programs and the adaptation of research results on food production and distribution.

Approach. A team of researchers (five or six people) familiar with the construction of sampling frames and with the general agricultural characteristics of the major continents should be assembled. They should choose six to eight countries in which to conduct background research. Host country teams of four to six researchers familiar with the host country's agriculture, mapping and photo materials, and land use also are required. A similar team familiar with sampling techniques for social and medical research, food consumption and human nutrition, and nutrition survey methodology is necessary for consumption and nutrition surveys.

In selecting host countries for the experiment, care must be taken to select countries that are "typical" for a region with respect to climate, type of agriculture, infrastructure, and the like. Thus small countries with relatively modest agricultural production should participate in the research effort. However, it must be recognized that information on countries with large production and/or large populations is relatively more important for policy decisions that are international in scope.

A general plan for developing a sampling frame should be devised and should include information on personnel requirements, costs, equipment requirements, and recommended materials. In addition, general specifications for stratification, subdivision of units within the strata, and a broad outline of the job should be developed. Small geographic areas of the countries being studied (5 million hectares for large countries or 1 million hectares for small countries) should be chosen for testing these specifications. With the frame developed for these areas, small research surveys covering crop production, livestock inventories, household characteristics, etc., can then be conducted to test frame characteristics and optimize its features. A local (central) statistical group should organize, train, and test the system developed.

The development of appropriate materials and specifications could proceed simultaneously with diplomatic efforts to find interested host countries and to organize their local teams. One to two years would be required to develop materials. Host country work would begin as agreements were developed.

Two to three years and a cost of around $4 million per country will be required to complete such a project. Implementing research results on an operational basis will eventually cost about $30,000 per 10-million-hectare area, and the same amount for comprehensive surveys of consumption and nutritional status for a sample of 2,500. Funding requirements could range between $1 to $10 million for semiannual operational national surveys, depending on the size of the country and the scope of the survey. This research should be carried out under the leadership of FAO and the Statistical Reporting Service (SRS) of the U.S. Department of Agriculture (USDA) because of their experience and relevant responsibilities.

Impact. This effort would provide the framework for a basic generalized agricultural and rural household survey system that, once established, could supply a wide range of data needed by planners, public and private sector decision makers, and development organizations in food and social and nutritional activities. In addition, it could provide scheduled data and information for a worldwide food and informational system that would meet specified statistical standards. The ultimate benefit would be the development of a generalized statistical frame that would advance the agricultural statistics systems of the developing countries significantly in the early 1980s.

These sampling frames also are needed for cost-effective and broadened census applications and high technology information systems, such as remote sensing. Once established, sampling frames can be used: (1) to improve existing censuses and surveys, (2) to provide statistically reliable estimates from remotely sensed data, and (3) to establish relationships between remotely sensed data and data collected by other means from the sampling frame, thus increasing the usefulness of both sets of data for policymaking.

## Recommendation 3. Agricultural Crop Monitoring

Problem. Researchers developing the basic technology and methodology for food production need information on the status of crops in the world's critical food-producing regions. Those responsible for incorporating research results into food production

systems and for maintaining and operating these systems also need this information.

Timely, accurate information on the state of agricultural production and on the condition of supporting natural resources on a worldwide scale is needed urgently. Information of this type produced currently is inadequate for predicting world food shortages far enough in advance so that governments can deal with them properly.

Systems capable of assessing the state of agricultural resources and the production outlook at critical times of the crop year generally are either nonexistent or are woefully inadequate to meet the requirements of planners and decision makers. However, during the last several decades remote sensing technology and methodology have been developed which, for the first time, make it possible to construct systems that can supply this type of information economically and on a worldwide scale. The World Meteorological Organization already uses some of this technology to acquire and disseminate meteorological measurements and observations.

The components of this technology include earth resources survey technology (LANDSAT) and meteorological satellites; ground reporting stations; cost-effective, high speed, large memory capacity digital computers; space and ground communications networks; multispectral and other remote sensors; mathematical models; and analysis methodology.

At the 1975 World Food Conference, FAO was charged with developing a global information and early warning system for the world food complex. Since then, FAO has taken a number of steps in that direction using traditional information collection and dissemination techniques. Remote sensing technology can be developed to facilitate and improve the operation of early warning and monitoring systems.

- <u>We recommend that a system be developed and implemented to monitor the world's critical food-producing regions and to provide early warning of possible production shortages. A supporting research and technology program should be organized to develop improvements for the initial monitoring system</u>.

<u>Objectives</u>. The supporting research and technology program, which would be organized to develop future improvements for the monitoring system we recommend, should address the following issues:

-- Developing improved yield models utilizing satellite-acquired measurements of meteorological variables such as rainfall, soil moisture, and temperature.
-- Utilizing remotely sensed direct measurements of the radiation characteristics of vegetation to assess crop stress and episodic events such as severe drought, hail damage, disease, and pestilence.
-- Utilizing improved sampling frames (see Recommendation 2).
-- Utilizing improved data bases (see Recommendation 4).
-- Investigating the use of this technology tc inventory and monitor oceanographic parameters and coastal fisheries resources important to the management of ocean resources to maximize their potential and the economical harvest of food from the sea. There is evidence of a correlation between the presence of fish and water color and turbidity. This research needs to be expanded to a number of species and to different geographic regions.

Approach. Five years probably will be required to study, design, and implement this information system. The initial system configuration would provide information vastly improved over what is available today, but later versions would realize still greater improvements through supporting research and would provide considerable benefits to other users of the world's resources.

A team or teams should be brought together to specify the information requirements for such a system. A preliminary system design capable of meeting these information requirements should be developed and its developmental and operational costs estimated. The preliminary organizational structure, perscnnel requirements, and training requirements should be delineated. A pilot system or systems should be constructed, operated, tested, and evaluated. Upon successful completion of this phase, the pilot system would be expanded to its complete operational form.

An effort of this kind must be genuinely international, with assurance that all of the data generated will be freely and widely accessible. The United States necessarily must take the initiative in assembling the required design teams, because at this time no other country or group of countries is in a position to do so. At the same time, the United States must actively support and encourage participation by other countries.

The probability of designing and successfully implementing a cost-effective crop monitoring system within five years is high (85 to 90 percent). Experiments such as the Large Area Crop Inventory Experiment (LACIE) already are developing a first version of the required technology. The National Aeronautics and Space Administration (NASA) is flying the first earth surface and meteorological remote sensing satellites.

The estimated research costs for an initial monitoring system are estimated to be $15 million per year for a five-year period. The United States should continue to fund LANDSAT-type satellites over this period through NASA. The development costs for an initial monitoring system should be estimated following a preliminary design by the design team(s). The costs of satellite acquisition elements would be prorated among the various users, and it is not expected that the entire burden would be carried by the crop monitoring system.

Impact. There is a dearth of available data to evaluate the accuracy of food production forecasts or estimates of the FAO or USDA worldwide information systems. Thus it is extremely difficult to measure the net returns from this proposal. A number of empirical studies have estimated the benefit-cost ratio in the United States of such a monitoring system. In a study done by ECON, Inc. (1976), the mean square root forecast error for wheat is shown to average close to 7 percent with similar data for the United States averaging somewhat less than 2 percent. Work by Peterson-Hayami (1972) showed that benefit-cost ratios were extremely high (600-800) for improvements made when forecast or sampling errors were greater than 2 percent but were generally very low (under 10 percent) for improvements below the 1 percent level of forecast error.

The Earth Satellite Corporation/Booz-Allen Applied Research Corporation report (1974) showed that with minor improvements in existing information for U.S. agricultural production, water resources, range management, and forestry and land use, benefits totaling $31 to $84 million could be realized. The ECON, Inc. study (1976) showed total benefits exceeding $400 million for data information systems that would reduce wheat forecast and estimation errors by approximately one-half to 3.5 percent.

All of these studies use the Peterson-Hayami model and make numerous economic and information use assumptions that are difficult to justify. The results should be considered very general indications of economic benefits. The models used estimate only social returns accruing to the consuming public due to

improved resource allocation, and thus would represent the lower bounds of total social returns. Benefits from better planning and resource allocation by governmental agencies are not estimated by the models. On a worldwide basis, such benefits would be significant particularly during periods of relative short supplies (Bullock 1976).

Recommendation 4. Data Bases

"Data Base" Defined. A "data base" as conceived in this discussion is an integrated statistical servicing system constructed upon a foundation of recurrent data (cf. Dunn 1974). For example, a land resource data base would contain "elements" on the number of hectares of particular soil associations, slope toxicity, etc. Similarly, a nutrition data base would contain elements concerning nutrient intake by age, sex, country, etc.

A data base should be constructed to permit "multiplication" of its data for specialized analysis purposes. For instance, a land resource data base, along with information from other bases, may be useful in assessing the worldwide effect of a 10 percent decrease in fertilizer availability, a 1°C decrease in mean temperature, or a 5 percent increase in yields of certain crops.

How effective a data base can be in aiding the decision maker in specialized analyses will depend on its characteristics including (1) its descriptive flexibility, (2) the availability and accessibility of a master sampling frame (see Recommendation 2), and (3) the availability of transformation coefficients and techniques. These considerations are taken into account in the following recommendations on specific data bases.

Data bases, as viewed in this context, are envisioned to be dynamic (see Appendix D) to preclude their being outdated as soon as they are established. A properly structured data base is one whose scope and detail can be adapted to existing planning capabilities and changing planning objectives.

Problem. Research on data bases has a high level of transferability among countries. In a pragmatic sense, research and development must be limited to a few data bases. Moreover, some data bases are more beneficial to world food availability and nutrition than others. Therefore, we will only discuss data bases for land and nutrition.

Land is the sine qua non of farm food production. Of course, land does have to combine with water, climate, suitable plant species, and management practices to produce food. Other factors affecting the

suitability of land for food production are slope, altitude, soil type, toxicity, etc. Land-use possibilities are further affected by tract size, ownership patterns, etc.

Scientists and policymakers are not so concerned about the total unavailability of land, but regional shortages are important. Considerable concern exists about the availability of land with particular characteristics as well as about the lack of knowledge about soil associations and related characteristics (moisture, temperature, slope, etc.) in vast regions. This lack of knowledge, coupled with problems of understanding social, cultural, and ownership structures, has impeded the development of crop varieties, livestock varieties, and, more importantly, "technology packages" suitable for particular regions. In part this lack of information is responsible for the slow rate of adoption of existing technology.

In the area of nutrition, the public (including policymakers and planners) appears to be uninformed about what is known in nutritional science, who is at nutritional risk, and for what reasons. In part this situation is due to the lack of a useful data base. The lack of such a base makes meaningful educational programs difficult, if not impossible.

Our current statistical systems measure nutrient disappearance, not nutrient intake. At the same time, nutrient availability may be understated because of nonmeasured sources such as home gardens. Finally, even if nutrient availability were equal to nutrient disappearance and if both were equal to nutrient intake, there is little information on the nutrient balance (or imbalance) between age groups, income groups, etc.

Closely related to the issue of adequate nutrient intake is the issue of food contamination. The ever-increasing complexity of industrial society and food trade makes contamination from industrial pollution, agricultural technology, and food processing an increasingly important specter. Although such contaminants are hazardous to human health, little information is currently available on the presence of such contaminants in food in various countries and regions.

At present, attention to the nutrient content of food is almost exclusively at the consumer level. However, for better nutrient management, more attention must be paid to nutrients produced. Thus a nutrient data base must be broad enough to account for this dimension.

The devastating effect of inadequate diets on our mental and physical capacities is generally accepted. A nutrition data base that provided information for

policymaking and education would help alleviate this effect.

- We recommend that research and development be undertaken to develop international data bases for land and for nutrition.

Objectives. Specifically, we recommend that the following objectives be pursued:

1. Design, develop, and implement a conceptual and methodological framework for a worldwide land resource data base and for an international nutrition data base which permit multiple use of data for specialized analyses. The land resource data base should be capable of being updated by a concomitant agricultural survey and monitoring systems (cf. Recommendations 2 and 3), and the nutrition data base by way of a concomitant nutrition and contamination monitoring system.
2. Develop remote sensing technology to enable the following on a worldwide basis: annual agricultural land-use inventory, soil mapping every five years, weekly soil erosion monitoring, weekly soil moisture measurements, weekly soil temperature measurements, and other characteristics as required.
3. Develop a system that will make available the sampled attributes essential for land resource decision making but not obtainable through remote sensing (e.g., ownership, management practices, etc.), which can be integrated with the remote data sensing base, and which is consistent with the first objective.
4. Design and develop information/communications methods and systems that will permit easy, rapid, and flexible access to the data bases by policymakers, scientists, producers, educators, and others.

Approach. Procedures to accomplish these objectives may be divided into three phases: research, development and implementation, and operation. In this discussion we concentrate on research.

The first step toward accomplishing Objective 1 is developing the appropriate concepts and methods. Specifically, this includes:

-- Developing a standardized descriptor. The flexibility and usefulness of the data base will be greatly determined by the choice of the descriptor of the element (for example, the element is "nutrition intake" and/or "contamination," and the

descriptor is related data such as age, sex, country, etc.). The more complete the descriptor, the higher the probability that the base is capable of a given special analysis--at least in theory. In practice, costs of operating the system rise as the descriptor increases in complexity, thus rendering the base economically infeasible.

The descriptor can be developed meaningfully within the social information processing context, i.e., the analyst assesses which nutrition data might be necessary for important policy decisions. This will lead to the necessary (devised) structure of the standardized descriptor and to identification of research and data needs.

-- Extending the standardized descriptor. Very simple methods currently are being used to extend standardized descriptors. For instance, to generate occupation by location for an industry, occupation by industry from one record might be cross-tabulated with geographic distribution of that industry from another (Dunn 1974). Much more efficient methods need to be developed.
-- Integrating sampled attributes (see Recommendation 2).
-- Using transformation coefficients.

Simultaneously, or once the above is accomplished, existing national programs will need to be studied. Then results provided from these two steps will permit the identification of food items, nutrients, and contaminants to be considered by the system as well as the specification of a sampling plan to establish and update the system.

Given the descriptor, associated extension and modification methods, and other factors to be considered, and the sampling plan, it would now be possible to identify a data handling system. The possibility of linkages to other systems, multiple form access and output, integration at varying intervals, etc., must receive attention.

International cooperation--or at least knowledge of international conditions--is required to carry out Objective 1. However, the primary requirement is for conceptual and mathematical/numerical analysis developments, which could be accomplished by mobilizing resources within the United States. Similarly, the basic hardware technology which offers a resolution of at least 80 $m^2$ for satellite band-scanners appears adequate for the purpose. However, models for adequately identifying various land uses and soil moisture and soil temperature measurements must be developed along with methods and systems of analysis to enable the delivery of results (i.e, on a weekly basis

and in time for decision making). Again, much of this can be accomplished through mobilization of resources within the United States.

Objective 3 is basically an extension of Recommendations 2 and 3, the extension being the requirement that remotely sensed data and those from a basic survey system can be integrated. Objectives 3 and 4 require international activity. It appears desirable, therefore, that FAO, which is already engaged in the beginnings of a food contamination monitoring program, and other international centers and agencies be considered the focal agency for Objectives 3 and 4. Sponsorship of and leadership for research and development related to Objectives 1 and 2 would rest logically with agencies such as NSF, NASA, USDA, the National Oceanic and Atmospheric Administration (NOAA), and AID.

The probability of success is considered high for research related to this recommendation. It is estimated that a commitment of about 60 scientist-years over a period of 6 to 10 years will achieve the objectives.

Impact. The land resource data base we have defined would help improve management of the world food and nutrition system in a variety of ways. Knowledge of available land resources and their characteristics will permit us to determine which crops and "technology packages" could be successfully adopted in various regions. This information also will allow us to evaluate needed research such as crop breeding, ways to combat soil toxicity, irrigation, sociological and economic structure, etc. Further, knowledge about the land resource base combined with monitoring of weather, plant growth, etc. (see Recommendation 3) will permit improved short-term forecasts of food supply, thus aiding in policymaking for existing but perhaps poorly distributed food stocks.

Improved health because of improved nutrition and absence of contamination is valuable, but this value is difficult to quantify. Available data on the social cost of illness should not be extrapolated to other professions and countries as the relationship between the existence of a nutrition data base and improved nutrition and consequent improvement in human productivity vary from country to country. Despite this, it would appear difficult indeed to underestimate the benefits from improved nutrition, particularly since such benefits can accrue to the developing and high-income countries. The effects are certainly more significant in the former than in the latter. The effect of improved nutrition is not only increased human productivity but also decreased medical needs and human suffering. A nutritional data base

will assist in redirecting the focus from a narrow view of nutritional intake to the broader relationships between nutrient requirements and nutrient production. Such will have a positive effect on nutrient output.

Recommendation 5. Primary Producers' Information Needs

Problem. When the information needs of expanded world food production are enumerated, the list usually starts with the macrodata requirements of planners. Next is the need for campaign-like programs of persuasive communication to speed the diffusion of new technology. Still a third kind of need assumes a growing importance as agriculture becomes modernized--the primary producer's need for facts on which to base day-to-day managerial decisions and functions. Up to now most research about information needs and effects has dealt with how innovations spread--where farm operators first learn about new practices and what kinds of communication are most persuasive in these early stages. Only slowly has the realization come that the continuing availability of managerial information is a necessity for efficiently using many forms of modern agricultural technology.

It is certainly more than coincidence that traditional agricultural economies place only minimal demands on external information systems. Modern agricultural technologies, on the other hand, are often infeasible and uneconomic unless the planner, change agent, or the ultimate user can count on information support. For example, a rice-growing region begins to depend on only one outstanding new crop variety. However, there can be catastrophic consequences if that variety is unusually susceptible to a particular pest or disease. When pesticides are expensive, as they are in most developing countries, wise farmers will resist the stampede to the new variety unless they can count on getting current, reliable advice at all times as to what their risks are and how best to deal with them.

The area of market information offers a similar example. Changes in the price of fertilizers dictate changes in the amount and kinds a farmer can use, as do changes in the cost or availability of credit needed for buying fertilizer. Product prices influence in a similar way the choice of what crops are grown, how they are grown, and when and where they are marketed.

Information needs of this kind are a direct consequence of modernization. Each change in technology requires a continuous series of informed judgments by the farmer which mean large implications for his or her income and productivity. Decisions at the individual level become increasingly crucial and

difficult as the needed information base becomes more complex. All of this suggests the value of analyzing, in a systematic way, the farm-level information requirements as well as the other requirements of any proposed change in agricultural technology.

- We recommend that research be undertaken to analyze the informational needs of the primary producer associated with the introduction of new agricultural technologies.

Objective. The objective of this recommendation is to assess the information needs of farmers to assure that the technology areas suggested by the World Food and Nutrition Study will be adopted.

Approach. A list of promising new technolcgies should be the object of an experiment/demonstration in which multidisciplinary groups specify the kinds of managerial information required by the users of each technology and the steps that must be taken to make such information available. For any given technology these needs will differ, but generally they might include such things as weather predictions and reports, current product price quotations, climatic data, product storage requirements, long-range market outlook, estimates of costs and returns for different levels of input use, early warning of disease or pest build-ups, accurate estimates of disease/pest risks, clear instructions on how to use new inputs, and guidance on the substitutability of inputs.

The experiments/demonstrations that are suggested should specify for each proposed change in technology: (1) what kinds of information the user must have, on a continuing basis, to apply the technology effectively; (2) who can most efficiently assemble or collect this information; (3) how this information can be made available to users (in what form, through what channels, and with what frequency); and (4) what communications infrastructure this will require.

This recommendation has a high probability of success and can be accomplished effectively within two years. The research effort probably would cost about $100,000 per technology studied. The individual research projects could be accomplished through a wide range of national and international research organizations, including universities and commodity-specific research centers.

Impact. Systematic attention to such information needs before a change in technology is introduced would mean its more widespread and successful application. The hypothesis that information needs of the kind described are best met for larger or more prosperous farmers, and least adequately satisfied for the small

farmer, should be tested. An experiment/demonstration of the kind described should be much more effective than trial and error or the transfer of patterns from other parts of the world in defining the kind of information services small farmers must have. Carefully planned experimentation also could demonstrate and give more accurate estimates of the actual value of, and therefore the justifiable investment in, user-oriented information facilities and services.

## Recommendation 6. Capacity of Information Users

Problem. A number of the recommendations of the World Food and Nutrition Study are aimed at increasing food production in the developing countries, particularly those in the tropics. But these areas are precisely those that are least equipped to utilize information systems. Not only do they lack material infrastructures, but more importantly they lack suitably trained personnel. Training is essential for two reasons. First, information staff are needed for the ongoing operation of the systems at the national or regional levels and for interface activities between the systems and their users. Second, the ultimate users must be trained in the appreciation and use of information.

Perhaps the shortest route to the better application of knowledge in planning and production lies in helping the developing countries build their policies and capabilities for information processing and delivery, but no simple solution exists for achieving this. There are as many different situations as there are countries, and each country must find its own way, taking into account its national institutional framework, educational system, physical communications facilities, and increasing awareness of its information needs. Efforts are being made, however, in the context of international information programs and systems to assist the developing countries in defining their policies and in building up their capacities to collect and manage their own information and to take maximum advantage of the information that is globally available.

The United Nations Educational, Scientific, and Cultural Organization (UNESCO) has considerable experience in helping countries plan their overall information programs. This is given high priority in its UNISIST program within the context of the International Nuclear Science Information System (INIS) and the International Information System for the Agricultural Sciences and Technology. Training seminars have been held at which scores of individuals from the developing countries have been taught how to exploit these systems. FAO (with U.N. Development Programme funds) has helped create national agricultural documentation centers in several countries. Both FAO and the U.N. Statistical Office

have programs to assist the developing countries in collecting and processing relevant data. Bilateral aid agencies have given technical assistance in many different forms (equipment, consultants, training). A new bilateral program is now under consideration by the authorities of Ghana and the National Academy of Sciences (NAS) and NSF. This effort will assist Ghana in developing a total information program in science and technology.

Successful application and utilization of an informatio system in one country, while not completely transferable to another, nevertheless would point up useful techniques and approaches adaptable over a wider range.

The rapid decrease in the cost of international communication, particularly due to communication satellites, could enable the developing countries to gain access on lin to information systems that have been developed elsewhere. Although most agricultural information is country-specific, much of it (such as genetic or disease informatic) may be regionally or even globally valid. Computer networks are becoming able to make such information available anywhere a true costs no greater than that within a country.

- We recommend that research and development be undertaken to increase the capacities of the developing countries to make efficient use of local and world agricultural and nutritional information.

Objectives. Specifically, the objectives of this research are: (1) to select a limited number of developing countries (six to eight) in which the current structure of agricultural and nutritional information storage and dissemination can be analyzed with particular emphasis on the end user; (2) from these analyses to develop and test alternative models of agricultural and nutritional information storage and dissemination; and (3) to use the experience with these models as a source of improved practices, policies, and institutions.

Approach. Initially six to eight developing countries would be invited to undertake, with international assistance, studies of their agricultural and nutritional documentation, data, and other information services. They would describe what exists and how it functions, and prescribe what is needed over a six-year period to construct an effective program of knowledge transfer for their agricultural sectors and for those involved with programs related to food consumption and nutrition (cost: $1 million; time: 18 months).

A person or persons with experience in infcrmation policymaking and planning would then analyze the products of the national studies on a comparative basis

to identify common needs and to bring them to the attention of other countries and international organizations (cost: $30,000; time: six months).

Assistance would be provided (equipment, consultants, training) to some or all of the participating countries or groups of countries to develop their capacities (cost: $6 million; time: five years).

The effectiveness of the assistance would be continuously monitored as well as evaluated at the end of the program to derive more widely applicable recommendations (cost: $60,000; time: one year).

Recommendation 7. Strengthening the "Response Capacity" of Centers of Scientific Excellence

Problem. In recent years technological innovation in agriculture has been stimulated increasingly by the existence of highly specialized international research centers. The International Rice Research Institute (IRRI) is perhaps the best known, but similar organizations are working with corn and wheat (Mexico), tropical food crops (Nigeria), and semiarid agriculture (India), to name only a few. Beyond this formally designated group of international centers, institutions elsewhere in the world have informally accepted some responsibility for international service (in Illinois for soybeans, Israel for irrigation, Wisconsin for land tenure problems).

Each institution of this kind has active research teams engaged in its own program of investigations. Each has also supplemented its data and knowledge with a wide ranging awareness of what others have reported in the world's scientific literature. Consequently, each has become a source of both information and advice in its special field for a worldwide community of scientists and policy planners.

The demands on such institutions have far outrun the resources available to meet them. This means unmet needs and opportunities not seized. Specialized centers of scientific excellence could provide a base for giving food producers everywhere more rapid direct access to the annual flood of scientific literature (recently estimated at about a quarter of a million items in food and agriculture, forestry, and fisheries). Many institutions are helping to maintain the basic inventory of this material, but only a few are in position to tailor it to the needs of various user groups. Yet such tailoring is indispensable. Whether the users are scientists or extension workers, their requirements will be met more speedily and more effectively by an institution that understands not only

how scientific information is generated but also where and how it can be applied.

The small farmer, in particular, stands to gain from this kind of approach. The high-income countries and the larger producers, even in the developing countries, know how to seek out current information that may help them. The developing country and the smaller farmer are at a disadvantage unless someone takes the initiative on their behalf.

Existing centers of scientific excellence are a useful starting point because they represent high priority areas in agricultural development. However, these institutions should serve broader constituencies, with assurance of the resources needed to make that possible.

Objectives. Strengthening the "response capacity" of these centers would permit them to go substantially further than they now do in:

-- providing informative or interpretative summaries of knowledge in the primary literature;
-- promoting the exchange of information about research in progress to stimulate cooperative efforts and minimize duplication;
-- encouraging the production of "state of the art" reviews in which available knowledge is consolidated and presented in ready form to priority target audiences;
-- publishing newsletters to inform user groups of significant new discoveries, developments, and events;
-- evaluating facts and data and issuing recommendations aimed at promoting acceptance of standards, best values, etc., in future research and practice;
-- maintaining a question-and-answer service.

- We recommend that steps be taken to strengthen the capacity of international centers of scientific excellence tc respond more efficiently to the information needs of users--both scientists and nonscientists.

Approach. To increase the respcnse capacity of centers of scientific excellence, institutions must commit themselves to responding to a world constituency--or more precisely a great variety cf local constituencies--as well as to their own more narrowly defined clienteles.

Responding to the needs of a worldwide community of scientists will certainly require added financial resources, but only minor changes in the way an institute views its mission and purposes. Responding

to those who apply research results (or set the policies that facilitate application) is a more difficult matter. Besides requiring added financial resources, it may require new priorities in an institute's plans. These will not normally conflict with its responsibility to its primary research mission, but will certainly call for: (1) assigning leadership in this task to qualified staff members, (2) choosing leaders who have practical field knowledge and experience and who are skilled in preparing informational and training materials for nonscientific audiences, (3) encouraging the persons so assigned to work closely and directly with national agencies in selecting from or adapting institute materials and reports for maximum usefulness, and (4) experimenting with faster physical means of communication to permit rapid individualized or localized responses to particular questions or needs.

This approach may involve a wide range of international agencies, but AID should serve as the focal agency. This agency should consult with other interested donors to construct a five-year international experimental program. This would require selecting a number of high priority topics, funding the establishment of specialized information analysis centers at institutions that have strong research capabilities in these topics, ensuring adequate exchanges among the centers on technical aspects (methodologies, services, forms of products, etc.), and evaluating the results in terms of their benefits to the user constituencies and ultimately in terms of the enhancement of agricultural production.

The probability of success of this undertaking is very high, and anticipated costs are approximately $200,000 per center per year, assuming that the analysis center is located where a research center already exists with a "good" library.

## Appendix A

## REVIEW OF EXISTING INFORMATION SYSTEMS

### INTERNATIONAL BIBLIOGRAPHIC INFORMATION SYSTEMS

Essentially all publications of significance are indexed by one or more of the existing bibliographic services. Ulrich's International Periodicals Directory lists over 100 abstracting and indexing periodicals that primarily are concerned with some aspect of food and agriculture. Many of these periodicals are subsets of a larger more general service such as Biological Abstracts and BioResearch Index. Others are limited to national coverage or are intended for a restricted audience by either a geographical area or subject.

### INIS

INIS (International Nuclear Science Information System), operated by the International Atomic Energy Agency in Vienna, Austria, is of only peripheral interest from the point of view of agriculture. Yet it must be considered, and first, because of its leading position in the field of international systems and because it has served as a basic model for the development of more recent arrivals in the field.

INIS is a decentralized system consisting of a partnership among some 50 countries and supranational organizations. INIS is coordinated in Vienna where the separate inputs are merged and processed to produce output in the form of magnetic tape and the printed INIS Atomindex. The computer used presently is an IBM 370, Model 145, and the programs require a 156K partition. The programming languages are PL/1 (F-compiler) and Assembler, and the operating system is OS.

Information is given in the form of bibliographic references, keyworded and categorized according to the controlled vocabulary of the INIS thesaurus, plus abstracts. (This last component was introduced only

recently as a logical developmental phase.) Author, corporate name, and subject indexes are compiled. The carrier language is English.

## AGRIS

AGRIS (International Information System for the Agricultural Sciences and Technology) is the most important of the international systems from our point of view. It was set up by FAO largely in response to representations made by the U.S. National Agricultural Library and the Commonwealth Agricultural Bureaux that their activities were not only wastefully overlapping but also missing a significant proportion of the total world agricultural literature. The system has been operational since January 1975. It is closely modelled on the INIS pattern, and indeed uses the same hardware in Vienna and modified software as INIS, but does not yet incorporate abstracts in the data base.

Input is provided from some 64 countries and from FAO itself for international publications, but not all input is made directly. There are regional input centers for Latin America, Southeast Asia, and the European Common Market where input from the constituent countries is merged before it is transmitted to the AGRIS Input Unit (AIU) in Vienna. Magnetic tape is the only input medium permitted, but for a build-up period the AIU is converting other input media such as worksheets or punched tape to magtape.

Some of the factors that multiply the difficulties of operating an INIS-type system in a field such as agriculture are: (1) the much larger number of input centers; (2) wide diversity of training, experience, and technical sophistication of input personnel; (3) wide diversity of subject matter and vocabulary (both in subject fields and in variations in usage); and (4) extreme diversity and variability of publication format, frequency, etc.

The initial outputs are a monthly magtape and the printed form, Agrindex, with author, corporate name, report number, and subject indexes. Specialized outputs derived from the data base also are available. The retrieval vocabulary is based presently on a broad categorization scheme coupled with classifications of crop and livestock names and geographic areas. It is currently undergoing extension and may later proceed to a full keyword approach.

The volume of input has been increasing since the operation started and will continue to do so. The present volume is about 5,000 items per month. Emphasis is placed on nonconventional material, each

citation of which includes information on the availability of the item.

The AGRIS format closely follows the principles established by UNISIST, and is now being used in several agricultural information activities that are not presently directly linked with AGRIS, so that the hopes for future compatibility are high.

## DEVSIS

DEVSIS (Development Sciences Information System) probably is outside the subject scope envisaged, but, as it is being planned to serve the development community, it is considered.

DEVSIS is not yet an operational system. Under the sponsorship of the International Development Research Center (IDRC), UNESCO, the Organization for Economic Cooperation and Development (OECD), the United Nations Development Programme (UNDP), the International Labor Organization (ILO), and the United Nations Department for Economic and Social Affairs (UN-ESA), a steering committee appointed a study team whose detailed report on the proposed operation has now been published. As proposed, DEVSIS is similar in many ways to INIS and AGRIS: it is a global, mission-oriented, decentralized system designed within the framework of UNISIST. It does, however, differ from INIS/AGRIS in two important areas. The DEVSIS data base is envisaged as consisting of two separate files: File One will be a bibliographic record organized in much the same way as INIS/AGRIS; File Two will provide a referral service, containing records of the sources and services from which specific information and data relating to economic and social development might be obtained. Developing a File Two will allow File One to be maintained at a manageable size--a projected volume for File One is 100,000 items a year. DEVSIS also differs from INIS/AGRIS in that French and Spanish, in addition to English, will be the carrier languages.

The principal outputs of File One will be, as with the other two systems, a magtape service and a printed bulletin, Devindex. File Two will produce a magtape and Devprofile, an indexed publication, each to be issued three times a year.

It is expected that, as with the other systems, the central authority for DEVSIS will be vested in an U.N. organization.

## IFIS

IFIS (International Food Information Service) differs radically from the systems previously listed. It is sponsored by the Commonwealth Agricultural Bureaux in Britain, the Institut fur Dokumentationswesen and the Zentralstelle fur maschinelle Dokumentation in the Federal Republic of Germany, the Institute of Food Technologists in the United States, and the Centrum voor Landbouwpublikaties en Landbouwdocumentatie in The Netherlands. IFIS is a wholly commercial operation.

All aspects of food science and technology are covered except the production of raw foods. In addition to data supplied by the sponsoring organizations, information also is received from other sources in seven countries. The main output is Food Science and Technology Abstracts, also available on magtape, issued monthly. It includes abstracts and author and subject indexes. Selective outputs include annotated bibliographies of particular items relating to specialized aspects of food science and technology.

## SSIE

SSIE (Smithsonian Science Information Exchange) is a nonprofit corporation wholly owned by the Smithsonian Institution. For more than 25 years SSIE has served as the primary source of up-to-date information about research in progress and recently terminated research in the life and physical sciences.

Each year SSIE processes data on more than 100,000 ongoing research studies. Project information is gathered from more than 1,300 supporting agencies, indexed by a professional staff of scientists and engineers, and entered into a computerized data base that has more than 170,000 projects in its active file (one and a half tc two years of data). SSIE scientists retrieve information via on-line terminals in-house in either highly specialized or broad subject areas and make the information available to SSIE users.

An extensive portion of the current research registered at SSIE is in the agricultural sciences area. About 40,000 (or 23.5 percent) of the projects registered are related to agronomy, horticulture, soil science, forestry, animal husbandry, veterinary medicine, aquaculture, pest control, nutrition, food technology, home economics, agricultural economics, rural development, rural sociology, and rural water resources. Each of the areas studied and researched involve disciplines such as plant and animal physiology, biochemistry, genetics, morphology,

taxonomy, mathematics, physics, electronics, optics, and environmental sciences. Most of the research registered currently is funded by U.S. government agencies and foundations, and is concerned with agricultural development in the United States. About 15 percent of the projects are related to agricultural research in or about foreign countries, particularly the developing countries.

## ASFIS

ASFIS (Aquatic Sciences and Fisheries Information System) operates similarly to IFIS. ASFIS was established in 1971 jointly by FAO and the Intergovernmental Oceanographic Commission of UNESCO. Operating from the Fisheries Department of FAO, abstracts are received from several national centers, such as NOAA in the United States, and also from a commercial information source in the United Kingdom. The operation is monitored by FAO, but production is a wholly commercial enterprise in the hands of Information Retrieval, Ltd., who publish the main output product, Aquatic Sciences and Fisheries Abstracts.

## CAB

CAB (Commonwealth Agricultural Bureaux), which has been producing abstract journals on selected fields of agriculture for many years, consists of 14 specialized bureaus and institutes. In recent years, their operation has been mechanized so that in addition to publishing a series of 20 abstract journals the combined data base may be searched. One result of this mechanization has been a new series of abstract journals, the subjects of which cut horizontally through the somewhat discipline-oriented scopes of the original series. The coverage is selective and concentrates on research publications. The abstracts are highly regarded and informative to those who do not have access to the original publication.

## Bibliography of Agriculture

This printed index of selected agricultural articles received by the U.S. National Agricultural Library (NAL) is one output of the CAIN system of the library. All material catalogued and indexed by the library since 1970 as well as several specialized subject files is entered on magnetic tapes. From this

tape Oryx Press publishes the Bibliography of Agriculture; Rowman and Littlefield publish the Monthly Catalog of the National Agricultural Library; and Lockheed Information Systems and System Development Corporation provides on-line access. Many centers search the tapes in batch mode and other products are prepared. The data base presently consists of approximately 750,000 entries and is growing at a rate of about 140,000 per year.

Articles selected for indexing from the journals received at NAL are evaluated for technical quality and pertinence to agriculture. Keywords may be added if the words in the title are not sufficiently descriptive. The subject and geographic coverage are very broad, with greater emphasis on practical agriculture than on other services.

## BioSciences Information Service

BioSciences Information Service of Biological Abstracts publishes detailed abstracts covering all areas of biological literature as well as several other indexes and alerting services of agricultural interest. The selection is limited to basic scientific publications but is of high quality and has worldwide coverage.

## Bulletin Signaletique

Bulletin Signaletique is published by the Centre National de Recherche Scientifique in many parts, some of which cover material of agricultural interest. Coverage is not extensive either in subject or geographic area, but the fact that it is in French may be important to certain countries.

## Ekspress-Informatziya

This is similar to the Bulletin Signaletique. It is a multiple part service in Russian.

## Landwirtschaftliches Zentralblatt

This is a four-part German agricultural abstracting service with combined general coverage.

## NATIONAL AND INTERNATIONAL DATA SYSTEMS

### The FAO System

FAO published the Food Quarterly for the first time in 1975. Issued under the Global Information and Early Warning System on Food and Agriculture, it provides information on current world food production based on data from official and nonofficial sources, and gives the latest developments and short-term prospects for food crops, livestock and fertilizers, trade availabilities and requirements, and stocks and prices. This quarterly report was supplemented on a monthly basis through the Early Warning System in 1976 as a trial undertaking and in an effort to fill many critical data needs.

In addition, FAO annually publishes two volumes of the Production Yearbook giving agricultural statistics for major geographic areas of the world and for more than 200 countries. Volume I provides data on food and agriculture related to land, population, and crops; livestock numbers and livestock products; means of production; and index numbers of food and agricultural production. Volume II contains data on prices of agricultural products, prices of certain production means, freight rates, farm wages, and index numbers of prices. These volumes are made possible by the cooperation of those governments that supply most cf the information to FAO.

### The USDA System

USDA collects information on the production and supply of crops on a worldwide basis and publishes regular crop reports on domestic and foreign crop production. USDA's activities include data collection, tabulation, and summarization; data analysis and publication of production forecasts during the growing season; and estimates after harvest.

Foreign crop production estimates are prepared and published quarterly by the Foreign Agricultural Service. The Foreign Commodity Analysis Office has primary responsibility for preparing production estimates of wheat and other grain crops for all major crop producing countries. Commodity analysts receive information on crops from several sources: agricultural attaches, foreign statistical publications, commodity periodicals, Reuters commodity reports, the commodity trade, foreign newspapers, and the wire services. Commodity analysts base their crop production estimates on information provided by these sources. They depend primarily on the attaches'

scheduled report, prepared quarterly and developed from information obtained from foreign governments and trade contacts. Analysis also is based upon an attache's own observations; information from grain importers, grain processors, and farm organizations; and various published reports available in the country.

The major constraints within the foreign crop estimating process are: (1) the quality of the data received for analysis; (2) the time required to collect, receive, review, and report; and (3) the limited application of data processing in support of the crop estimating process.

The present system for collecting, maintaining, analyzing, and estimating foreign crop production could be improved significantly by applying more advanced data processing techniques and by exploiting advanced data gathering techniques. Improving data processing techniques will require the development of an integrated crop production information system.

USDA's Statistical Reporting Service is responsible for collecting, maintaining, analyzing, and reporting crop production estimates within the United States. By regulation, SRS is required to prepare and issue official state and national estimates and reports of the USDA relating to crop production, livestock and livestock products, stocks of agricultural commodities, local market prices, value of farm products, and other subjects as required. Crop reports prepared by SRS include estimates of acreages farmers intend to plant, acres planted and harvested, production, disposition of crops, and crop stock levels, both on and off the farm.

The preparation of crop production estimates by SRS requires that various types of information be collected and analyzed. This information usually is collected at the state level through the SRS State Statistical Offices by a variety of methods including both nonprobability and probability surveys, field observations, and personal interviews. The data then are processed by the state office, reviewed, summarized, and forwarded to Washington, D.C. The summarized data are received by the Survey Division of SRS for further processing and distribution to the appropriate office within the Estimates Division.

Nonprobability surveys are currently limited to mail surveys, where questionnaires are sent out to farmers asking for specific information about their agricultural activities.

Today mail surveys also supplement probability surveys. Probability surveys, first initiated by SRS in 1954, include both enumerative and objective yield surveys. Probability sampling techniques used by SRS include the area frame, list frame, and multiple frame

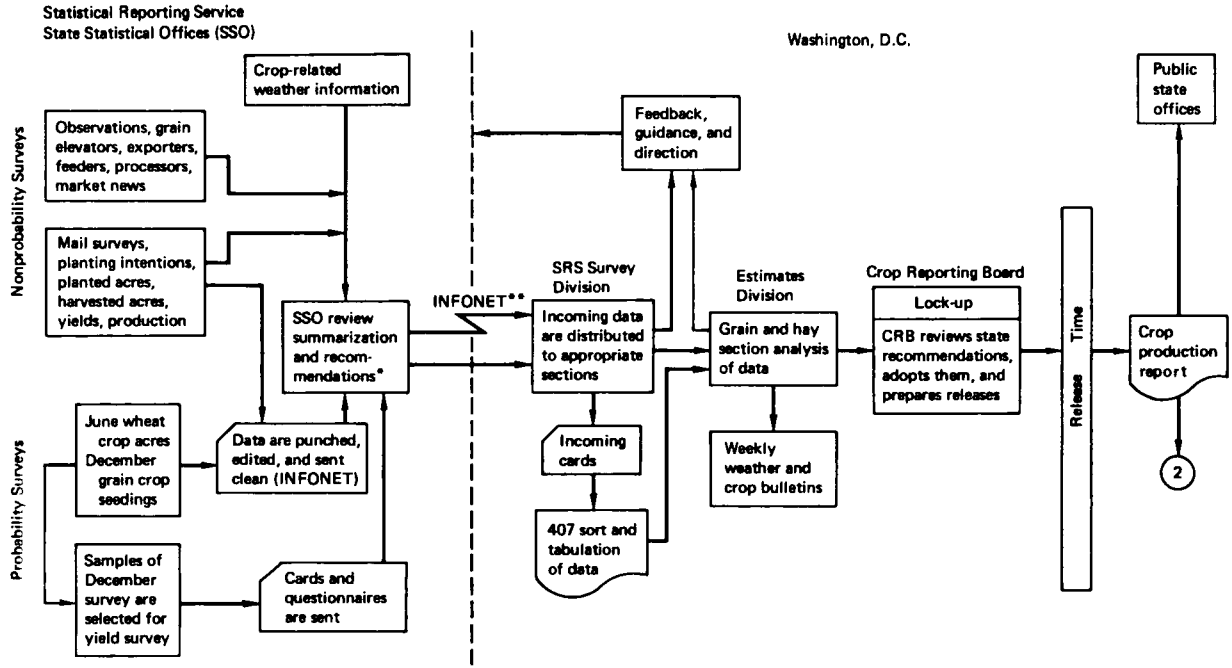
samples depending on the type of crop or other agricultural product being surveyed.

If the incoming state information concerns a commodity defined by law as speculative, the information is handled according to special security procedures and is turned over to the Crop Reporting Board, consisting of a chairman, other appointed members selected for their specialized knowledge of a particular crop, and individuals from the field and Washington, D.C. staffs who analyze the data and prepare the official production estimate. This crop reporting process takes place in what is termed a "lock-up" wherein the Crop Reporting Board and other support personnel are restricted from outside contact until the crop report has been released. Figure 2 illustrates the U.S. crop reporting process as it exists today.

The SRS crop reporting estimates are accurate, reliable, and impartial when compared to those in most foreign countries. Based on these SRS estimates, farmers, businessmen, and the U.S. government make decisions each year that can involve billions of dollars. Constraints within the SRS crop reporting process present less of a problem than those within the USDA foreign crop estimating processes.

The SRS Survey Division currently maintains production estimates for most commodities from the 1800s to 1959, and area, yield, and production estimates from 1964 to the present time. The more recent data on area, yield, and production include all reported commodities; however, only the official final estimate for the year is available. In addition to this limited data base, data input from some state offices is constrained by having to be delivered by mail. However, some state offices can now enter data using the INFONET system or transmit the data using teletype or a facsimile.

At this time, a development effort is underway within SRS to create a SRS data system that will eliminate these data-handling constraints. The new SRS data system will be composed of various subsystems related to SRS functional areas. The crop subsystem will include an Official Estimates Data Base that will contain estimates made by the Crop Reporting Board at each scheduled report date. It also is anticipated that state estimates will be entered directly as recommendations, via telecommunications, and the data base will aid the Crop Reporting Board in its review process. Special computer security procedures and techniques also will be used extensively in this system. This development effort appears to be well planned and logically organized for supporting SRS information and reporting needs.




*Speculative data are sealed and sent to the secretary of the Crop Reporting Board.
**Used when available.

SOURCE: Statistical Reporting Service, U.S. Department of Agriculture, 1976.

FIGURE 2 U.S. crop reporting process.

The limited use of meteorological data by SRS in making current forecasts and estimates is due to the SRS reporting methods that are designed to reflect the effects of weather on crop production to the date of the surveys. Short-term and long-term weather forecasts have not been utilized because they lack the precision needed to evaluate prospects at the state level. Objective yield models used by SRS rely on actual measurements rather than on subjective appraisals of crop developments.

## CSRS

CSRS (Cooperative State Research Service) maintains a computer data base of all existing research projects with information on findings, publications, names of principal investigators, and related information through the Current Research Information System (CRIS).

## The Australian System

The Australian Bureau of Statistics is responsible for the collecting, tabulating, and publishing of official statistics for agricultural and other sectors of the economy. The integrated statistical services provide national and state statistics under the direction of the Australian Statistician and the Australian Statistics Advisory Council.

The bureau is currently developing several survey systems to provide data bases that can respond to increasing requests for agricultural statistics relating to the structure of agriculture, the efficiency of agricultural units, and the extent of nonagricultural activities of agricultural units. Definitions of three of these systems are: (1) a land-based system which would obtain data down to the smallest possible geographic area for commodities, land, and other resources; (2) an economic unit system to provide data on types, structure, significance, and performance of agricultural units; and (3) a linkage of agricultural organizations to households dependent upon them.

The land-based system is active and data are currently obtained from the annual agricultural census conducted in March. Commodity and related data are collected at the holding level from all units producing agricultural products. In all, over 850 individual items including acreage, production and varieties of crops, livestock numbers, wool production, areas of holdings, fertilizer usage, employment, and machinery and irrigation usage are used in the census.

The economic system currently is being developed to provide data for the agricultural sector compatible in concept with that available for other economic areas, such as manufacturing and retailing, and with the general analytical framework of national accounts. A register of business units engaged in the agricultural sector--obtained by conducting a census of them--has been set up to create the economic unit system. This register is designed to record data at four levels--enterprise group, enterprise, establishment, and holding.

Relatively little work has been undertaken on the linking system. It is envisioned that data probably will be collected from farm households to be identified by a general household census. The linking process will tie both the land base units and the economic units to the social unit. This will permit cross classification for various demographic farm households and their economic activity.

Two other important surveys conducted periodically are the Agricultural Finance Survey and the Forestry Statistics Survey.

## The Swedish System

The National Central Bureau of Statistics (SCB) is the central administrative agency for official statistics. It collaborates closely with the National Board of Agriculture and the National Agricultural Marketing Board in agricultural statistics work. SCB's data collection system has three principal components: current agricultural statistical activities, agricultural censuses, and special statistics surveys.

Current agricultural statistics are made up of (1) the farm register system which provides data on units with agricultural operations, their size, commodities produced, and specialized agricultural items through an annual survey of all holdings of two hectares or more; (2) data obtained from the farm register on the agricultural structure of units, their land resources, machines, animals, labor force, etc.; (3) data from the farm register on crop area for 25 crops, available land, natural pastures, grass-sown land, and forest land; (4) qualitative information based on three surveys made to the county agricultural boards on crop outlook and development of crops during the growing season; (5) quantitative data on probable crop yields from objective surveys; (6) statistics on numbers of livestock by category, animal, and milk production; (7) data on agricultural requisites such as the consumption of fertilizer, pesticides, and feedstuffs; and (8) data on economic factors such as labor, farm wages, real

estate and buildings, cash income and expenditures, and price statistics.

An agricultural census is conducted annually using a sampling method that ensures that each unit will be included at intervals of about five years. It uses the farm register and provides general agricultural statistics similar to the current agricultural statistics program for individual parishes and communities. Certain agricultural data also are collected annually in the general census of population and housing.

Special studies are conducted periodically using the farm register. These provide data on dwellings, stable buildings, plants, farmers' education, and methods of grain harvesting.

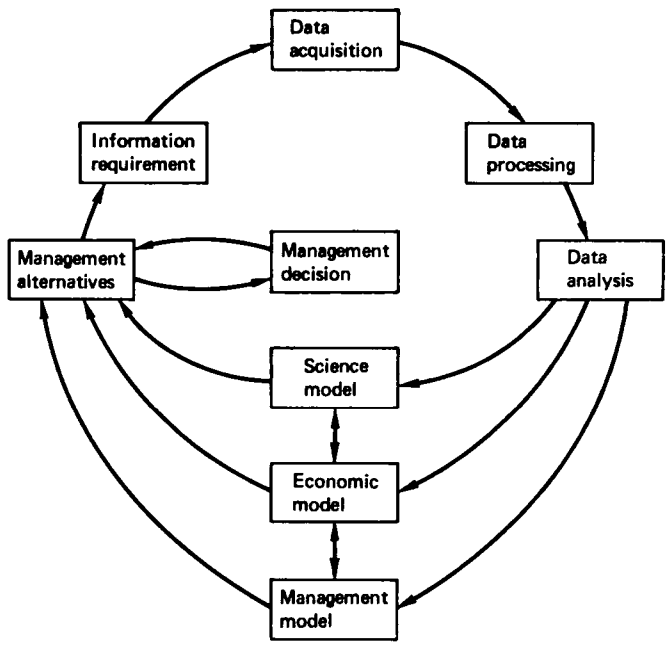
## Appendix B

## UNDERSTANDING INFORMATION NEEDS FOR PRIMARY PRODUCERS

What information does each developing country require to implement national policies that will increase agricultural production? What facts do national agricultural planners need, and how can these facts be gathered on a continuous basis and analyzed and processed into usable form? The model in Figure 3, developed in connection with a proposed scheme to keep a constant inventory of the world food situation through remote sensing devices (Park 1976), shows the planner's requirements rather well. One could use an almost identical model (although with quite different information inputs) to describe the difficulties faced by the individual farm operator in his or her role as a resource manager or the nutritional planner.

National planners looking for ways to increase farm production are prone to search for unitary innovations that can be adopted in a single step and that are widely applicable. The "miracle" grain varieties have been appealing for exactly this reason. The fact that they have been disappointing in some ways does not negate their dramatic contributions to gross annual food production.

One cannot stress too strongly the way information enters the picture when new farming technologies are selectively applicable only to particular individual situations or are <u>applicable at varying levels depending on external circumstances</u>. An example of the former would be the improved IRRI rice varieties of the past decade, most of which can be used to best advantage only by farmers who can irrigate their paddy land for double cropping. Examples of the latter would include pesticides, which are expensive in most developing countries and are used at high or low levels depending on the nature and seriousness of the hazard at any given time, and fertilizers, whose optimal levels of application depend on knowing what nutrients are already in the soil and what fertilizer costs and product prices are and likely will be. One also might




SOURCE: Park (1976).

FIGURE 3 Resource management model.

note how neighboring farmers can make quite different choices, all equally defensible, as to whether their paddy fields should be left unweeded, weeded by hand, or treated with herbicides. The price of rice, the cost of herbicides, the family labor supply, and the condition of the field all enter into this calculation.

Information systems for farmer decision making have had only limited attention from international bodies because local and national resources and commitments are the keys to such systems. An international agency or a global study can do little to assure that individual needs are met. At least, however, we can acknowledge that a farmer will need to apply many of the following kinds of information to his or her own situation if his or her agricultural enterprise is to be as productive as possible:

-- day-to-day market changes (prices of inputs, prices of products, outlook for future price change);
-- longer range market prospects (new crops, change in urban or export demand, opportunities in animal agriculture);
-- diseases and pests (early warning of localized outbreaks, realistic estimates of degree of threat);
-- short-term weather (predictions related to timing of such operations as planting and harvesting);
-- climate (long-term or seasonal predictions that permit changes in cropping to deal with shortage or surplus of water or with other climatic factors);
-- physical availability of new technologies not previously accessible;
-- economic availability of new technologies because of lower costs, higher productivity, or shifts in factor prices;
-- off-farm employment and income possibilities.

The research task that is most urgent in meeting farmers' information needs is simply identifying the kinds of information most needed. What questions important to farmers could best be answered by systematic data collection? At what costs, and with what probable benefits?

A satisfactory information system for farmer decision making should include some mechanism for continuous collection of the kinds of information specified; data facilities where it can be accumulated, ordered, and held; capacity to process it into usable form; channels for its regular and widespread distribution; and ability to respond promptly to particular questions. Anyone familiar with U.S. agriculture still may be surprised to realize how fully and systematically all of these requirements have been

met for the U.S. farmer and agricultural marketing system. These requirements are not necessarily the creators of a modern agriculture, but each change in technology inevitably has demanded more in the way of decision information.

In the Third World, only in the case of plantation crops are these requirements remotely met. This single crop emphasis in plantation production has probably been a model, and a useful one, for other crops. The Philippine Council for Agricultural Research (PCAR) has distributed early copies of a new looseleaf series, "The Philippines Recommends," dealing initially with cotton, tobacco, sorghum, mangoes, vegetable crops, and timber. The Rubber Board of India has put into an annually revised manual all of the information it believes a small holder needs. A small group of World Bank staff members has produced a similar systematic report, considerably more detailed as it is intended for planners even more than for farmers, reviewing all of the factors that go into cacao production. These books or booklets cannot give timely or localized information, and they have little to suggest about alternative cropping or income-generating programs for the farmer. However, they anticipate well the questions he or she will have to ask when facing the problems of changing technology.

Most extension services claim the capacity to respond to questions from farmers and field staff that relate to farm-level decision making. Often the extension worker is as badly served as the farmer because the information (1) is not regularly collected, (2) is not available in one place, (3) cannot be readily called up, and (4) cannot be organized and adapted to answer individual questions rather than simply to describe or record.

## Appendix C

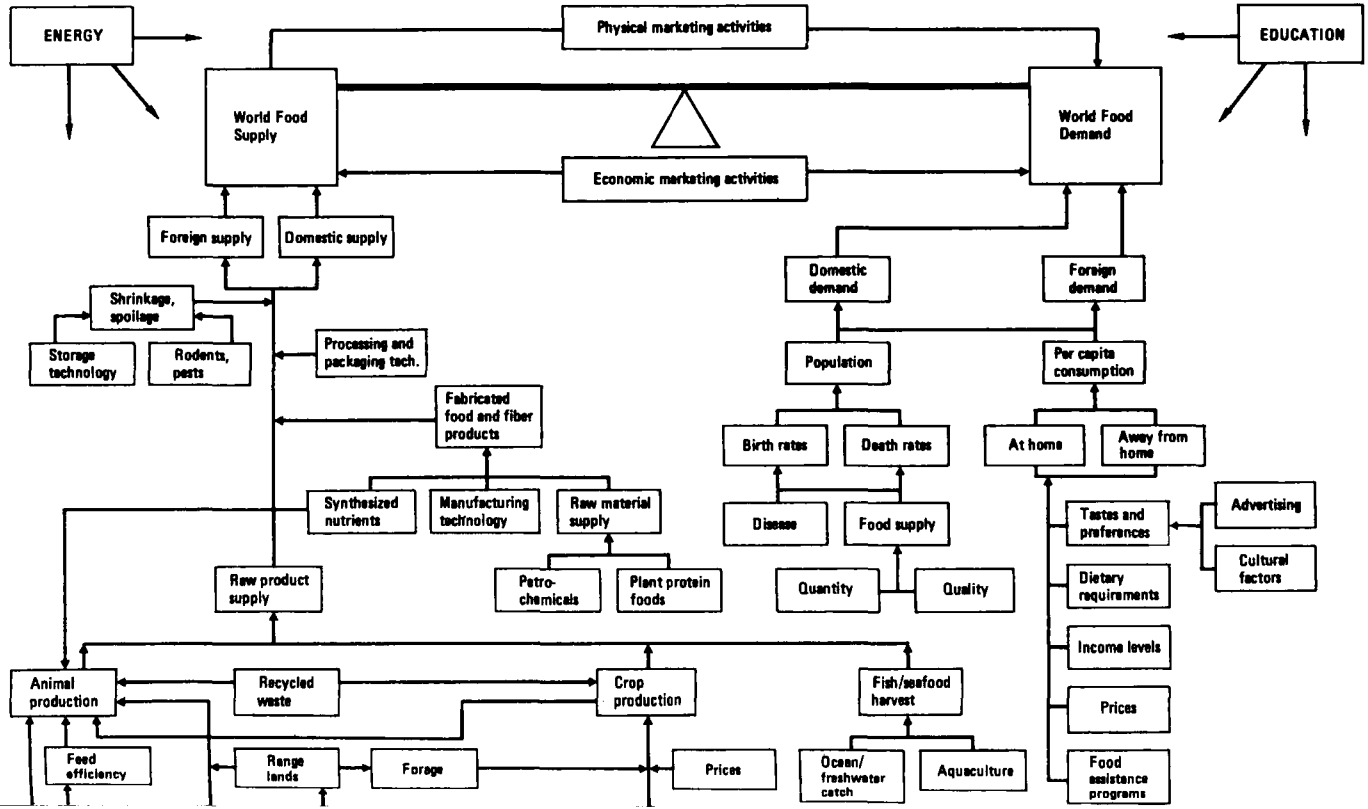
## COMPONENTS OF AN INFORMATION SYSTEM FOR WORLD FOOD AND NUTRITION

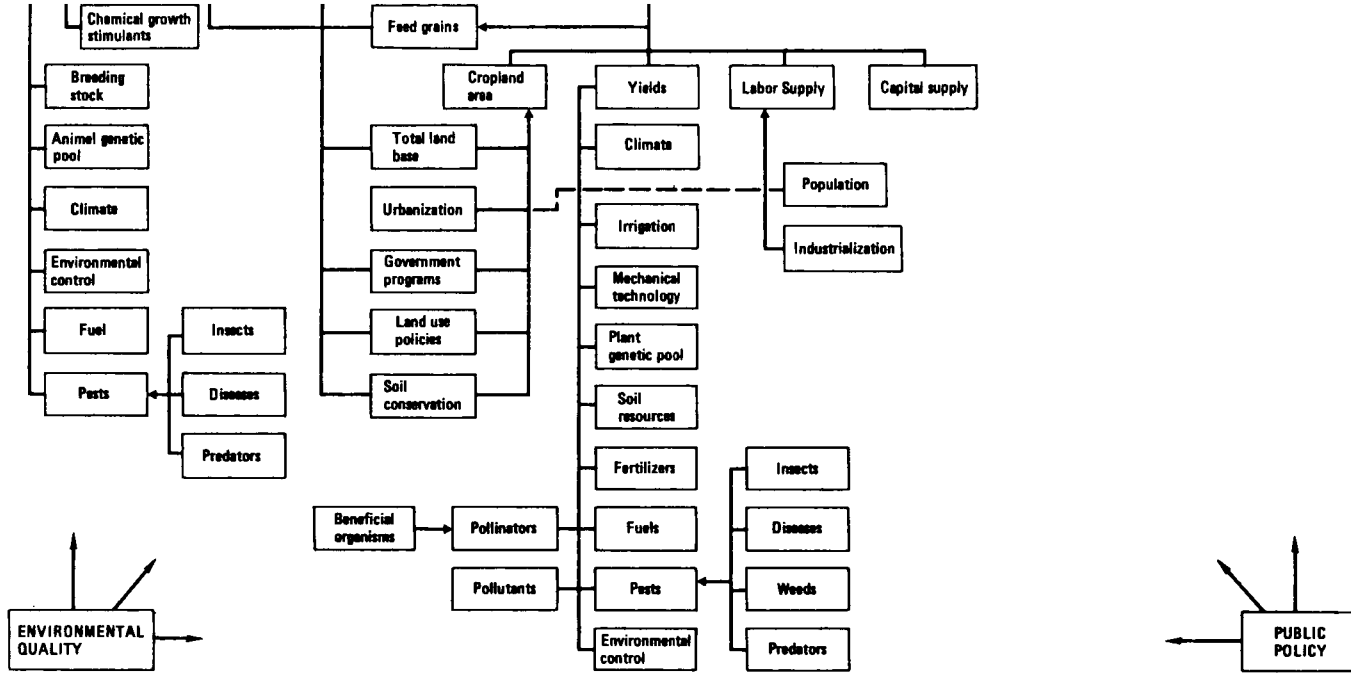
Developing an information system for world agriculture and nutrition requires a conceptualization of the world food complex, and this is not a simple task. One may broadly define the components of the system to be: (1) the production and distribution of food and fiber, (2) the consumption of food and fiber, (3) the nutritional aspects of the complex, and (4) the institutional structure.

A detailed description of the world food complex is provided in A Hungry World: The Challenge to Agriculture (University of California Task Force 1974) (Figure 4). This representation of the world food system considers four outside influences: education, public policy, environmental quality, and energy. The system itself can be viewed as a balance of world supply and demand for food. This world balance is tempered and constrained by economic and physical marketing activities.

Appropriately, the supply and demand factors that influence the balance of the system are related contemporaneously. Crop and livestock production are linked to the economic indicators expressed through consumer demands and constrained by the limitations of resource scarcity. The great detail of the system is expressed through the broad range of factors that has an effect on world food production such as pest control, irrigation, mechanical and genetic technology, disease, weed control, and, broadly, the competition of agriculture and the industrial world for scarce resources.

Figure 4 is a deceptively simple representation of the world food and nutrition complex. For example, the "four outside influences"--energy, education, public policy, and environmental quality--are themselves complex systems interrelated with the food and nutrition system. Although it implies such, the schematic is not explicit about the coverage of


ENERGY
Physical marketing activities
EDUCATION
World Food Supply
World Food Demand
Economic marketing activities
Foreign supply
Domestic supply
Shrinkage, spoilage
Storage technology
Rodents, pests
Processing and packaging tech.
Fabricated food and fiber products
Synthesized nutrients
Manufacturing technology
Raw material supply
Raw product supply
Petro-chemicals
Plant protein foods
Animal production
Recycled waste
Crop production
Fish/seafood harvest
Feed efficiency
Range lands
Forage
Prices
Ocean/ freshwater catch
Aquaculture
Domestic demand
Foreign demand
Population
Per capita consumption
Birth rates
Death rates
At home
Away from home
Disease
Food supply
Quantity
Quality
Tastes and preferences
Advertising
Cultural factors
Dietary requirements
Income levels
Prices
Food assistance programs




SOURCE: University of California Task Force (1974).

FIGURE 4 The world food complex.

hundreds of commodities, soil types, countries, types of users, etc. Further, it does not state explicitly that the world food and nutrition complex has constantly changing parameters and objectives (i.e., is dynamic). Finally, Figure 4 is incomplete in that it does not show that for each of the complex's components, information has to be provided repeatedly with a certain degree of accuracy and timeliness. Currently, some information is available on each of the food and nutrition complex components as shown in Figure 4. The quantity and quality of information available, of course, varies widely from commodity to commodity, country to country, etc. Also, the "component information systems" have typically been developed without a view toward a worldwide food and nutrition information system. Thus data and information are frequently incompatible (because of format, difference in timing, etc.). The challenge then is to develop research and development projects that will lead to an improved world food and nutrition information system.

## Appendix D

## DEFINITION OF AN INFORMATION SYSTEM[1]

All information systems are purposive because they are subsets or components of social systems that are designed for problem-solving purposes. Thus data collection and analysis always have a purpose and can be understood fully only in a social system context.

Theory and data are epistemologically interdependent. A conceptual framework can never be improved without empirical tests. At the same time, the state of the information system is limited by the state of the theory because the purpose of the information system is to serve theory. Without the interdependence it would be impossible to test theory and meaningless to collect data.

Given this formulation, the most fundamental error in an information system can be either deductive or inductive. Deductive error involves empiric failure either in the measurement process or in the failure to attempt an empiric test of the theories or concepts around which the information system is built. Inductive error involves conceptual failure usually attributable to obsolescence. Conceptual obsolescence can occur either when there is an environmental change--the world changes but the concept does not--or when there is a functional change--the purpose of the system changes but the data collected do not.

An information system attempts to represent reality as conceived through theory by describing specific phenomena in some system of categories, usually in quantified form. Data are the result of quantifying information, but before they can be measured or quantified, one must determine what is to be counted and why.

Data presuppose a concept, and concepts cannot be measured directly (or in a strictly logical sense measured at all). Rather, we operationalize the concepts by establishing (defining) categories of empirical phenomena (variables) which are as highly

correlated as possible with (i.e., represent) the reality of the object of our inquiry.

Thus three distinct steps or actions must be taken before one can produce data that purport to represent any reality: (1) conceptualization, (2) operationalization of concept (definition of empirical variables), and (3) measurement. The failures and limitations of any one of these data system components constrain the quality and characteristics of the data produced.

An inadequacy at any stage can be offset only to a limited extent by improvements or manipulations at the other stages. Thus the great improvements in statistical methodology and data processing techniques over the last generation cannot offset failures at the conceptual level, for no matter how well one manipulates the numbers, one may still be measuring the wrong thing.

It is worth noting that the term "reliability of data" has three different possible meanings in this paradigm: (1) reliability of measurement, which is the way the statistician normally uses the term; (2) reliability of operationalization; and (3) conceptual reliability.

## DATA, ANALYSIS, AND INFORMATION

Data are not information (Dunn 1974, Eisgruber 1972); they are symbolic artifacts. Information is a process that imposes form and gives meaning. Data acquire meaning only in the context of some information process.

An information system not only produces data but also analyzes and interprets these data in some purposeful policy decision or problem-solution context. The demand for data is generated by the need to make decisions on problems. Decision makers rarely use raw data. Rather, there are intervening acts of interpretation through statistical and economic analysis, policy staff and political evaluation, etc., which transform data into information by placing them in a specific problem context that gives the data meaning and form. Symbolic data acquire most of their "meaning" and value from the context and design of the information system in which they appear.

Most analysts have acquired much the same epistemological sense of how one analyzes and solves problems. That is, there is a base of received theoretical concepts, a body of theory purporting to represent reality which the analysts operationalize through definition of variables, often specified formally in a model that must be matched with data or

measured representations of these same variables. The model or analytical framework is then tested against the data and conclusions drawn. Thus in these three steps in analysis one finds two of the same components observed in a data system: theoretical concepts and operationalization of those concepts.

In data systems and in analytical systems of inquiry, one is operating from the same set of theoretical concepts and, ideally, the same set of definitions that operationalize those concepts. Unless social theory and statistics meet on a common conceptual ground, there can be no mesh between empirical analysis and theory, between the inductive and deductive process of "knowing."

Social scientists have special concerns in the area of information. They, like other scientists, clearly are responsible not only for the design and maintenance of the analytical framework but also for the design of the conceptual base of the data systems that provide the empirical content for that analysis. The commonplace notion held by social scientists that statisticians alone are responsible for the design and production of data is a grave distortion of their professional responsibilities. It reflects not only an epistemologic weakness in the training of social scientists but also a lack of understanding of the historical development of data systems. From earliest times, data systems have been conceived to help solve problems, and the disciplines and professionals whose knowledge was relevant to the problem were involved in design of the data system.

## THE CONCEPT OF A SYSTEM

Systems are made up of sets of interdependent components that work together in a holistic manner toward some overall objective. The systems approach is simply a way of thinking about total systems and their components (Churchman 1968:11).

According to Churchman, five basic considerations must be kept in mind about the meaning of a system:

1. the total system objective and, more specifically, the performance measures of the whole system;
2. the system's environment: the fixed constraints;
3. the resources of the system;
4. the components of the system, their activities, goals and measures of performance;
5. the management of the system.

From the point of view of information systems, it is worth noting that the idea of "information" as well as the idea of "systems" both involve purpose or a set of purposes. That is, they do not exist without ends. Both ideas are multidisciplinary in knowledge base and concepts. Finally, problem solving is an inherent characteristic in the ideas of information and of system, if not indeed the general purpose. In this sense, the idea of system and that of information are processes.

## THE CONCEPT OF DYNAMICS

Any information system with even the most limited adaptive capability can be considered dynamic. If there are feedback loops in the system, then there is some potential for heuristic processing of information. With the possibility of learning within the system, functioning parts of the system can be altered. For example, in the national planning processes of most countries information processing is cast in some degree in a developmental mode. That is, the purpose of the system of planning and the underlying information system is to create some specified change in the system's environment. However, as one proceeds in a planning process and learning takes place, the objectives of the planning system will themselves change. This creates quite a different kind of information processing and information design problem. One purpose of the information system in this case is to assist the decision maker in specifying the goals of the system in a progressively more complete form. This has been described as information processing in a developmental mode (Dunn 1974:32-33, 77-85).

When an information system is tracking phenomena that have an unchanging structure and thus behave in some consistent pattern over time, there is no real need to redesign data and the information system. However, when the object being tracked changes in nature, the conceptual base of the information system must be progressively modified if it is to be capable of representing accurately that which it is tracking. In this case, the information system must contain within itself the capability of redesigning its own conceptual base and nature.

## THE USER

In any information system the user is a decision maker. The purpose or purposes of the information system is the purpose or purposes of the decision

maker. The normative content of any information system is imposed by the decision maker and the normative imperatives of the system's environment. Thus to the extent that an information system does not serve the user's purpose, it is socially deficient and dysfunctional.

One of the great problems of the management of information systems arises out of the fact that few information systems are managed in their entirety by the user. Thus subordinate and highly specialized subsystem purposes often are imposed on data and information systems to the detriment of overall system performance. To handle this problem, the design of an information system must be devised to cope with the problem of managing the divergent interests of specialized and often not too well-coordinated organizational components, divergent disciplinary interests, the scientist's tendency to avoid responsibility for design of data, and the statistician's bad habit of viewing the production of data as an end in itself.

## NOTE

1. Most of the information in this appendix is adapted from Bonnen (1975:757-759).

## REFERENCES


Bonnen, J. T. (1975) Improving information on agricultural and rural life. American Journal of Agricultural Economics 57(5):727-763.

Bullock, B. (1976) Social costs caused by errors in agricultural production forecasts. American Journal of Agricultural Economics 58(1):76-80.

Churchman, C. W. (1968) The Systems Approach. New York: Dell.

Dunn, E. S. (1974) Social Information Processing and Statistical Systems: Change and Reform. New York: John Wiley & Sons.

Earth Satellite Corporation and Booz-Allen Applied Research Corporation (1974) Earth Resource Survey Benefit Cost Study. Report for the U.S. Department of the Interior/Geological Survey.

ECON, Inc. (1976) TOSS (Tersee Operational Systems Study). Princeton, N. J.

Eisgruber, L. M. (1972) Potential Benefits of Remote Sensing: Theoretical Framework and Empirical Estimates. LARS Information Note 030872, Purdue University, Lafayette, Ind.

Park, A. B. (1976) A Global Agricultural Information System. Paper prepared for the U.S. Congress, Office of Technology Assessment, Washington, D.C.

Peterson, W. and Y. Hayami (1972) Social returns to public information services: statistical reporting of U.S. commodities. The American Economic Review 62(1):119-130.

University of California Food Task Force (1974) A Hungry World: The Challenge to Agriculture. University of California Division of Agricultural Sciences, Berkeley.

## BIBLIOGRAPHY


Agricultural Research Policy Advisory Committee (1975) Research to Meet U.S. and World Food Needs. Kansas City, Mo.

Beaton, G. H. (1974) Defining a Food and Nutrition Policy. Paper presented at the Ninth Session of the Joint FAO/WHO Committee of Experts on Nutrition. Rome: FAO.

Buntrock, H. and P. J. Boyle (1973) Survey of World Agriculture and Documentary Service. Prepared on behalf of the FAO Panel of Experts in AGRIS of working group for Agricultural Documentation Information of the European Communities. FAO/DC/AGRIS VI. Rome: FAO.

Buss, D. H. and M. H. Lorstad (1975) Food Consumption Surveys: A Data Source for Contamination Monitoring Programmes. Paper presented at the Roundtable Conference on Methodology of Food Intake Surveys.

Central Intelligence Agency (1974) A Study of Climatological Research as it Pertains to Intelligence Programs. Washington, D.C.: U.S. Government Printing Office.

Eisgruber, L. M. (1973) Managerial information on decision systems. American Journal of Agricultural Economics 55:930-937.

Food and Agriculture Organization of the U.N. (1971) AGRIS Study Team Report. Rome: FAO.

Food and Agriculture Organization of the U.N. (1974) Report of the World Food Conference. Rome: FAO.

Hathaway, D. E. (1975) A Statement on World Food Information Systems: Progress and Problems. Presented to the U.S. Congress, Office of Technology Assessment, Washington, D.C.

Hirschleifer, J. (1973) Where are we in the theory of information? American Economic Review 63(2):31-39.

Hjort, H. W. (1975) World Agricultural Information System: A Critical Evaluation. Paper prepared for the U.S. Congress, Office of Technology Assessment, Washington, D.C.

National Oceanic and Atmospheric Administration (1975) Application of Remote Sensing for Fishery Resources Assessment and Monitoring. Department of Commerce. Washington, D.C.: U.S. Government Printing Office.

National Research Council (1975) Enhancement of Food Production for the United States. Washington, D.C.: National Academy of Sciences.

National Research Council (1975) Interim Report. World Food and Nutrition Study. Washington, D.C.: National Academy of Sciences.

National Research Council (1975) Practical Applications of Space Systems. (Support papers: 1. Weather and Climate; 3. Land Use Planning; 4. Agriculture, Forest, and Range; 8. Marine and Maritime Users; 10. Institutional Arrangements; 11. Costs and Benefits; 13. Information Services and Information Processing). Washington, D.C.: National Academy of Sciences.

North American Institute for Modernization of Land Data Systems (1975) Proceedings of the North American Conference on Modernization of Land Data Systems (A Multi-Purpose Approach). Washington, D.C.

Office of Technology Assessment (1975) Food, Agriculture and Nutrition Information Systems: Assessment and Recommendations. Washington, D.C.

Pool, I., E. Friedman, and C. Warren (1976) Low-Cost Data and Text Communication for the Less Developed Countries. Cambridge, Mass.: MIT Press.

U.S. Department of Interior (1974) Earth Resources--Survey Benefit-Cost Study. Washington, D.C.: U.S. Government Printing Office.

Report of Study Team 10

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## INTRODUCTION

The demand for food depends upon and is related to many sectors of the human social and ecological system, including human population numbers and standard of living (affluence) (Figure 1). Food supply is influenced by such well-recognized factors as arable land, water, climate, fertilizers, and fossil energy, and is affected by food losses, public health, labor availability, environmental pollution, national development, trade and comity of nations, and peoples' life-styles. Experience has shown that finding ways to augment per capita food supply is a difficult task because of these influences. This analysis focuses on the major interdependencies and interrelationships in the social and ecological systems that influence food demand and supply.

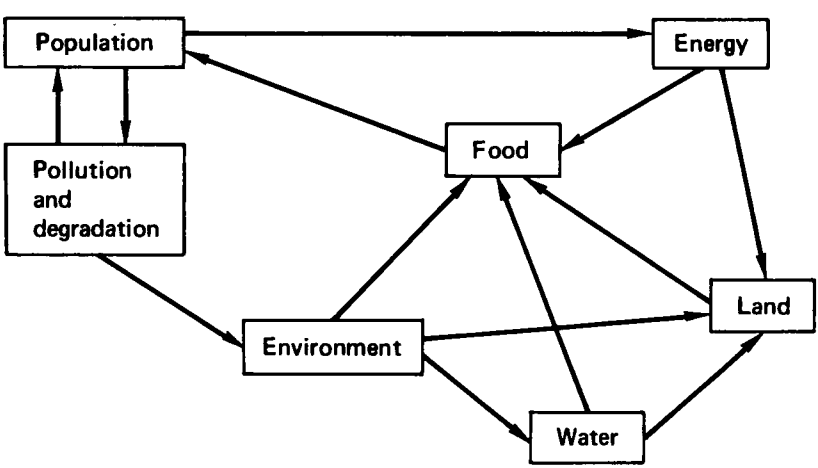


FIGURE 1 Interdependencies of food, population, health, environment, energy, and other factors of the world system.

## POPULATION

Rapid population growth has resulted in an increased need for food. The Food and Agriculture Organization (FAO) of the United Nations (1974a) estimates that today about 500 million humans or about 15 percent of the population of the developing nations are seriously malnourished.

For about a million years the population growth rate was about 0.001 percent per year and the world population numbered less than 10 million (Keyfitz 1976). Rapid growth in population started after 1700 and accelerated to today's rate of nearly 2 percent per year or 2,000 times the historic rate (NRC 1975d, Keyfitz 1976).

The world population is now about 4 billion and is expanding at the rate of 200,000 persons per day. By 2000, it will reach 6 to 7 billion (NRC 1971, NRC 1975d, United Nations 1973). Stability and maximum population numbers, however, are not expected until after 2100 when the world population will probably number between 10 and 16 billion (United Nations 1973, NRC 1975d).

Effective public health measures, increased income, and improved nutrition have contributed to reduced mortality rates without a commensurate or concurrent reduction of birth rates; population growth rates have increased as a consequence. Further improvements in supplies and distribution of food are likely to add, at least in the short run, to the already extreme pressures of rapid population growth.

To reduce the annual rate of population growth from 2 percent to even 1 percent, more than a billion births will have to be prevented during the next 25 years. The "task may well be the most difficult mankind has ever faced (NRC 1971)." If birth rates are to be reduced on such a massive scale, parents must see that it is in their own interests to have fewer children. This can be accomplished only if the direct costs to parents rise, i.e., investments in schooling of children become attractive to parents, and socially acceptable substitutes for children are developed within each society.

## ARABLE LAND

An estimated 1.5 billion hectares of the world's arable land is currently in use (11 percent of the world's total land area). In 1650, with a world population of 500 million, available cropland per capita was about 2 hectares. Because we now have a world population of 4 billion, available cropland has

been reduced to about 0.4 hectares per capita. For the 6 to 7 billion population projected for the year 2000, only 0.2 hectares will be available per person.

Arable land resources might be expanded to about 15 percent of the world's land area (2 billion hectares) without great cost and effort. If marshlands are drained, some arid land irrigated, and other lands altered by technological means, about 25 percent of the total land area or 3.4 billion hectares could be cultivated (Buringh et al. 1975, Kovda 1971). At a maximum world population density of 16 billion, land satisfactory for cultivation per capita would only be 0.2 hectare.

This 0.2 hectare per capita assumes no degradation of the land. Unfortunately, arable land is being degraded at an alarming rate. For example, in the United States from 1945 to 1970 over 29 million hectares, of which about half had been cropland, were lost to highways and urbanization (USDA 1971, 1974a). Soil erosion has rendered another estimated 80 million hectares either totally ruined for crop production or so seriously eroded that the land is only marginally suitable for production (Bennett 1939, Pimentel et al. 1976, U.S. Natural Resources Board 1935). The soil erosion rate in the developing countries is estimated to be nearly twice that of the United States (Ingraham 1975).

The rate of soil erosion per hectare of cropland in the United States is estimated at 27 tons annually (Hargrove 1972, Wadleigh 1968). This relatively high rate has resulted in the loss of at least one-third of the topsoil in use today (NRC 1970).

The reduced productivity of U.S. cropland due to soil erosion has had to be offset by increased quantities of fossil energy in the form of fertilizers and other inputs (Hargrove 1972). An estimated 47 liters of fuel equivalents per hectare per year are being used to offset only the soil erosion loss (Pimentel et al. 1976).

Erosion also degrades reservoirs, rivers, and lakes by depositing in them annually about 1.4 billion tons of soil (USDA 1968). Soil sediments, associated nutrients (nitrogen, phosphorus, potassium, etc.), and pesticides have an ecological effect upon stream fauna and flora (Pimentel et al. 1976).

## WATER

Most crop plants use large quantities of water, which are largely provided by rainfall. A hectare of corn, for instance, requires from 6 to 12 million liters of water per growing season. In the United

States, agricultural production accounts for 96 percent of the water consumed, whereas industry and urban areas consume less than 4 percent (NRC 1974a).

Only about 14 percent of the world's cultivated land is now irrigated (Buringh et al. 1975). Conflicting demands in arid regions for available water among agriculture (irrigation), urban population, industry, and fossil energy mining indicate that changes in water use are inevitable. Considering these four competing uses, the proportion of water allotted to agriculture probably will decline because economic yields from agriculture per quantity of water presently are far less than yields from such activities as industry and mining (Gertel and Wollman 1960).

Irrigation is limited in that it often requires enormous amounts of energy. About 20.6 million kilocalories (kcal) are required to pump the 12 million liters of water needed for a hectare of corn from a depth of 90 meters for sprinkle irrigation (Smerdon 1974). This is more than three times the total used (6.6 million kcal) to produce a hectare of corn employing U.S. technology. This energy input does not include that required for supplying and maintaining the irrigation equipment (an additional 13 percent in energy), nor does it consider the environmental costs of salinization or soil waterlogging problems associated with irrigation.

Too much water or rapid runoff also can be a serious problem. Removing trees on slopes, in particular, promotes rapid water runoff and flood damage to crops and pastures (Beasley 1972). An estimated $1.3 billion in U.S. crops and pastures is lost annually by "flood water, sediment, and related watershed damage (USDA 1965)."

## CLIMATE

Within any given decade irregularities in temperature and rainfall patterns are likely to cccur which can either improve or inflict damage on agricultural yields. In addition, long-term climatic trends may have major effects on agriculture.

Since around 1940 temperatures of the northern hemisphere have declined about 0.1°C per decade (Bryson 1974, Bryson and Wendland 1975). Because a mere 0.6°C drop in temperature shortens the growing season about two weeks (Malone 1974), yields may be substantially reduced in marginal crop growing regions. For instance, shortening the critical corn growing season in the U.S. corn belt by two weeks would result in a yield reduction of nearly 882 kilograms (kg) per

hectare (H.J. Stockdale 1975, personal communication, Iowa State University).

Increased fossil energy consumption by expanding industries and a rapidly growing world population also may have an impact on climate and in turn an impact on agriculture. This additional consumption is expected to increase significantly the carbon dioxide ($CO_2$) and particulate matter content of the atmosphere (Kellogg 1975, Schneider 1976, Singer 1975). What impact these changes could have on the atmosphere and therefore on climate are now being questioned. (See the report of Study Team 5, "Weather and Climate.")

These irregularities in climatic patterns call attention to the interdependency of nations and the importance of food trade among countries. They also point to the need for international food reserves to offset a bad crop year(s) in the world's food-producing regions.

## PHOSPHATE AND POTASH FERTILIZERS

The major nutrients that sustain plant growth are phosphorus, potassium, and nitrogen. The use of chemical fertilizers has grown rapidly during this century, more than fivefold since 1950. This heavy use of fertilizer is one of the main reasons that the minimum food needs of the world population are nearly met today. (Also see Subgroup C, Study Team 4, "Fertilizers.")

The world's phosphate and potash reserves are large but unevenly distributed. North America is well endowed with both in contrast to South America which must import fertilizer supplies. North and West Africa have large reserves of phosphate; exports from Morocco will soon be a substantial portion of the world market. As a whole, however, Africa is lacking in known reserves of potash. Asia has little of either fertilizer.

This uneven distribution of phosphate and potash fertilizers again emphasizes the interdependency among nations for vital resources and the importance of exchanging resources via an effective trade system.

## PESTICIDE BENEFITS AND RISKS

An estimated 2 billion kgs of pesticides are applied annually worldwide (Pimentel 1976). Pesticide use is expected to continue to increase, reaching 4 billion kgs by the year 2000. (See Study Team 1, Subgroup A, "Pest Control.")

In spite of all the pesticides and bioenvironmental (nonchemical) pest controls employed today, pests (insects, pathogens, and weeds) destroy more than a third of all crops (Cramer 1967, Pimentel 1976). The dominant means of pest control in the United States and elsewhere is bioenvironmental pest management.

Pesticides can create serious environmental and health problems. For example, the use of pesticides in the world results in 20,000 to 50,000 human poisonings annually (see U.S. Environmental Protection Agency 1974 and Central American Research Institute for Industry 1975 for examples). In addition, beneficial biota often are destroyed from the use of pesticides (Pimentel and Goodman 1974). Natural enemies of pests often are eliminated with pesticide use and sometimes outbreaks of other pests occur when their prime biological control is exterminated (Van den Bosch and Messenger 1973). Additional pesticides are usually required then to control the new pests. Frequently the next result is pesticide resistance evolving in the treated pest population. Today, nearly 365 species of pest insects and mites are resistant to pesticides (G.P. Georghiou 1976, personal communication, University of California, Riverside).

## ENERGY

People's use of energy to manipulate and manage their ecosystems is probably the most important factor responsible for rapid population growth. Energy has been used to improve public health, to increase food production, to improve food storage and processing, and to effectively distribute food. Exponential increases in human numbers directly coincide with increases in the use of fossil energy (see Figure 2).

World energy consumption has about doubled during the past 10 years (Darmstadter et al. 1971). This rapid increase reflects life-styles highly dependent on energy, with the result that known fossil fuel supplies are being used up rapidly. Known world reserves of petroleum and natural gas are expected to be more than half depleted within the next 25 years and more than half the coal reserves will be depleted about the year 2100 (Hubbert 1972), about the time the world population is projected to reach its maximum density of 10 to 16 billion.

U.S. agricultural output depends upon large expenditures of energy. For example, producing 1 hectare of corn in the United States requires the equivalent of about 660 liters of fuel (Pimentel et al. 1973). More than half of this energy input is attributed to fuel and nitrogen fertilizer.

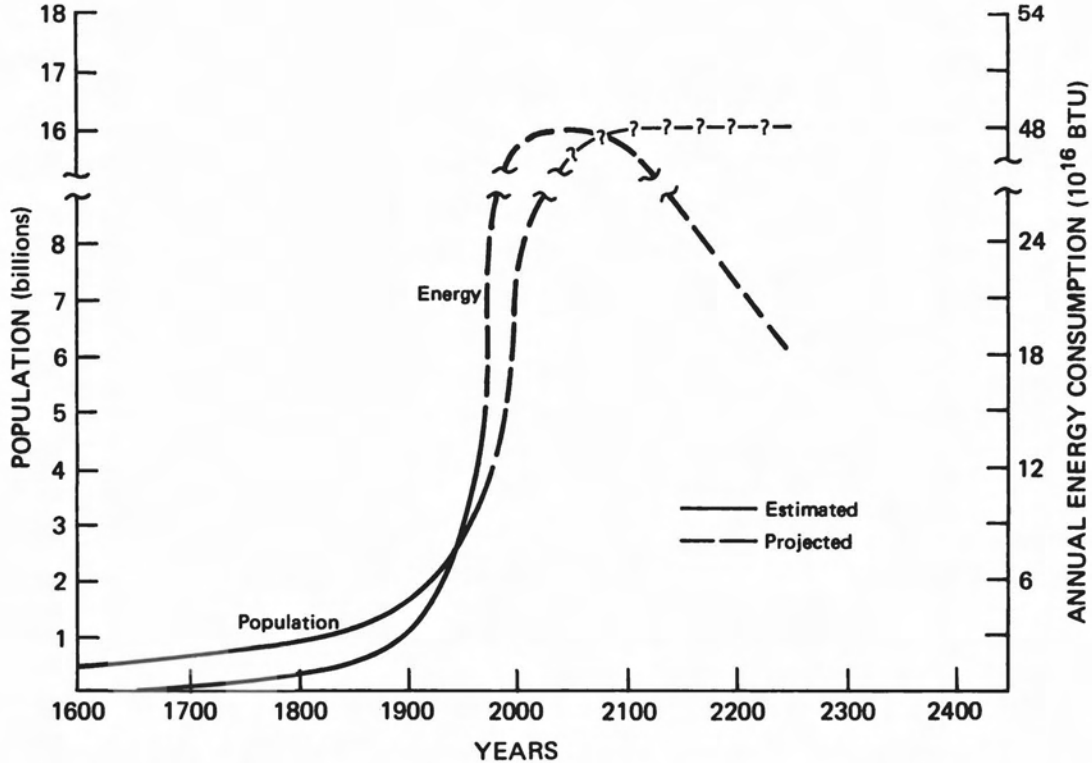


FIGURE 2 Estimated world population numbers from 1600 to 1975 and projected numbers to 2250 (Freedman and Berelson 1974, NRC 1971, United Nations 1973). Estimated fossil fuel consumption from1650 to 1975 and projected to the year 2250 (Hubbert 1972, U.S. Department of the Interior 1975).

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Substituting machinery for human labor has reduced the labor-hour input to only 22 hours per hectare in the United States, whereas producing corn primarily by hand labor requires about 1,144 labor-hours (Lewis 1951).

## AGRICULTURAL DEVELOPMENT

Agricultural production is an essential step in industrial development, and must have a high priority in the overall growth and development of the developing countries.

A major factor in the successful development of the developing countries in the early stages is generating food surpluses over and above what the farm sector needs. This is necessary to supply the industrial sector with essential food.

Successful national development usually results in a declining share of labor in farming and rural migration to cities. Relocation of the farm labor force to urban centers may in turn contribute toward reducing population growth rates.

## EMPLOYMENT AND ECONOMIC DEVELOPMENT

Rapid population growth results in a high ratio of children to adults and thus a large, youthful labor force. And, a large labor force tends to reduce the growth of per capita incomes in the developing countries. In addition, food production must be greatly increased to meet the needs of a rapidly growing population, which limits the allocation of resources to other sectors for economic and social development.

The effective use of the large, expanding labor force in countries with rapidly growing populations deserves high priority. Increasing food production can provide an interim use for this labor force. Also, the biological improvements of crops and the use of fertilizers increase the potential for farms to use more of the available human labor.

## EDUCATION AND DEVELOPMENT

In this technological age, education is essential for effective agricultural and industrial development. For example, in most developing countries the quantity of resources allocated to the education of farmers has been insufficient to support the transition from low-productivity to high-productivity agriculture.

Educational budgets are insufficient and stressed when populations grow rapidly because the number of children who need to be educated is larger than the adult population that funds the educational program.

## HEALTH, NUTRITION, AND DEVELOPMENT

Malnutrition and poor health result from inadequate food supplies, from unequal distribution of income, and, to a lesser extent, from a lack of knowledge about nutrition. Poor health results in a less productive labor force, wastes food resources, and may retard the mental development of children. As with education, a rapidly increasing population reduces the amount of funding for public health and other developmental programs.

## TRADE AND INTERNATIONAL ORDER

International trade could lead to the more efficient use of agricultural and other resources--land, water, energy, fertilizers, minerals, and other resources are unevenly distributed in the world. All nations import some of their essential needs including food, fuel, and minerals. The United States, for example, imports more than 40 percent of its oil and about 100 percent of its needs in tin, platinum, and manganese. Other nations must import a portion of their food as well as other resources vital to their industrial and agricultural programs.

Because of the uneven distribution of resources and population numbers, serious economic and social stresses would be placed on most nations that attempted to be totally self-sufficient. But, on the other hand, relying on other nations and especially on a single nation for essential resources like food or oil also involves political and economic risks.

Each nation must choose whether to increase food self-sufficiency and/or expand food imports (financed by exports of industrial goods and agricultural export crops). Relying on a trading system to partially meet expanded food requirements is appropriate when the costs of doing so, in terms of achieving general economic development, agricultural development, and food supply goals, are lower than the alternative course of expanding indigenous food production.

Food security should be a major goal of a new international order among nations. The goal of this new system would be to improve the quality of human life and to strengthen amity among the high-income and developing nations, thus stabilizing global politics.

Improved trade policies among nations would enhance the possibility of establishing such a system within the community of world nations. In such a program U.S. participation and leadership are essential.

Obviously new U.S. trade policies would require changes in both U.S. domestic economic programs and foreign economic policies. Some U.S. agriculture and industry would benefit from the changes and others would suffer adverse effects. However, in the long term both the United States and the world community would benefit.

## A COHESIVE U.S. POLICY

U.S. policies related to food, energy, environment, and trade should be integrated and cohesive. Complex trade-offs will be necessary among different groups within society and the different agencies of the federal government in integrating these policies. However, if the trade-offs are explained and understood by the interested groups within the United States and other nations, the U.S. government would be able to function with credibility and respect.

Report of Subgroup A, Study Team 10

# POPULATION AND HEALTH

## INTRODUCTION

A consideration of interactions between population and health and food and nutrition policy must start with certain assumptions. A fundamental assumption is that the goal of increased food production and nutrition programs is improved health. Further, the success of any development effort can only be measured in terms of improving people's personal, physical, and mental well-being and their general social and economic advancement, particularly those in the poorer segments of society. Human numbers also must be considered because rapid population growth exerts pressure on world food supplies and makes it more difficult to improve the balance and distribution of food to the population. And, as we will show, there are disturbing signs that current food and development priorities in themselves will not necessarily lead to the widely presumed reduction in the population growth rates of the developing countries to the 1.5 to 2.0 percent range within the next 15 years.

There are two distinct but related issues involved in assessing the causes of population growth. The first deals with the involuntary biological mechanisms that relate health and nutrition to the fecundity, or reproductive potential, of a population. The second issue concerns the more or less voluntary social and individual behavioral processes that link the social and economic environment of the individual family to family size objectives, ultimately influencing the actual reproductive performance, or fertility. Performance here is conditioned by underlying cultural norms and by responses to a wide range of environmental situations (see Figure 3).

In every human population the biological limits to fecundity will prevent some members from having the number of offspring they desire. It is impossible to imagine a human population in which some members do not eventually adapt their reproductive behavior to their own self-interests, and in which social institutions do not limit fertility in a way that can be conceived as ultimately beneficial for the society. Thus both the

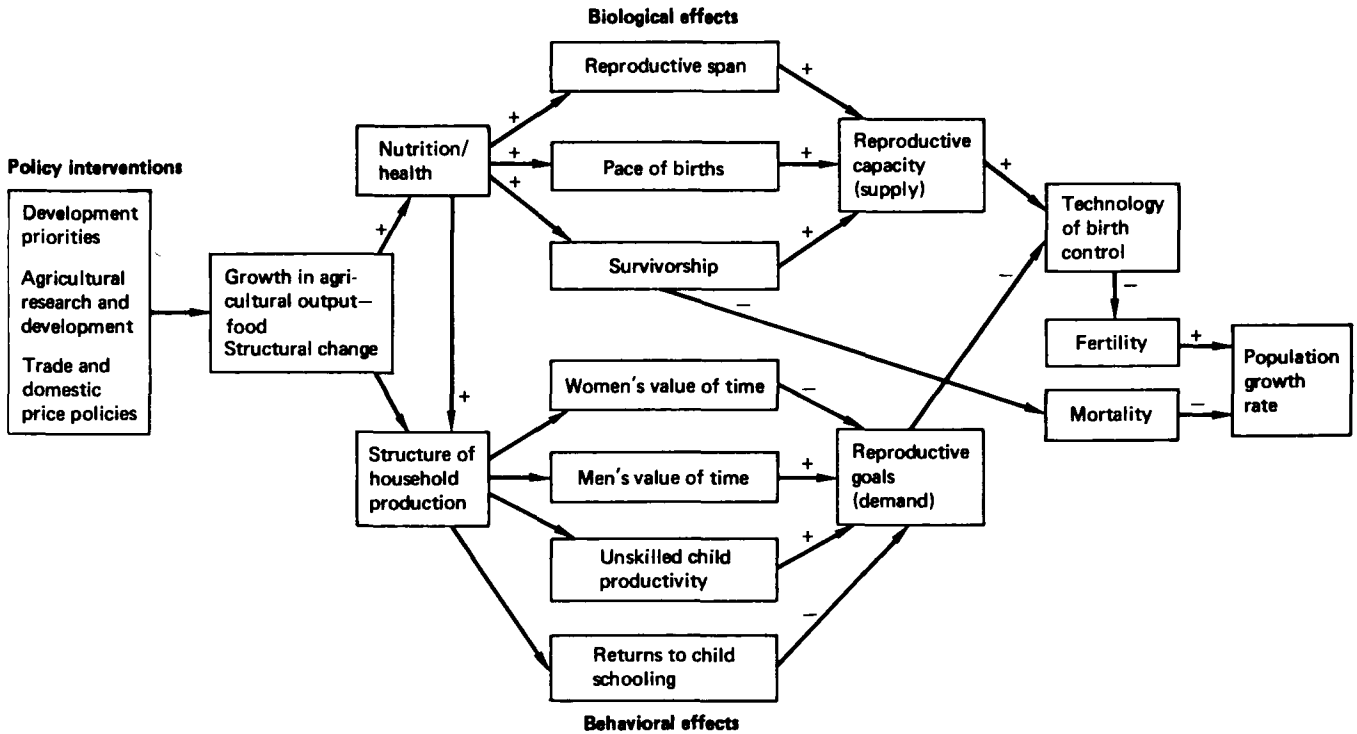


FIGURE 3 Schematic summary of factors affecting population growth.

biological capacity and behavioral motivation of people to have children (or not to have them) interact in determining the fertility of every human population, with the relative importance of the two factors differing from one society to another, or from one time to another.

Generally it is presumed that biological constraints are binding on an ever-smaller proportion of any population as it becomes more socially and economically developed (Tabbarah 1971). Therefore, biological determinants of reproductive performance might be more useful for understanding reproduction in the low-income countries, and social determinants of fertility might be more helpful in understanding reproduction in the higher income countries. But both factors are at work in all populations.

Thus while health and development interventions can augment productive and economic growth, they also serve to relax or tighten constraints upon population growth by influencing reproductive performance. Increasing the food supply and improving the general level of nutrition can be expected to increase fecundity and reduce mortality, thereby increasing the number of offspring per family who survive to childbearing age. The extent to which an increase in fertility is finally realized, however, will depend upon the range of reproductive preference and norms in a society, or--in economic terms--on the elasticity of demand for births and the effort or cost required to regulate the increased reproductive capacity. Even with the availability of modern means of birth control, the regulation of births requires some change in behavioral patterns, frequently entailing psychic, time, and monetary outlays.

Therefore, the task of evaluating the interaction between food and nutrition programs on the one hand and population growth on the other requires an analysis of how any such program will affect three relationships: the biological supply of births, the behavioral demand for births or birth limitation, and the cost of reproductive regulation.

## OUR CONCLUSIONS

For the least developed countries, the biolcgical relationships between health and human reproduction have serious policy implications. Better nutrition and health improve reproductive efficiency, that is, parents are able to achieve their desired family size at less social cost and less loss of life. Improvements in health services reduce mortality and morbidity, which increases the intrinsic rate of

population growth to the extent that it decreases the mortality of persons under 30, the mean maternal age of childbearing.

Many developing countries have had gains of 50 percent or more in reproductive potential in the last several decades as life expectancy has nearly doubled. This has not resulted from large increases in fertility, except as pregnancy wastage has diminished and improved health has shortened the sterile period that follows each birth. The primary change has been the reduction in mortality which is proportionately greatest among infants and preschool-aged children. An immediate implication is that parents have experienced for an extended period a regime of diminishing mortality, with proportionately more of their children reaching maturity. If their desires for surviving offspring are somewhat inelastic, parents will search for means of controlling their demonstrated increased reproductive potential. Food and nutrition interventions which improve health and extend life should provide parents with a means of controlling their reproductive potential. In the face of mounting unwanted fertility in many parts of the world, the health hazards of nonmedically induced abortion may replace those of the infectious and parasitic diseases that modern medical technology has brought under control in recent years.

In poorly nourished populations, prolonged lactation, often until the arrival of the next pregnancy, extends intervals between births and achieves a certain natural spacing of births. Thus the decline in infant mortality naturally helps to postpone the arrival of subsequent births. Even though this compensating mechanism can reduce births by at most one-third the amount of the reduction in infant deaths (Committee for International Coordination of National Research in Demography 1975, 1976; Preston 1975), this margin of natural compensation is an important aid in slowing population growth until modern birth control is available and adopted.

If breast-feeding practices change, as appears to be occurring in a growing number of countries, and the period of breast-feeding is reduced and the diet of infants is supplemented earlier, reproductive potential can rise by as much as one-third, triggering another imbalance between inelastic demands for children and the limited effectiveness of traditional means for regulating fertility. To the extent that traditional breast-feeding practices can be altered as little as possible without sacrificing the health of the child, this natural birth spacing mechanism should be sustained, relieving the need to gain immediate acceptance of modern birth control measures. One

approach to this dilemma is to direct foods to lactating mothers rather than directly to their infants. The efficiency and effectiveness of such a food distribution strategy remain to be proven.

There is much evidence that fertility across a society varies substantially from one socioeconomic group to another, and from one region to another. Although empirical evidence is fragmentary and often interpreted in an inadequate framework, evidence from cross-sections of societies at all levels of development documents that reproductive performance varies directly with child mortality, inversely with the net private resources used to rear children, and typically directly with the husband's income. The classic demographic model of Malthus did not emphasize the role of relative prices or of child mortality, but did assume for the most part that parents would have more children as real wages increased. Although the last century of economic and demographic developments in the industrialized world has undermined the credibility of Malthus' model, modern quantitative social science has confirmed certain ominous aspects of the Malthusian dynamics.

It is widely observed that individual, class, and regional differences in child mortality are directly associated with fertility, moderating differences in surviving family size. Evidence of both a biological (lactational amenorrhea) and a behavioral response is implicated (Schultz 1976b). The main factor responsible for increasing the relative cost of children, and thereby reducing the demand for surviving children, has been the rising value of the time parents allocate to the care and enjoyment of their children. In particular, the wage a woman is offered in the labor market outside of the home, and the education she is encouraged to obtain, are strong depressants on her lifetime reproductive performance. Although this relationship has different response thresholds in different societies, it is this "price-of-time" effect that appears to have been omitted from the Malthusian predications. The element of truth in the Malthusian model is that where the structure of sex roles does not change with development, and productivity increases flow largely to the husband's labors, there is no reason to assume that development will reduce birth rates.

The migration of families to the cities within the developing countries often results in the employment of women outside the home which is accompanied by a decrease in fertility. This is not to say that heavy migration to overcrowded urban areas is desirable, but rather that the process of development typically concentrated in urban areas should be shifted to the

rural areas. Capital investments should be directed toward producing opportunities for productive employment in rural areas. While in the short run this may be in labor-intensive agricultural endeavors, the investments should be explicitly designed to avoid perpetuating traditional productive roles that would only exacerbate the present situation in which population growth in the developing countries outstrips productivity gains.

Two measures--promoting productive employment in rural areas and involving women more extensively in rural and agricultural development--may be prerequisites to slowing population growth and resolving the Malthusian dilemma that faces the least developed countries today.

We do not argue that assistance in increasing food supplies and improving nutrition should be offered only on the condition that the recipients take radical action to curb population growth. The developing countries are amply aware of the long-run implications of population growth rates that exceed or even closely approach rates of increase in productivity. Rather, the desire has been to identify those factors that do not involve direct incentives or disincentives and egoistical interventions into the realms of choice that should be open to every human being, but that are permissive in that they give prospective parents the most absolute freedom of choice in the matter of when--and whether--to bear children.

Interventions selected by developing countries to improve nutrition and health, while not infringing on a person's right to bear children, should lessen the importance of the identifiable inducements to produce children. Interventions selected should:

-- increase the most productive employment opportunities in the rural areas through rural development and capitalization;
-- not maintain traditional role patterns in agriculture;
-- not distort food prices and wages in favor of urban populations, thereby contributing to excessive rural-urban migration, nor discourage internal mobility of labor that is virtually the functional equivalent of development;
-- entail increases in old age security for the general population;
-- involve an increasing number of women in productive labor outside the home, with due and humane regard for any undesirable repercussions on the health of their existing children;

-- entail ever-increasing education and, by implication, opportunity cost to parents of children of both sexes;
-- be accompanied by training in effective methods of birth control, for which the necessary technology should be made available.

## Profile 1

## BIOLOGICAL FACTORS LINKING NUTRITION TO POPULATION GROWTH

### PROBLEM STATEMENT

If human reproduction is simply considered a biological process with the population in one generation producing offspring for the next generation, the relevant biological factors can be classified into three sets: the duration of the reproductive span (for females), the pace at which successive pregnancies can occur during the reproductive span, and the survival of offspring to the next generation of reproductive adults (Mosley and Chen 1976).

#### Reproductive Span

There is considerable evidence that the limits of the reproductive span are influenced by changes in nutritional status. In the industrialized countries, there has been a secular decline in the age of menarche over the past century, dropping from about 16.5 years to 12 years (Tanner 1968). Differences of two or three years in the age of menarche also have been documented between different countries and socioeconomic subgroups within countries, with healthier, better-fed groups having the earlier onset (Chinnatamby 1962, Zacharias and Wurtman 1969). Finally, it is suggested that menarche is associated with attaining a critical body weight and fat composition, both of which are related to nutrition (Frisch and Revelle 1970, Frisch and McArthur 1974.

Similarly, a slow secular increase of two or three years in the age of menopause has been observed in industrialized countries (Wolansky 1972).

In this same framework, diseases that produce sterility, such as gonorrhea, may be considered a most important factor in reducing the average reproductive span of females. In some African and Pacific Island

populations, the frequency of childlessness among married menopausal women, an indirect measure of sterility (apparently chiefly the result of gonorrhea), exceeds manyfold the expected prevalence of congenital sterility (Conde 1971, Pirie 1972, Ring and Scragg 1973, Romaniuk 1968, Tabbarah 1971). Work on clinical populations also suggests that anovulation (sterility) may ensue under conditions of extreme malnutrition (Frisch and Revelle 1970, Frisch and McArthur 1974), but the relevance of this finding to low-income populations is yet to be determined.

Many studies relevant to this discussion are based upon atypical populations, those subject to severe stress or psychological maladies or to unusual circumstances such as war, famine, or enprisonment. Nevertheless, current evidence suggests that well-nourished, high-income populations may be expected to have an effective mean reproductive lifetime significantly longer than that of chronically malnourished populations. Conceivably this difference might approach a theoretical maximum of 10 years, a 40 percent increase over the reproductive span of some societies, although a more conservative view is that improved nutrition could be expected to increase the effective reproductive span of females in malnourished countries by some 10 to 20 percent.

It is uncertain that such an increase would effect an equal increase in reproductive potential, for it is unclear whether the extended years on the extremes of the reproductive span are as fertile as those toward the center. Furthermore, a decrease in the age of puberty will alter fertility only in societies where sexual exposure precedes or coincides with menarche.

## Intervals Between Births

The biological effect of changes in health and nutrition on the interval of menstruation between pregnancies is difficult to assess as this component is strongly influenced by behavior. In one U.S. study, the average menstruating interval to conception reported by couples who terminated contraception for the purpose of childbearing was about five months (Westoff 1961). Studies in rural, apparently noncontracepting communities in India, Bangladesh, and Senegal found intervals from the return of menses to conception ranging from 7 to 12 months (Cantrelle and Leridon 1971, Chen et al. 1974, Potter et al. 1965). How much of the difference between these intervals is due solely to health and nutrition is uncertain.

The factor most profoundly influencing the pace of pregnancies is the prolongation of the postpartum

sterile period by lactational amenorrhea associated with breast-feeding practices. Lactational amenorrhea in breast-feeding women has generally been observed to range from 6 to 12 months. Among poorer populations in the developing countries, such as rural Bangladesh and rural Indonesia, lactational amenorrhea has been reported in the range of 18 to 24 months. Combining its effects with the expected delays in conception, breast-feeding women report an average interval between live births of from 18 to 36 months. There is reason to think that the shorter end of this range is provided by well-nourished women, the longer by malnourished ones.

The important feature to note is that in many traditional societies lactational amenorrhea has a marked effect on the spacing of births and can account for up to half of the interval between births. This interdependency of breast-feeding practices and fertility as well as the nutrition of the mother and infant is of critical importance in nutrition intervention programs. Specifically, programs designed to improve infant nutrition by encouraging early introduction of supplemental feeding can reduce the period of breast-feeding and lactational amenorrhea and substantially increase birth rates (Berg 1973).

## Survivorship

The low-income countries have had a relatively recent decline in mortality rates. Stolnitz (1955, 1956, 1965) has concluded that innovations in public health and sanitation, rather than increases in overall income levels, are the direct cause of this decline. Other scholars stress the catalytic role of international agencies and outside assistance in reducing death rates while not effecting a corresponding increase in material levels of living (Coale 1975, Glass and Grebenik 1966:86-89). Consequently, it is asserted frequently that private wealth and consumption levels are much less relevant to the secular trends in mortality in the low-income countries today than they were in the high-income countries at a similar stage in their demographic and economic development.

Recently, great importance has been attached to investments in public health, organizational capacity, and new medical technology to further increase survival rates in the low-income countries. Although this widely accepted view may be plausible, it has not been rigorously inferred from quantitative analysis of mortality trends and differentials. Even in the most dramatic instance of Ceylon, only a quarter of the

postwar decline in mortality can be attributed to the control of parasitic disease (malaria); the remainder is not associated with the direct utilization of various public health services (Gray 1974). Rather, socioeconomic development and redistribution of income would appear to be responsible for a large part of the recent unexplained decline in Ceylon's death rate (Barlow 1967; Newman 1965, 1970).

Further support for the thesis that political stability and development are the major determinants of recent declines in mortality in the developing countries, particularly as declines relate to a stable, well-distributed food supply, comes from studies by Davis of India (1951) and Mosley of Bangladesh (1977). On a more global scale, Marshall (1974) makes a strong case for better food supplies being the primary determinant of rapid population growth in most developing countries.

Field research shows that high levels of childhood mortality in the low-income countries are primarily caused by gastroenteritis and diarrheal diseases (Gordon et al. 1964, McDermott 1966). Diarrheal disease is related to nutritional deficiencies which in turn are related to family income and the educational level of the mother. In some chronically malnourished populations of Asia, Africa, and Latin America, malnutrition has been documented as the direct or contributing cause in more than 50 percent of all deaths, particularly in infants and young children (Puffer and Serrano 1973).

In sum, persistently high levels of diarrheal diesease and the resulting mortality among children in the low-income countries are not easily controlled by modern Western medical technology and are related to shortcomings in nutrition and living conditions. In the low-income countries, increasing food supply and improving nutrition can be expected to produce a dramatic decline in childhood mortality--perhaps approaching one-third in some instances. The resulting rise in the general level of health and well-being, of course, means a significant increase in the number of those who survive long enough to reproduce.

* * * * *

Each of these factors is influenced by the health and nutritional status of the population. Poor health and malnutrition depress reproductive potential. Conversely, improvements in nutrition can increase reproductive potential. In the absence of any other factor constraining human reproduction, simply increasing the food supply and improving nutrition in a population may lead to the dilemma of accelerating

population growth which can aggravate the food and nutrition problem in the long run.

Yet the evidence linking nutrition to these reproductive parameters does not provide a sound quantitative basis for answering the questions relevant to this study, namely: How will marginal improvements in food supplies and nutrition affect reproductive capacity? Which segments of the population will be most affected? Over what time period will the effect develop? Existing information is based on clinical samples selected for other health or psychological reasons, from historical circumstances of famine, war or prison life, and from time series and cross-section changes for countries, all of which necessarily neglect many potentially contaminating factors and limit the generality of findings. Controls also are needed for psychological states, childbearing preferences, and economic determinants of reproductive demands to isolate the independent role of nutrition in biologically implicated but voluntary behavior, such as breast-feeding.

## RESEARCH NEEDS

There is sufficient evidence to conclude that improved nutrition and health lengthen the reproductive span, abbreviate the natural spacing of births, and increase chances for offspring survival, all of which increase the potential reproductive performance of a population. But we do not know how much of an effect improved diet will have on any of these reproductive components in the span of a generation. Nor do we know the indirect effects of increased child survival on reproductive potential, although its effect clearly offsets some part of the direct effects of nutrition on reproductive potential. Moreover, this knowledge is not likely to emerge as a spinoff from ongoing research and evaluation efforts. The critical issues probably could be resolved by a concerted research program within 10 to 15 years. This knowledge would permit sounder choices among nutrition and development strategies by disentangling past and future effects on fertility arising from improved nutrition and from other socioeconomic change and the delivery of improved birth control technology.

Reproductive processes in representative populations must be studied carefully over time to estimate their response to modest changes in diet, measured along a variety of dimensions. To estimate the nonlinear or threshold form of the response curve and the time lag from diet change to biological outcome will require extensive, long-term field studies. The

following distinct reproductive components must be studied: (1) age at menarche, (2) age of menopause, (3) duration of anovulation following a birth, (4) proportion of anovulatory cycles and the probability of conception, (5) pregnancy wastage including stillbirth, (6) birth weight, and (7) survival of offspring by age and cause of ultimate death.

Implicated in this process, in a complicated way, is breast-feeding, both as a regulator of reproductive capacity (i.e., natural spacing of births) and as a reflection of other unobserved behaviorally involved mechanisms to backstop the natural contraceptive effect of continued breast-feeding. Certain of these components are more likely than others to respond significantly in the short run to feasible diet changes, and these should obviously receive concerted and immediate study.

To accomplish this research objective, populations at different initial nutritional levels must be monitored for nutritional status at the family and individual level. Data also should be collected on health status, biological reproductive performance indicators, and socioeconomic and demographic characteristics.

## IMPACT

What we know today about the critical response parameters that link nutritional status to mortality, fertility, and labor productivity is based for the most part on clinical studies of limited generality and on scattered evidence of cross-sectional association. We lack precise information on the biological and behavioral factors that determine the relative importance of nutritional feedback mechanisms that may stimulate population growth or economic development. Therefore it is impossible to plan scientifically for the consequences of nutritional interventions and thus select those that have the greatest potential for increasing a population's long-run welfare.

## IMPLEMENTATION

In 1975, the National Research Council's Food and Nutrition Board recommended establishing programs to monitor the nutritional status of populations at whatever scale necessary (NRC 1975a:21). The value of these Nutritional Monitoring Programs (NMP) would be increased substantially if they were designed to jointly collect and analyze appropriate biological, demographic, and socioeconomic data as required to

answer the above research questions. Frcm the outset, NMPs should designate a unit responsible for ascertaining how nutritional status depends on environmental conditions and how both nutrition and environment impinge on mortality, morbidity, reproduction, and labor productivity. This unit also would determine not only what additional information should be collected and how, but also how these materials would be used in experimental evaluation and nonexperimental research into the static and dynamic determinants and consequences of nutritional status.

The optimal number and location of NMPs will depend upon the initial nutritional status and customary diet of populations and upon the prevailing level (and structure) of mortality, fertility, and socioeconomic preconditions. It would be desirable to designate a common core of demographic and economic outcomes and preconditions to measure in all NMPs for policy evaluation purposes and interpopulation comparisons over a wide range of conditions. The institutional setting and cultural factors that bear on nutritional status and its consequences will differ from population to population, and will require special intensive studies by several social science disciplines. The incremental cost of such a research and evaluation unit could add about 10 to 15 percent to the overall monitoring and intervention program, and not add notably to the time required to organize and initiate the NMPs.

## Profile 2

## BEHAVIORAL DETERMINANTS OF FERTILITY AND THE DESIGN OF FOOD AND NUTRITION POLICY

The biological effects of improved nutrition increase human reproductive capacity and reduce mortality, both of which lead to rapid population growth in precisely those countries in which income, nutrition, and health conditions are the least favorable. Nutritional interventions also may improve adult health and enhance the productivity of labor. Although nutrition interventions may have a great effect on productivity, they are difficult to document convincingly and have been rarely studied under conditions common in the developing countries. Moreover, there is growing evidence that increases in the income of male workers and the increases in the productivity of unskilled child labor, which might accompany increases in agricultural productivity, generally are associated with increased demand for surviving offspring and increased fertility, unless offsetting changes are brought about.

The fundamental policy problem is how to offset the effects of nutrition interventions on population growth to secure the most favorable long-run prospects for improved individual welfare. The answer lies only partially in subsidizing the dissemination of birth control methods and in perfecting the technological shortcomings of existing methods. Basically, the problem is more social: parents want more children than are needed to replace themselves, indeed, often many more. The behavioral sciences must be able to understand the complex motivations of parents to have children. This knowledge is essential to disseminate birth control techniques effectively and to choose wisely among alternative food and development strategies.

A comprehensive theory of the principal determinants of fertility which can be adapted to a variety of cultural settings is required. The outlines for such a theory are developing rapidly, but much more

effort is required to formulate: (1) the underlying conceptual framework in general but testable terms, (2) the statistical model in a form that can define both long-run tendencies and the path of short-run adjustment, and (3) the empirical applications that must incorporate extensive knowledge of heterogeneous aspects of the society and household in various cultures. Once it is agreed how to measure the effect of nutrition and food programs on population and economic growth, improved information and management techniques could be applied readily to help design and implement any such programs and integrate them into broader health and development plans. Present systems analyses of the population problem lack the basic knowledge of fertility determinants.

## PROBLEM STATEMENT

Reproductive capacity is determined by biological factors, but its realization is moderated by behavior, much of it socially constrained and channeled. For present purposes this behavior has three major elements: a female's age at marriage, rate of celibacy, and the practice of birth control or voluntary restraint. The incidence of all three elements varies substantially in different times and places, and clearly an increase in any of them for whatever reason will tend to decrease fertility, that is, the reproduction that is actually accomplished. For present purposes, these motivating factors and their results can be discussed under a single heading.

### A Simple Demand Framework

In the last decade much progress has been made in accounting for differences in reproductive behavior in premodern, preindustrial, and industrial populations. The unifying framework for this work is that human reproductive behavior--like all other human behavior--adapts to the self-interest of the individuals concerned (in this case, the parents), and these interests in turn respond to the changing configurations of social, economic, and demographic constraints on the family unit. A parent's scarce resources certainly are not the only important factor determining fertility, but it is a factor that is relevant to reproductive goals and behavior, and it often explains variation in reproductive behavior in different social circumstances. This has been shown by comparisons of non-Western societies in various levels of socioeconomic development (Dumond 1975) as well as

by wideranging comparisons of fertility between rural and urban people and recent migrants to cities within the developing countries (Schultz 1976a, 1976b).

Expressed in economic terms, a couple's choice of what they consume during their married life is limited by their time and nonhuman capital resources. Often market-determined wages for husband and wife provide an opportunity to exchange their own time for market goods--two scarce inputs into family consumption. Because children can absorb a substantial share of a couple's available time and market income, it is likely that market prices, levels of spouses' wages, and nonhuman wealth exert substantial effects on the number of children parents want. This demand framework for understanding individual differences in fertility was conceptualized by Becker (1960), implemented empirically by Mincer (1963), and has led to a number of more recent investigations of reproductive behavior in various societies (Schultz 1976a).

The framework posits that the effect of nonhuman wealth in itself is to increase the demand for children. Thus given plausible assumptions concerning the differential amount of time spent in childrearing by wives on the one hand and husbands on the other, and the alternative opportunities for the use of their time, the household demand framework predicts that any relative increase in the value of the husband's time will tend to increase the demand for children. Conversely, however, an increase in the value of the wife's time will reduce the demand for children. These differential effects of physical wealth and values of time on fertility have been confirmed in most empirical studies that appropriately exclude other jointly determined variables in the prediction equation (Schultz 1976a).

It is important to stress that this framework implies that the effect of household income on fertility may differ dramatically depending upon the sources of that income. Income generated by the productivity of unskilled children increases the attractions of a large family, and so promote increased reproduction. This appears to be the case even when labor is already abundant and the productivity of additional children is consequently low simply because the presence of an ever-increasing number of children in the household provides domestic labor and serves to further reduce the opportunity cost in terms of the time that parents are required to commit to each additional child. Hence even with the intermittant and marginal contribution of a child to household income, parents may understandably view him or her as worth the minor costs (White 1975).

Increased income traced to the contribution of adult women, in cases where their productive roles are not readily combined with childrearing, is associated with decreased reproductive performance. The "price of time" of the mother increases the resource potential of the household, and also increases the opportunity cost of any additional child. This pattern recurs across cultures and populations even when substitutes for a mother's time in the childrearing process appear to be available. When women gain access to education and take on productive roles outside the agricultural household, fertility is lower (DaVanzo 1972, Maurer et al. 1973, Schultz 1976a.

Although employment of women may reduce available child care, the offsetting increases in household market income need not imply a net deterioration in child nutrition, health, and mental development (Gonzalo 1976, Lindert 1974). The same situation, of course, also promises to increase the age of marriage and celibacy rates by inducing women to delay or forego marriage.

## Other Aspects of Cost

A common direct and opportunity cost of children is the cost of an education or the acquisition of necessary vocational skills. Similar to this is the cost of the material goods that offspring are expected to own for their livelihood and the self-respect of the parents, be it a dowry for a daughter or sufficient land to establish a son. As these costs rise with development, and associated gains are not perceived by parents to increase by a commensurate amount, fertility may be expected to decrease. Initially, among low-income people in the developing countries, these would be largely opportunity costs as the potential income of children attending school is foregone and the productive advantages of educated offspring may not be apparent to parents. Different development strategies can increase or decrease the value of unskilled child labor, and others will enhance or diminish the premium received for schooling in the marketplace.

## Less Direct Values of Offspring

There are also less direct economic values of additional offspring. Among these are situations in which extreme value may be placed on producing an offspring of a particular sex--generally male--to fulfill religious or genealogical functions. More common, perhaps, are situations in which a large number

of surviving adult offspring are believed necessary for security in old age and the pooling of risks associated with the economic failure or accidental death of offspring.

### Elasticity of Demand

If the demand for children were constant, as the framework described might seem to imply, the rates of fertility should parallel those of mortality, provided the former were within biologically feasible limits. Indeed, it is widely observed that regional and individual differences in fertility are directly related to differences in child mortality, thus moderating the strict inverse correlation between mortality rates and the number of offspring who survive to childbearing age. That is, when child mortality drops, so does fertility.

Evidence from the low-income countries, however, suggests that the reduction in fertility that initially accompanies a reduction in child mortality is little more than one-half the amount required to achieve a constant surviving family size (Schultz 1976b). Thus demand for children in most of these societies is somewhat, although by no means completely, elastic, so that as it becomes possible to raise additional offspring to adulthood, at least some additional offspring tend to be so raised.

## RESEARCH NEEDS

The first research priority is to discover what measures taken to increase agricultural productivity would change the social and economic organization of production so as to alter the period and increase the desirability of female labor outside the home, thereby enhancing the productivity of women in a manner that will be associated with diminished reproductive goals and fertility. To what extent can these changes in women's roles in development change marriage patterns, and hence fertility? What are the consequences of land tenure arrangements and inheritance practices on age at marriage, frequency of marriage, and reproductive performance within marriage? How long does reproductive behavior lag behind changes in these factors?

For reasons that may be intuitively plausible, if not derived from a formal model of reproductive behavior, fertility generally is higher in populations with higher child mortality rates. It is widely observed that regional and individual differences in

child mortality are directly associated with differences in fertility, moderating surviving family size. Evidence of association across regions, groups, and individuals suggests that fertility reaches some manner of equilibrium given environmental health and economic constraints, within the elastic range of social norms. But existing evidence does not explain how interventions impinge on this complex biological-social-economic interactive system, revealed only partially in a cross-section. Nor is it now clear how rapidly the observed cross-sectional relations will reassert themselves once the conditioning variables are modified.

Statistical problems cloud the precise meaning of empirical analyses of fertility differences, but these broad conclusions do not seem in doubt. Extensive empirical research is necessary to design and to evaluate sound policy interventions that would promptly reduce fertility. Cultural heterogeneity precludes making generalizations about reproductive motivations and appropriate social interventions, but this aspect of the cultural diversity that the social sciences must deal with should not diminish the priority assigned to the task. Translating these general concepts of resources, costs, and returns into measurable dimensions of the family's environment that can be changed by policy interventions is the difficult but tractable job for a team of social scientists, including possibly anthropologists, economists, psychologists, sociologists, statisticians, and survey researchers.

## IMPLEMENTATION

The best research minds in the social sciences are needed if these basic and applied research issues are to be clarified, and future population policies are to be better founded. Unfortunately, grand designs for social science research rarely can be broken down into a list of tasks and assigned to teams of experts.

Since there is not one best approach in acquiring an understanding of the determinants of fertility, a hedging strategy that supports research based on contending viewpoints is appropriate at this time. For this reason, a variety of agencies such as the National Science Foundation (NSF), the National Institutes of Health (NIH), and the U.S. Agency for International Development (AID) should support this research. Duplication may be less costly than would the foreclosure of options at this critical juncture. Yet it would appear that NIH and NSF are reducing their

commitment to research on these problems in the developing countries.

U.S. support of population and related research at home and abroad was $67 million in 1975. About one-fifth was spent on demography and other social sciences, including research on the clinical delivery of family planning services, mostly in the United States. Roughly 3 percent of federal population research funds were applied to the study of the determinants of fertility, and only a small fraction of that amount was used to study populations in the developing countries. This imbalance in research priorities is not consistent with the national interests of the United States. Earmarked funds should be appropriated to NSF as well as to NIH and AID to support basic research on the determinants of fertility in the developing countries, and on the consequences of population growth that stem from alternative health, nutrition, food, and development policies.

If some $2 million are currently being spent each year on socioeconomic and management studies of the determinants of fertility in the developing countries, this amount could profitably be increased to $10 million by 1980. The initial emphasis should be on refining and testing a common theoretical and statistical framework and subsequently applying it to a representative set of populations throughout the world. Established Nutrition Monitoring Programs may provide a biological, demographic, and socioeconomic data base for such analyses in future years. Coordination of this research program should be encouraged, but centralization probably would not be productive. Much of the data collection, processing, and analysis could be done in the developing countries, but essential specialized skills will not be available in most of these countries. International teams will be required with a large U.S. component, at least initially.

A strong effort should be made to disseminate information to promote an exhaustive and prompt analysis of these complex data files. Two or three international research centers might be established under long-term funding to analyze the biological and behavioral determinants of fertility, and to design policy interventions to speed development and slow population growth. Such a redirection of population research in the behavioral sciences is long overdue to cope with the limited effects of family planning on world fertility. This is a critical next step in coping with the Malthusian dilemma: how to improve the long-run capability of the developing countries to feed themselves.

Report of Subgroup B, Study Team 10

# ENERGY, RESOURCES, AND ENVIRONMENT

In the future, the food sector (food production, processing, and distribution) will be in increasing competition with the nonfood sectors for energy, land, water, and other resources. Moreover, rising output in the food sector is generating growing pressures on the environment because of erosion, fertilizer and pesticide pollution, and so on, and these pressures impinge on nonfood sector activities. The nonfood sectors also generate environmental pressures, some of which affect the food sector--for example, sulfur dioxide emissions from steam electric generating plants may damage crops.

The principal effects of this competition between the food and nonfood sectors for energy and other resources are on the prices of these resources.[1] The effects are different on the environment which serves as the receptor of the effluents of the food and nonfood sectors. Environmental resources--land, air, and water--typically are not priced or "supplied" in the ordinary sense, and thus it would be awkward to express the competition for them in terms of cost or availability. Instead, the discussion of environmental interdependencies between the food and nonfood sectors is focused on the effects of each sector's activities on the quality of the environmental resources available to the other.

## ENERGY

To adequately feed the world's expanding population and meet other social and economic goals of development, the amount of energy used per person and per hectare in agricultural production, processing, and distribution will have to be greatly increased from present levels, especially in the developing countries. (Also see report of Study Team 4, Subgroup B, "Land and Water.") Extending the low energy techniques still widely used--the man or woman with only a hoe, or bullock and plow, or oxcart transport to the nearest

village--will not produce the surpluses needed to feed rapidly growing urban populations, often located far from farms. Only more energy, vastly more than can be provided by humans and animals alone, will do the job.[2] The question then is not whether more energy will be needed but what forms it might take.

## Petroleum and Natural Gas

The rapid increases in food production, processing, and distribution achieved in some countries in recent decades have resulted from increased use of fossil fuels, primarily petroleum and natural gas, in the form of fertilizer, pesticides, and energy to drive farm machinery and food processing and distribution systems. The long-term prospects for prices of petroleum and natural gas, therefore, have an important bearing on the world's capacity to increase food supplies in response to rising demand.

Petroleum prices are dominated by the Organization of Petroleum Exporting Countries (OPEC), and reflect political decisions made by OPEC rather than the economic costs of production and distribution. A study by Resources for the Future (1976:Chapter 6) indicates that the political decisions of OPEC likely will dominate world petroleum prices until at least the end of the century. The study assumes that if OPEC remains cohesive, the price per barrel will stay at about $12--1975 prices--until about 2010. At that point consumption will begin to press upon reserves hard enough to raise the price considerably above $12 by 2020. If OPEC does not remain cohesive, the price would fall from the 1975 level. This study concludes that the lower price could be maintained until about 2000, but because the lower price would encourage faster consumption from 1975 to 2000, depletion of reserves would be more rapid, and at about 2000 the price would begin to rise more steeply than if the $12 price had been maintained. Other projections of petroleum prices show either increases or decreasess from 1975 to the end of the century depending for the most part on assumptions about the behavior of OPEC.

After reviewing these projections, the staff of the World Food and Nutrition Study (WFNS) developed a projection showing the price in 1985 some 18 percent above the price in 1975, after adjustment for inflation. From 1985 to 2000 the price is projected to decline to the 1974 level.

Given the great uncertainty inherent in all projections of petroleum prices, there is little point in analyzing the implications of any single projection. It is more interesting to compare the implications of

widely differing projections. Dvoskin and Heady (1976) made a single projection of U.S. agricultural production in 1985 with the assumptions that petroleum and natural gas prices (1) in real terms, would remain at the 1974 level, and (2) would increase 100 percent above the 1974 level. They found that doubling the real price of petroleum and natural gas would increase the total cost of producing the output projected to 1985 by about 13 percent. Total land in crops would increase slightly, but irrigated cropland would decline by 20 to 25 percent and dry cropland would increase by about 3 percent. Nitrogen fertilizer purchased would decline about 15 percent, and total energy consumption, measured in kilocalories (1 kcal = 1,000 calories), would decline by about 5 percent. The decline in energy use would be entirely in natural gas and electricity, reflecting the reduction in irrigated acreage. Energy used to drive machinery would increase slightly because of the increase in cropland.

Dvoskin and Heady may underestimate the costs and other consequences of a doubling of real energy prices. Their estimates do not include, for example, the social costs of the shift of people and resources from irrigated to dryland farming, and they assume that the costs of production on land newly converted to crops will be the same as on presently cropped land. In fact, bringing new land under cultivation likely will entail increased costs for clearing, leveling, and draining. On the other hand, the Dvoskin-Heady model does not include all of the possibilities open to U.S. farmers for economizing on the use of energy and, therefore, the model would overestimate the effects of a doubling of energy prices on farm production costs and resource use. For example, the model assumes a fixed amount of irrigation water per hectare for each crop, but less water might be used when its cost rises because of higher energy prices. Moreover, the study assumes that energy prices double by 1985. If prices did not double until after 1985 farmers would have more time to adjust to the higher prices, thus mitigating the impact on production costs and resource use.

The Dvoskin-Heady work suggests that U.S. agriculture could absorb any increase in energy prices now considered likely without major consequences for food production costs or patterns of resource use.[3] The energy intensity of U.S. agriculture (the cost of energy as a percent of total cost) is probably as high as in any country. Thus the effects of higher energy prices on U.S. agriculture probably represent the maximum to be expected anywhere.[4] We can only speculate about these effects in the developing countries. The effects may be less than in the United States because the marginal productivity of energy in

the agriculture of these countries may be higher than in the United States. (There is evidence that this is true for nitrogen fertilizer.) In this case, the higher cost of energy would have less effect on reducing demand for energy by farmers in the developing countries than in the United States. Offsetting this, however, are the more limited financial resources of farmers in the developing countries, making it more difficult for them to buy higher priced energy and less able than U.S. farmers to absorb losses in case of crop failure. What the balance may be between these opposing forces is not clear. It is encouraging, however, that in the Indian subcontinent food production in the 1975-76 crop year was up considerably from the previous year. While this was due primarily to favorable weather, it is clear that with favorable weather high energy prices did not prevent Indian farmers from reaping a record harvest.

The discussion of the effects of high energy prices is reassuring when placed against some of the doomsday speculation about the consequences of these prices for the world's capacity to feed itself at reasonable cost. There is no implication, however, that the United States or other countries should be indifferent to the price of energy. The world's capacity to produce food already is stretched thin, making any increase in food costs, no matter how small, undesirable.

## Alternatives to Petroleum and Natural Gas

So far the search for alternatives to petroleum and natural gas has produced no dramatic breakthroughs. Presently nuclear fission and coal are the most promising substitutes, with coal gasification, oil shale, biomass, solar and geothermal power, and nuclear fusion in the more distant future. These substitutes are likely to have a more direct effect on the nonfood sectors than on the food sector because none of them can substitute economically for natural gas in the production of nitrogen fertilizers or for natural gas and petroleum to drive irrigation pumps, farm machinery, and trucks and trains used in food distribution. These substitutes could indirectly favor the food sector, however, by reducing nonfood sector demands for petroleum and natural gas, thus restraining the rise in the price of these resources.

Discussion of energy alternatives to petroleum and natural gas for use in the food sector has focused primarily on food production rather than on processing and distribution. The principal alternatives considered have been nonpetroleum and natural gas substitutes for nitrogen fertilizer and pesticides, use

of biomass to generate petroleum or methane gas, and increased use of direct solar energy by improving the efficiency of photosynthesis and for pumping and crop drying. Another "alternative" discussed is simply more efficient use of existing technologies based on petroleum and natural gas.

While production of nitrogen fertilizers is highly energy-intensive, it now is generally agreed that the 1973-74 increase in prices of these fertilizers was because of capacity limitations rather than higher energy costs (see Study Team 4, Subgroup C). Most projections of these prices, including those done for WFNS, indicate a continued decline in real prices from 1975 levels until roughly the mid-1980s. After that date the projections diverge, but apparently there is a consensus that even in 2000 the real price of nitrogen fertilizer will be well below the levels of 1974 and 1975, even if the prices of petroleum and natural gas stay high or rise further. In this event farmers over the balance of the century will have less incentive to find substitutes for nitrogen fertilizer than seemed likely in 1974 and early 1975 when fertilizer prices were at their peaks and there was much uncertainty about their future course. It is well that this should be so because it seems unlikely that economically feasible alternatives to these fertilizers will be available within the next decade or so.[5]

Work is underway to develop pest-resistant varieties, biological controls, and integrated pest management techniques as substitutes for chemical pesticides (see Study Team 1, Subgroup A). After a review of this work, however, the National Research Council (1975c:97) saw no convincing evidence that the alternative techniques would displace chemical pesticides on a large scale within a decade. Over the longer term, say by 2000, considerable substitution by these techniques is more likely, particularly if concern persists about the environmental consequences of chemical pesticides.

Photosynthesis presently converts only about .05 to 1.5 percent of the sun's energy falling on an acre of food crops to food energy useful to an animal (NRC 1975a:113). Research to increase the efficiency of photosynthesis is following several lines, such as altering plant leaf structure to capture a larger amount of sunlight, reducing the rate of photorespiration (which wastes energy) in $C_3$ species such as soybeans and wheat, and carbon dioxide enrichment of the atmosphere in which plants grow. This research shows promise, but photosynthesis is still not completely understood, and none of the efforts to improve it has yet contributed to increased energy efficiency at the farm level (NRC 1975a:113).

The technology exists to convert the biomass represented by crop residues and animal wastes to liquid fuel or methane gas. However, in the United States at least, converting biomass to liquid fuel is not economically competitive at present with conventional sources of petroleum (Heichel 1976). Makhijani (1975:101) argues that biogasification of plant and animal wastes to produce methane gas is economically promising for widespread use in the near future, although opinions differ on this. There is some evidence that the process may be economically viable only in tropical or subtropical areas, if anywhere. Much of the experience with the process has been in India where thousands of small biogasification plants have been built in rural areas (Makhijani 1975:102). So far the fuel produced in these plants has been used primarily for domestic purposes. The gas can be stored and used for machinery.

One of the most attractive alternatives may be to adopt a variety of known techniques to economize on the use of petroleum and natural gas. Among these are more efficient water management to offset the increased cost of pumping; foliar application of fertilizers, application through irrigation systems, and more timely application to maximize crop uptake; and more timely and more sparing use of insecticides, aiming to keep insect pest damage below the economic threshold rather than at total elimination of the pests. Under some circumstances minimum tillage also offers energy savings relative to conventional tillage. With minimum tillage, preservation of crop remains encourages insect and slug populations, plant pathogens, and weeds. Using more pesticides to control these pests offsets some of the energy savings achieved by lower tractor fuel requirements. Whether there is a net saving of energy depends upon the crop and specific technology employed. Minimum tillage apparently sacrifices little if anything in yields compared to conventional tillage and has proven to be economically viable under a wide variety of conditions in both the United States and developing countries (Elias 1969, Greenland 1975, Heichel 1976, Jacobs and Timmons 1974, Wittwer 1974).

It sometimes is argued that, especially in the developing countries, the proper response to high energy prices is substituting labor and animal power for tractors and other farm machinery. In many developing countries government policies have encouraged socially inefficient degrees of farm mechanization. It does not follow, however, that labor and animal power should substitute for farm machinery in the sense that these resources should account for an increasing share of total energy use in agriculture. Such a policy inevitably would reduce food production

unless there were a massive return of people from the cities to the farms, a move that would condemn the developing countries to permanent stagnation at an even lower level of income than they now have achieved.

Evidence on energy use in India (Revelle 1976) strongly indicates that the only way per capita food production in the developing countries can keep pace with rising demand is to increase the amount of nonhuman, nonanimal energy used on the farm. Numerous studies on adoption of Green Revolution technology in the developing countries have shown that increased mechanization frequently is an important component of this technology, even in areas dominated by small farms. Where irrigation is available, the high yielding varieties of rice and wheat permit growing more than one crop per year, but this requires plowing and planting within a narrow time span, something most economically done with a tractor. Moreover, higher yields from the improved seed varieties increase the demand for labor at harvest, creating labor shortages and opportunities for efficient mechanization even in areas where labor may be underutilized much of the rest of the year.

This is not an argument for rapid and wholesale mechanization of agriculture in the developing countries. In particular, rapidly displacing animal power surely would make little economic sense. Rather, the point is that even with high energy prices, there will be many opportunities to increase mechanization in those countries as part of the gradual process of moving from low to high productivity agriculture, and that those opportunities should not be lost because of a superficial interpretation of the significance of high energy prices.[6]

## RESOURCES

The food sector also will be in competition with the nonfood sectors for land, water, and other resources. Of these, land and water are by far the most important. By comparison, the present and prospective costs of the iron ore and other metals embodied in farm machinery and structures are trivial. The cost of cement needed to build dams and irrigation canals is more important, but the literature indicates little concern about long-run increases in these costs. In any case, these costs should be considered part of the cost of providing water.

Phosphate rock and potash provide essential fertilizer materials, the consumption of which must surely grow rapidly if food production is to keep pace with rising demand. Most phosphate rock and potash are

used only in fertilizer production, however, so there is little interdependency in the use of these materials between the food and nonfood sectors. Moreover, reserves of these materials are very large relative to prospective demands, a fact reflected in projections of phosphate and potash fertilizer prices made for WFNS. These projections indicate that real prices would decline between 1975 and 1985, then would rise until 2000. In that year, however, prices of phosphate fertilizers would be well under 1974 prices and potash prices only slightly above. This longer term outlook for prices of these materials is consistent with views expressed in other studies (Emigh 1972, Goeller and Weinberg 1976, Wells, 1975a and 1975b).[7]

## Land

The principal competitors with the food sector for land are forestry, recreation, transportation, energy development, and urban uses. In the United States, the strength of this competition will depend in good measure on the success of the developing countries in increasing food production fast enough to keep pace with rising demand in those countries. If they succeed, demand for U.S. food exports probably will not rise much from levels of the mid-1970s. In this event, with only modest increases in yields, U.S. agriculture could accommodate both domestic and export demand with land presently in crops, or with even less land.

If the developing countries fail to accelerate their food production, but succeed in achieving overall economic growth on the order of 6 percent annually, the demand for U.S. exports of food could mount substantially above the levels of the mid-1970s. Unless yields increase much faster than they have since about 1970, American farmers could accommodate both export and domestic demand only by bringing considerably more land under cultivation, perhaps as much as 16 to 20 million hectares (12 to 15 percent more land than was harvested in 1975).

Most of the additional land that might be brought under cultivation would be in the Plains and Corn Belt states where competition with forestry would be slight. Much of the land converted to crops might now be in pasture, however, which could increase competition between grazing and forestry in other parts of the country, particularly the south and southeast.

There has been much discussion in the last several years of developing the vast coal reserves of the western United States by strip mining. Some of the land overlaying these reserves is, or potentially could be, turned to crop or animal production. The extent of

the competition for these lands over the next 25 years appears insignificant, however, from the perspective of the nation as a whole (NRC 1974b:35). Strip mining in the midwestern states also competes with agriculture for land. However, midwestern reserves of coal suitable for strip mining, most of which are in Illinois, are small relative to western reserves. Even if all the midwestern coal were mined in the next 25 years, the amount of land disturbed likely would be small relative to total cropland in the area.

Between 1950 and 1970 urban growth absorbed about 1.9 million hectares of cropland in the United States (USDA no date:8). Although the amount of land affected was relatively small (a little over 1 percent of total cropland) and the effect on national agricultural production negligible, the shift to urban uses nevertheless may have been a significant factor in the steady increase in the price of farmland over the last several decades (Held and Clawson 1965:107). With continued rapid growth in demand for U.S. food exports, the competition for land between the food sector and urban areas likely will become more severe, and the price of agricultural land in the United States, particularly around urban areas, is likely to continue to rise over the balance of the century.

It is difficult to judge the strength of the competition for land by the food and nonfood sectors in the developing countries because of a lack of information about the growth in demand for land by various sectors and about the costs of turning land to alternative uses. It seems certain, however, that the demand for land by both sectors will increase significantly. The demand for farmland probably will increase by 1 to 1.5 percent annually over the balance of the century[8] for a total increase of about 30 to 45 percent in the next 25 years. Urban demands for land also will increase, reflecting urban population growth of 4 to 6 percent annually, although the total amount of land converted to urban uses likely will be small relative to that turned to agricultural uses. If the developing countries achieve satisfactory economic growth, then the demand for land for recreation, forestry, and transportation also will increase.

There still is plenty of lightly used cultivable land in the developing countries, particularly in Latin America and Africa.[9] The appearance may be deceiving, however, given present knowledge about soil and other technical and economic conditions relevant to farming in those areas. In Africa, large areas of potential grazing land remain unusable because of tsetse fly infestation. The vast Amazon Basin frequently is cited as part of the unexploited agricultural land base of Latin America, but the crop potential of this region is

greatly exaggerated, given current agricultural technologies. Many of the soils in the region are of low fertility, and removal of the forest cover exposes the soil to the tropical sun and rains with seriously damaging results. Much of the region is far removed from existing population centers and is equipped with only a primitive transport network. Opening it to large-scale crop production would require substantial investments in transportation, storage, and other infrastructure.

There undoubtedly is considerable potential for expanding the world's cultivated area. However, it seems likely that the cost of land in the developing countries will rise over the next several decades in the absence of significant technological breakthroughs such as the elimination of the tsetse fly or ways to increase and maintain the fertility of tropical soils under continuous cropping in areas such as the Amazon Basin.

## Water

In the United States, the principal competitors of the food sector for water probably will be urbanization and energy development in the western states. In some of these states, urban growth has resulted in the transfer of water rights from agricultural to urban uses. Since continued urban growth in the region seems assured, additional transfers can be anticipated.

The transport of massive quantities of western coal as a slurry through pipelines to power stations, a concept now under consideration, would require large amounts of water presently used for irrigation. Coal gasification and the production of oil from shale are water-intensive activities also now being considered in the western states. Neither of these processes is presently competitive with natural gas or petroleum from conventional sources, but they could become so if the real prices of these sources should rise to the high end of the range of current projections or with breakthroughs in the technology of coal gasification and oil shale production.

Our discussion of energy stressed the relation of the price of energy to the cost of pump irrigation from groundwater.[10] The cost of water for irrigation in turn affects the price of land since dryland farming and irrigated farming are alternative uses of the land. These relations between the prices of energy, land, and water are important in the United States, particularly in the high plains where irrigation is by groundwater. These relations are of special concern in the developing countries because the continued spread in

those countries of the technology associated with the Green Revolution probably will require further increases in the irrigated area.

Urban (including industrial), transportation, and recreational activities also compete for water with the food sector, both in the United States and in the developing countries. These activities typically are not large consumers of water since most of the water they use is returned to streams. However, urban activities may seriously degrade water quality.

## ENVIRONMENT

Land, water, and air transmit effluents of the food and nonfood sectors. The quality of the environment depends upon the quantity and nature of these effluents.

If the demand for food exports rises significantly over the balance of this century, the most important single effluent from the U.S. food sector during this period probably will be soil washed from eroding farmland. Erosion clogs reservoirs, irrigation canals, and stream beds, thus reducing irrigation and electric-generating capacity and causing floods, and diminishes the productive capacity of the land if permitted to continue. A study by the Soil Conservation Service (Grant 1975) indicates that in the United States the high food prices of 1973-74 and the expansion of the harvested area from 116 million hectares in 1972 to 130 million hectares in 1974 led to significant increases in erosion. The high prices weakened farmers' incentives to maintain erosion control practices on already-cropped land or to adopt them on the newly cropped land.

Other sources of environmental damage from food sector activities appear to be of second or third order importance in the United States compared with erosion. Some of these sources of damage are:

-- Water pollution from feedlots and food processing plants. This is important in some areas but is expected to be brought under control by the mid-1980s.
-- Increasing salinity from irrigation return flows. The extent of damages is not clear. Given the increasing competition for water from the nonagricultural sector in the west, it is unlikely that the irrigated area in that region will expand, although the spread of salinity is not just a function of the spread of the irrigated area.
-- Fertilizers. There is evidence that nitrogen fertilizers, through complex chemical processes,

may damage the ozone shield. This threat results from fertilizer use worldwide, not just in the United States, and there is much debate about its seriousness. Nitrogen and phosphorus fertilizer also contribute to water pollution. A recent review of this problem by Crosson and Frederick (1977) suggests that prospective levels of use of these materials in the United States probably will not pose a major environmental threat.

-- Pesticide use. The severity of this threat is hard to determine because future levels of use are highly uncertain and because relatively little is known about how pesticides move through the environment and the damages they do to unintended targets. However, there are two encouraging aspects to trends in pesticide use: (1) the substitution of organophosphorous compounds for the persistent insecticides, mostly organochlorine compounds; and (2) an even sharper shift toward herbicides relative to insecticides (Andrilenas 1974) which has accompanied the shift toward organophosphorous compounds. A report by a commission of the Secretary of Health, Education, and Welfare (U.S. Department of Health, Education, and Welfare 1969:203) has asserted that "[h]erbicides as presently used do not present serious and widespread hazards to nontarget organisms. With few exceptions, most herbicides have a low order of toxicity to aquatic and terrestrial animals." This seems to be the consensus about the threat of herbicides to humans and animals (NRC 1975c). However, Oka and Pimentel (1976) indicate that herbicides may increase insect and disease damages to crops, thus increasing the need for heavier applications of insecticides and fungicides.

In the developing countries, the range of natural, economic, political, and institutional conditions is considerably wider than in the United States. The range of potentially significant environmental damages from food sector activities is correspondingly wider. The encroachment of the desert in sub-Sahara Africa has raised international concern. The effects of climate play a role in this process, but the fundamental cause is excessive grazing caused by too many animals and too many people employing primitive range management techniques. The phenomenon is found in parts of Asia and Latin America as well (Eckholm 1976).

The spread of schistosomiasis associated with the development of irrigation systems is of major concern, particularly in Africa, but also in Southeast Asia, northeast Brazil, and parts of the Caribbean.

Estimates of the number of people affected range from 125 to 200 million. While it has not been convincingly demonstrated that the disease seriously reduces the economic productivity of those who have it, it is sufficiently debilitating in many cases to suggest that productivity must be affected. Satisfactory growth of food production in the developing countries will require continued expansion of the irrigated area, at a rate perhaps of 1 percent per year. This suggests that schistosomiasis will continue to spread unless remedial measures, e.g., improved sanitary facilities in rural areas, are taken.

Present rates of fertilizer and pesticide consumption per hectare of cropped land in the developing countries are low. This consumption could grow by 8 to 10 percent annually for 15 or 20 years--enough to assure healthy, sustained increases in yield--before reaching the present consumption levels of the United States, Western Europe, and Japan. Use of these materials in these countries does not presently appear to pose major environmental threats.[11] Thus we conclude that in the developing countries fertilizer and pesticide pollution should not be a significant issue for at least another decade or so. The conclusion should be treated with caution, however. It rests on experience in temperate zone agriculture, and there is evidence that in tropical areas the undesired effects of given doses of fertilizer and pesticides, particularly the latter, may be greater than in temperate zones. For example, a significant problem with insecticides is the build-up of insect resistance. In tropical areas many insects breed faster than in temperate zones, increasing the rate of development of insect resistance.

It now appears that in the developing countries, as in the United States, erosion damages may pose the most important single threat from food sector activities. The problem is particularly severe in areas such as the Himalayan foothills, inhabited parts of the Andes, and mountainous regions of East Africa where population pressure has led to the deforestation of mountain slopes to clear land for crops, to feed animals, and to collect wood for fuel. Quantitative estimates of the amounts of erosion in these areas or the damages resulting from it are not available, but Eckholm (1976) has compiled impressive anecdotal evidence indicating that the problem is widespread and the damages severe.

Given prospective rates of increase of population in rural areas of the developing countries, the erosion problem is sure to get worse unless there are significant changes in cultural practices, in institutions for managing agricultural and forest lands, and in conditions of availability of fuel for

home use. Contour plowing, terracing, strip cropping, and mulching are proven techniques for erosion control. Minimum tillage also holds high promise as a technological alternative (Greenland 1975, Jacobs and Timmons 1974). It appears economically attractive under a wide variety of conditions, including those found in the developing countries. Whether this technique could be widely employed in the mountainous areas now suffering most from erosion is uncertain.

Since one of the main causes of erosion in mountainous regions is the cutting of trees for fuel, the problem will be difficult to solve unless rural families have access to alternative fuels on terms at least as good as those for trees. The use of biomass to generate methane gas appears to be among the more promising alternatives at present. Methane generation can be based on all biological materials encountered in nature except, apparently, mature wood (Makhijani 1975:101). Hence development and spread of the process on favorable terms would reduce the pressure for deforestation. There is a qualification, however. Crop residues and animal dung currently are the principal sources of biomass. Crop residues left in the soil also play a role in reducing erosion. Conceivably the spread of biogasification could strip these protective residues from the land, thereby substituting one source of erosion for another.

It now appears that effluents of nonfood sector activities will have relatively small effects on the quality of the land, water, and air used by the food sector. Air pollution from urban and industrial activities damages crops in some parts of the United States, although the value of crop losses is small relative to total crop production (Heck 1973:124, USDA 1974b:550). With continued progress in cleaning up the air, this problem is not likely to become serious. Air pollution from urban-industrial activities may, over the long run, affect the global climate, with possible adverse effects on agriculture. However, this is not likely to be significant in the next decade or perhaps for several decades (Sterling Forest Conference 1974).

In the developing countries water polluted by urban-industrial wastes frequently is used for irrigation, sometimes causing public health problems. While the problems are serious in some places and may become more so, their solution does not require research but investment in sewage treatment facilities.

Report of Subgroup C, Study Team 10

# INTERNATIONAL TRADE POLICY AND COMITY OF NATIONS

# INTRODUCTION

We were asked to consider desirable changes over the next several decades in global production and trade for major commodities and for agricultural inputs, and to assess their implications for U.S. research and development strategy as well as for overall foreign relations.

We accepted as valid the numerous studies available on the projected food supply-demand imbalances for the developing countries as a whole, for regions, and for individual countries. We also assumed that the projected "food gap" would have to be closed by some combination of:

-- Accelerating the rate of growth of indigenous agricultural output which would entail among other things large imports of agricultural inputs, expanded transfers of economic resource, and increased agricultural development assistance.
-- Sustained transfers of basic foods on concessional terms to food-deficit countries which do not have the ability either to expand indigenous output rapidly enough or to finance adequate commercial purchases from international food markets.
-- Expanded commercial purchases from world food markets.

We paid particular attention to the third method because we believe that increased reliance on the trading system could lead to a more efficient use of world agricultural resources. It would avoid encouraging some developing countries to follow food supply policies that are inappropriate to their resource endowments, as would be the case if exclusive emphasis were placed on increasing self-sufficiency. However, the trade option would require multidimensional national and international policy changes and would have important impacts on other approaches to the global attack on hunger. U.S. leadership or concurrence would be required which would entail changes in U.S. domestic economic programs and

foreign economic policies. This would have beneficial effects on some U.S. industries and adverse affects on others.

Expanded research in this area could clarify policy choices and improve national and multilateral decision making. More importantly, it could greatly increase the effectiveness of the methods used to solve the problem of world hunger. We sought to identify interdependencies and priority research needs by addressing the following questions: What factors are crucial for the developing countries in determining their choice between greater reliance on external sources of foods, production requisites, and technologies as opposed to increasing self-sufficiency? What changes in trade and trade-related policies are required to foster the trade option? What would be the major effects of implementing such policies? What interdependencies between trade and other issues are being considered in the World Food and Nutrition Study?

## COMMERCIAL FOOD TRADE

The food supply policies of governments of the developing countries are inextricably interwoven with their more general development strategies. The choice between expanding indigenous food production or expanding food imports has to be judged in terms not only of a more adequate and reliable food supply but also the effect on other national goals such as economic growth, internal price stability, and external payments balance.

Domestic income and employment goals, balance of payments constraints, and the political uncertainty associated with heavy dependence upon imported food supplies will lead most developing countries to develop domestic food production to the maximum economic levels. However, the use of trade can allow greater specialization of resources and thus increase food availability.

It is appropriate for the developing countries to rely on the trading system to meet part of expanded food requirements when the opportunity costs of so doing, in terms of achieving general economic development, agricultural development, and food supply goals, are lower than those for expanding indigenous food production. This will be determined in large part by the international distribution of comparative advantage, which in turn is a function of resource endowments, inherited economic structures, and ability to redeploy domestic resources to take advantage of international trade opportunities. The ability of the developing countries to exploit their inherent

comparative advantage also is constrained by the policies of other countries which frustrate and distort international competition.

Even if tariff and nontariff trade barriers were lowered, there is a question as to whether trade liberalization alone would increase foreign exchange earnings enough to enable the food-deficit developing countries to purchase significantly greater quantities of foreign-produced foods, to meet expanded requirements for other essential imports, and to service and retire external debts. Many develcping countries believe that freer trade, while important, would not increase foreign exchange earnings enough to support the increased imports that would be associated with the accelerated rates of economic development to which they aspire. Accordingly, they are seeking more far-reaching changes in international economic systems that would redistribute income between rich and poor countries.

Even if expanding food imports were ostensibly the best use to which the developing countries could put additional foreign exchange earnings, their willingness to do so would be affected by the risks of increased dependence on external food supply sources. These include the following:

-- Uncertainty about the long-run production capacity, export availability, and supply price of Western grains and other basic food stuffs.
-- The high probability of sharp variations of prices in world food markets due to variations in output, export demand, and government policies in the high-income countries over which the developing countries have no control.
-- The danger that foreign exchange availability might be inadequate in the short run due to fluctuations in capital inflows, variations in demand, supply and price of exports of commodities and other products, or interrupted access to foreign markets for such products.
-- The risk that access to foreign food supplies might be denied as a form of political pressure.

## POLICY RESPONSES

Contemporary international economic policy addresses these issues. Trade reform would enable the developing countries to increase their foreign exchange earnings and thereby expand their capacity to purchase foods from foreign sources. Simultaneously, measures are being explored to enhance the stability of international food markets and thereby reduce the

discount factor which developing countries must presently apply to the food trade option.

Two broad approaches to trade reform are being pursued. The first aims to foster international specialization and improve the developing countries' access to foreign markets by lowering barriers to trade in agricultural and nonagricultural products of export interest to the developing countries. This is being pursued in the current General Agreement on Tariffs and Trade (GATT) negotiations. Second, within the U.N. framework, and under the rubric of creating a "new international economic order," the developing countries are seeking much more radical changes in international economic systems which would accelerate their economic development and yield larger and more stable foreign exchange earnings from commodity exports than they expect from trade liberalization. International commodity policy is a key element of the proposed new economic order. A "reformed" system of commodity trade would involve programs to stabilize international markets and to transfer income from the high-income to the developing countries. The programs would include:

-- improved access to markets in the high-income countries;
-- multilateral agreements on the management of product pricing and exchange of a wide range of commodities that would have the effect of raising their unit prices and gross receipts;
-- tying commodity prices to an index of import prices to protect their real values against inflation and other monetary perturbations;
-- international compensatory financial arrangements to stabilize receipts from commodity exports;
-- intergovernmental contractual supply and purchase commitments;
-- progressive transfer of agricultural processing activities to the developing countries.

A number of initiatives in international trade policy are directed toward reducing instabilities in international food markets and thereby enhancing the attractiveness of the trade option to the developing countries. First, those elements of international commodity policy listed above aimed at stabilizing the developing countries' foreign exchange earnings have an obvious bearing on the developing countries' ability to sustain a larger volume of food imports. Second, negotiations are in process that would use international codes to constrain national governments from destabilizing international food markets by unilaterally restricting access to supplies. Third, successful negotiations to liberalize trade in

agricultural products would result in adjustments of prices and consumption to shortages being spread more widely, instead of being concentrated in the international markets from which the developing countries must now buy. Fourth, negotiations are being conducted on specific proposals to stabilize the all-important international market for grains by establishing a system of international grain reserves and by concluding an international commodity agreement for wheat, and possibly for all the major grains.

## INTERDEPENDENCIES

It is apparent from the foregoing that the desirability, willingness, and ability of the developing countries to use international markets to satisfy some part of their rising food needs depend on a wide range of internal considerations, economic trends in world food markets, and policy decisions affecting world economic systems. The degree to which they use the trade option has important implications for internal development, the priorities of nations providing food assistance, policies of the international community, and the market situation in countries that are net exporters of foodstuffs.

From the viewpoint of the developing countries, the major influences on world food markets, i.e., the factors that determine price and availability of supplies, stem primarily from agricultural and food trade policies of the high-income countries. The attractiveness of the trade option to the developing countries would depend directly on the willingness of the high-income countries to make appropriate changes in trade and agricultural policies such as acceptance of increased imports, grains stocking arrangements, export management practices, and bilateral and multilateral trade agreements.

Some elements of general trade and international commodity policy favored by the developing countries are consistent with U.S. trade principles and interests, for example, broad moves to lower trade barriers and improve compensatory finance arrangements. Others, however, are in conflict with U.S. goals, including measures to raise and stabilize the developing countries' foreign exchange earnings by detailed management of international commodity production, pricing, and trade through multilateral agreements. Some sectors of the U.S. food and agricultural system would gain from an enhanced ability of the developing countries to use the world market (e.g., grain producers), while other sectors, which presently enjoy effective protection from developing

country exports, would be disadvantaged by trade liberalization. And, of course, U.S. agriculture would be affected by the creation of a global regulatory system for commodities.

The central issue is the extent to which the United States should encourage increased self-sufficiency in food for the developing countries or concentrate efforts on strengthening international trading systems to enhance the developing countries' ability to satisfy part of their rising food needs from world markets. That is to say, there is a direct and crucially important interdependency and some degree of choice between agricultural development assistance and trade policy initiatives. The effects of encouraging autarkic food policies would be markedly different from promoting international exchanges in terms of the international distribution of production and income, trade flows in food products, production requisites, and internal income distribution, employment, and degree of urbanization within the developing countries. And there would be differential effects within the agricultural sectors of the developing countries in terms of product mix, employment, income levels and distribution, and use of inputs.

Reducing trade barriers to exports from developing countries would create expanded market opportunities for the developing country exporters. Exploiting these opportunities, however, would demand agile international merchandizing and the ability to meet foreign health and sanitary regulations, grading, labeling, and packaging standards, etc. Assistance programs for exporters would be needed to complement trade liberalization policies.

In some developing countries, multinational corporations are an important influence on agricultural production, processing, and export marketing. This factor cannot be ignored in assessing the response to expanded trade opportunities in terms of resource use, income distribution, ability to diversify vertically into processing, and ability to supply and service foreign markets.

As indicated above, international policy also must be concerned with reducing risks to the developing countries of increased dependence on commercial food markets. They would have to be assured that they would not face a rapidly rising supply price for imported foods resulting from the failure of exporting countries to increase agricultural productivity. On the other hand, exporters of grains and other foodstuffs who gear up their production capacity are vulnerable since indigenous output of the developing countries fluctuates widely. Consequently, agricultural assistance programs designed to stabilize food output

from the developing countries would be needed. Both the high-income and developing countries would face uncertainties about resource reallocations which might stem from greater stability in prices and earnings.

## CONCESSIONAL FOOD SUPPLIES

Some developing countries will be dependent upon food aid for a long time. This raises a number of questions involving interdependencies:

-- Will future food aid represent additional resource transfers now that its motivation is no longer surplus disposal?
-- What are the benefit-cost ratios of food aid versus other resource transfers (including balance of payments support)? The opportunity costs of concessional grain supplies have risen, forcing donor countries to choose among alternative ways of helping to alleviate hunger in the developing countries.
-- Can food aid be supplied in such a way that recipient countries will maintain the price incentives needed to encourage local food production and will not place lower priorities on agricultural production? Should food aid be made conditional upon increased investments in agricultural and rural development and population control, and if so, how might this best be accomplished?
-- What are the output, price, and income effects of variations in the level of food aid programs on commodity groups in donor countries?
-- What changes are required in the administration of food aid programs to ensure that malnourished groups in the developing countries are reached, including the rural poor?
-- How can equitable formulas for sharing the costs of providing food aid be incorporated in multilateral agreements between donor countries? How would the apportionment of such costs affect commercial market opportunities for the grain exporters in the high-income countries?
-- Would national or multilateral grain reserves lower the cost of meeting food aid commitments to consumers in donor countries and thereby strengthen the political acceptability and continuity of such programs?
-- In the absence of specific stocks policies and adequate grain inventories, is there a danger that meeting commitments under a series of bilateral commercial grain supply and purchase agreements

among the high-income countries will periodically jeopardize the availability of concessional food supplies to the developing countries?

## TRADE INPUTS AND THE TRANSFER OF TECHNOLOGY

These two issues are linked. There is no sense in developing and/or transferring technology without assuring the availability of complementary inputs on reasonable terms.

Many of the interdependencies of the import sector are similar to those of the food trade sector. For instance, the opportunity costs to the developing countries of developing indigenous supplies and manufacturing capability rather than relying on trade are important but are poorly understood. The risk of dislocations in external supplies due to market fluctuations or to the actions of national governments or exporter cartels affect the developing countries' choice between self-supply and reliance on trade.

The developing countries are, and will remain, highly dependent on imported supplies of key agricultural inputs, notably fuels, fertilizers, and pesticides. However, the resource costs, value, terms, and impacts of concessional supplies of inputs have received less attention than in the case of food aid.

A number of other interdependencies are particularly important in the area of input supplies. Environmental policies in the high-income countries affect the availability of inputs to the developing countries. One example is banning the use of "broad spectrum" insecticides which increased pesticide costs to the developing countries.

The potential contribution of private Western agribusiness firms to agricultural development in the developing countries in the supply of inputs is considerable: this may be impeded, however, by a hostile environment to foreign direct investment. Attempts being explored in the intergovernmental organizations to devise means of "unpackaging" technology, management, and ownership have relevance to the supply of agricultural inputs in the developing countries.

The developing countries want access to Western technology on easier terms--one of the explicit goals of the proposed new international economic order. In general, their access to Western agricultural technology is not impeded. Indeed, much of agricultural development assistance is concerned with the development, transfer, and adaptation of agricultural and food technologies suited to their needs. However, private "property rights" embodied in

patents and licenses and the policies of transnational corporations may be a constraint on their access to useful technologies in such areas as plant varieties and in the use of processes for manufacturing some inputs and processing raw products.

Much of the technology produced to meet conditions in the developing countries is financed by public funds of the high-income countries. Export of technology constitutes a transfer of comparative advantage. We know little about the impact of this on international competition. But there is a continuing risk to the developing countries that the flow of such technology will be interrupted by political pressure from producers of competitive products in the high-income countries.

## Profile 1

## FOOD SUPPLY, TRADE, AND COMMODITY MANAGEMENT

Most developing countries are strongly motivated to increase their self-sufficiency in basic foodstuffs. These motivations include domestic income and employment goals, balance-of-payments problems, and political concerns about excessive dependence upon outside sources for basic foods.

At the same time, the developing countries are pressing for trade liberalization and preferences for their exports to the high-income countries. This would, if achieved, have different effects upon the export earnings for different countries and potentially affect the comparative advantage for domestic production.

Concurrently, there are substantial pressures for managing international trade in key commodities, including agricultural and food products. Such schemes could have a marked effect upon the functioning of world trade and upon the willingness and ability of the developing countries to use imports as a source of food supply.

Even though all these issues are important, too little is known about some of the fundamental relationships involved in such issues to permit sound decisions on the necessary policy variables. The answers to these fundamental questions are lacking:

-- What are the costs of alternative sources of food supplies, i.e., domestic production, commercial imports with and without stabilized commodity markets, and potential bilateral and multilateral concessionary food aid?
-- To what extent and for which countries would a substantial liberalization of trade in basic foodstuffs substantially enhance their ability to earn foreign exchange and thus their ability to import the necessary food via commercial channels?
-- To what extent will the continuing quest for managed internal commodity markets enhance or

reduce the ability of the developing countries to use food imports as a source of their basic foods?

These issues become inextricably intertwined in decisions faced by U.S. policymakers as well as policymakers in the developing countries. They involve the proper emphasis for U.S. financial and technical assistance in agricultural development, the size and use of food aid, U.S. negotiations on trade liberalization, U.S. discussions on commodity management programs, and U.S. discussions on international grain reserves.

Policymakers in the developing countries find the issues equally important. Their basic development strategy and priorities for external assistance and international negotiations rest upon greater knowledge of some of these fundamental issues.

## RESEARCH NEEDS

Many related research issues are involved which must be dealt with in some integrated fashion in the planning and execution of the research, although it does not necessarily follow that all of the research needs to be done in one location.

Research on the prospective costs and implications of alternative levels of domestic food production should be done in collaboration with developing country researchers familiar with local resource bases, technology, and constraints. Research on the implication of trade liberalization and alternative forms of managed commodity trade should be done in close collaboration with GATT, the U.N. Conference on Trade and Development (UNCTAD), and World Bank personnel already working on related matters.

Given the nature of the issues and working relations involved, this research probably could not be organized by U.S. universities. The fact that the Economic Research Service (ERS) of the U.S. Department of Agriculture provides policy analysis for one of the major governments involved might hamper its working relations and would likely make its research results suspect.

The most likely place for such a research effort would be within a collaborative research effort involving several of the international agricultural research centers. The technically oriented centers such as the International Rice Research Institute (IRRI), the International Maize and Wheat Improvement Center (CIMMYT), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), etc., have the competence and ties to develop research on the

costs of domestic production in the developing countries. A policy-oriented center such as the International Food Policy Research Institute (IFPRI) has the competence and working relations to work on the issues of trade liberalization and management of commodity trade. All of these institutions could and should draw upon competent individuals and institutions in both the United States and abroad for specific subsets of the research program.

The alternative model would be to develop and fund a new research group on development and food trade issues. This would appear feasible but duplicative and more costly than the alternative suggested above.

## IMPACT

The benefits to the United States of this research effort would be high both in planning its financial, technical, and food aid and in having developing country policymakers better informed as to the costs and benefits of different options they might consider.

## IMPLEMENTATION

This research would require an international research team comprised of at least 10 senior scientists as a core team working for five years with perhaps twice that many individuals in national institutions for a shorter period. The appropriate international centers should participate in this effort. Some 50 scientist-years plus research assistants and computer time would be needed. This would cost an estimated $3.5 million.

The research should be done at various existing national and international institutions. No new organizations need to be formed; however, careful organization and planning would be needed to execute the research program.

Report of Subgroup D, Study Team 10

# NATIONAL DEVELOPMENT POLICIES

# INTRODUCTION

This report concentrates on several important interactions between food/nutrition policy and national development policy. Before dealing with them, however, we should emphasize a more general relationship: the pivotal role agriculture should play in almost any broadly based development program, the exceptions being countries with unusual economies like the city-states of Hong Kong and Singapore or the small oil states.

This role has been increasingly recognized during the last decade or so as strategies emphasizing industry or mining while neglecting agriculture have often produced disappointing results in terms of growth rates, employment, and income distribution. In many countries, food output has failed to keep pace with population growth, and in some, food consumption per capita appears to have fallen. The burden on agriculture is lightened where population growth can be curtailed. But dramatic declines in population rates cannot be expected in the near future.

Given the prior importance of agriculture and food production in overall development, careful planning in its growth must be viewed as the first item of business in effective overall planning. To successfully advance agriculture may or may not require a high share of a country's human and capital resources; however, it does require the sort of priority that assures it of the resources needed. And a serious attempt to emphasize agriculture calls for an overall development strategy that supports rather than competes with the steps directly or obviously related to agricultural development. For example, heavy taxing of agricultural exports or imports substitution which substantially raises the price of agricultural inputs may work against positive steps taken in agricultural policy itself.

For agriculture (and food, in particular)[12] to contribute significantly to development, a number of institutional factors often must be overcome. Although less in vogue than before, the concept of the development process as involving mainly

industrialization still persists. Such a concept proceeds incorrectly from the empirical fact that industry and other nonagricultural sectors generally grow faster than agriculture in successfully developing countries. This leads to the conclusion that agricultural growth is not of key importance in development. Agriculture is seldom a "prestige" sector--sometimes it is assumed that it can simply take care of itself. But in fact, agricultural development must to a large extent be a public responsibility. This contrasts with the industrial sector since successful development of agriculture probably requires more careful policy, more substantial involvement, and more resources than does industry. If not strongly emphasized, agriculture tends to receive neither the resources nor the attention needed. Those resources needed include public sector funds, highly qualified human resources from the public sector, and foreign exchange. When agriculture does receive due emphasis, we are optimistic that food production can be increased in most developing countries.

The fact that agriculture warrants significantly higher priority in most of the developing countries does not mean that they should or will remain agricultural economies in the future. Development normally results in a decreasing share of output and employment in the agricultural sector as productivity rises and the composition of demand shifts toward less necessary items with basic food needs being satisfied.[13] Emphasis on agriculture is not designed to reverse these trends but rather to make agriculture more productive precisely so that more resources can eventually be allocated elsewhere, with higher incomes through higher productivity creating the demand for nonagricultural goods.

When all goes well, the agricultural emphasis we argue for can be viewed as an interim step along the development route. But if this step is not taken, the economy may not move to the next level of development. Ironically, some countries that have neglected agriculture the most remain the most highly agricultural in terms of the share of the labor force found in that sector.

To emphasize the need for agricultural production is not to deny the economic validity of normal trends characterizing the development process.[14] Rather it is to suggest that in many countries too few of certain resources (especially public sector ones) are found in agriculture relative to the country's current level of development, or that the resources found there are used too inefficiently. This calls for a temporary increase in the share of such resources being applied in agriculture.

Successful development implies a fairly small share of the labor force in agriculture, and a somewhat smaller share in food production. How small these shares become and how similar the developing country production and consumption policies will be in relation to current patterns in Europe and North America will depend on the future resources/person ratio of the developing countries. Population growth will be a key negative factor. Technological improvements that raise land productivity will be important. Future prices and availability of other resources, especially fertilizer, water, and energy, also will affect these developments.

These arguments are quite consistent with the proposition that international trade in food products can and should contribute more to welfare, nutrition, and overall development in the developing countries than it now does. The allocation of more resources to agriculture will create export potential. Increasing overall self-sufficiency in food will be efficient for many developing countries because the returns to investment (especially public) in agriculture are high. In the longer run this will be less uniformly true; increasing interdependence and food trade are keys to an efficient world agriculture.

## MAJOR INTERACTIONS

### Decentralization and Planning Procedures

Agriculture in most countries is carried out by many small producers dispersed over a wide range of ecological and economic situations. Taxing or raising resources in agriculture is difficult unless the funds are put to uses that the farmers feel are worthwhile. For both reasons, an efficient, flexible public sector involvement in agriculture requires decentralizing various aspects of agriculture- and nonagriculture-related policy to increase the local contributions to development. It is important to take the fullest advantage of local savings potential for both public and private investment in the rural economy. Investment in local infrastructure is likely to be both greater and more effectively chosen if funds are generated locally and the community is involved in the spending decisions.

In most countries, local decision making, taxing, and spending have been quite limited. Developing institutional frameworks within which communities can organize their efforts and resources, together with those supplied from the outside (e.g., certain types of technical skills lacking in the community), should be a

priority of most governments of the developing countries. Much can be learned by some of the success stories, such as the Comilla project in Pakistan, but much more thought and probably considerable experimentation will be necessary to find the best form for each country or region. Here, perhaps more than for the other major foci of a good agricultural strategy, adequate understanding of political and cultural dimensions will be the key to success.

Making good use of local expertise and knowledge may be as important as generating resources locally. Serious errors are inevitable in allocating development efforts when the decision maker does not know the region. Much of the secret of successful mobilizing both local knowledge and resources revolves around the right kind of leadership--the knowledgeable, respected, responsible local leader.

To be effective in terms of agricultural development, decentralization must involve a town/country dimension. It is not enough for localities to acquire substantial taxing/spending autonomy if each is dominated by a town or city whose interests are emphasized in planning and investment. Farmers and persons linked to agriculture must have institutional channels whereby they can channel their own funds into what they consider productive uses and can present requests for additional funds from higher levels of government.

Decision making should be lodged at the lowest level at which a reasonable combination of community interests and available decision-making skills is found and where no substantial externalities exist. In some countries, there are only two major levels of government; in others, three or even more. In many countries, decision-making power is highly concentrated at the central government level. In others (e.g., India), states are powerful and the decentralization encouraged here would involve transferring some authority from that level to a lower one. In recent years a number of countries have altered their administrative structures to locate more authority at the lower levels of government. Such shifts are not likely to be cure-alls, of course. Frequently, local control comes into conflict with equity as local vested interests are either more conservative or in a better position to direct public resources in their own direction than are national vested interests (vis-a-vis national policy). However, this is not always the case; it depends in part on the regional distribution of income and influence. And some types of policymaking--trade and price policy, for example--will remain the responsibility of the central government.

When more than one level of government has significant decision-making power, some friction will normally arise. Frequently, the different types or qualities of personnel employed within each level will create certain imbalances. Such tendencies must be taken into account in the design of government hierarchies and/or in the assignment of responsibilities by level. In most developing countries high quality decision-making skills will remain scarce for the time being, but gradual improvement is found in many countries and can be expected to continue as the relatively heavy emphasis on education of the last decade makes itself felt. This trend should increase the attractiveness of decentralized decision making since many skills tend first to be concentrated at the government level and to become widely dispersed only when their supply is enlarged.

When regional or local planning activities are an offshoot of central or national government planning, they are often conceived of as a scaled-down version of the latter. In fact, local planning is quite different; it involves investment decisions and regulations toward which fairly basic concepts of benefit-cost analysis, accounting, and management are necessary ingredients as contrasted to the higher degree of academic analysis used in national planning.

Successful national agricultural policies depend upon inputs of local information and preferences, and of local funds where possible (e.g., via matching fund arrangements). Many policies should have a spatial dimension since their application should vary according to local circumstances.

## Protection, Industrialization, and Price Policy

Allocating first priority to agriculture and food production in a country is likely to imply some reduction of public sector resources available to develop other sectors, such as manufacturing. At the same time, complementarities between agricultural and industrial growth imply modifications within the industrial strategy according to how agriculture will develop. Different country situations and different ways in which agriculture may grow call for different infusions of capital, public sector human resources, imports, etc. Often the need for private capital and imports will be moderate so that supplies of these resources to other sectors will not be affected much.[15]

Agricultural growth usually implies rising income and purchasing power in rural areas and small towns.

The consumer goods purchased will be fairly simple, low-cost items rather than expensive imports. There will be rising needs for implements, repairs, and other inputs to agricultural production. In general, such growth will create a basis for a more dispersed and smaller scale industrial sector than would otherwise evolve. This should, in turn, receive such public reinforcement as is needed to aid its growth (technical assistance, access to inputs, improved transportation and communications, appropriate trade policies, etc.).

Dispersed industry, commerce, etc. also may facilitate use of rural labor by permitting persons to divide their time between farming and other activities. The need for long-distance migration of families to find adequate employment would diminish.

Small-scale industry can be and often is at least as efficient as larger scale production. Economies of agglomeration in large cities often have been exaggerated; they refer mainly to capital-intensive types of industry whose desirability in the developing countries is doubtful. Even large cities favored in various ways by public policy are not growing much if any faster than towns and smaller cities. This suggests that the latter are by no means devoid of economic advantages. "Market towns,"[16]--centers larger than the village but smaller than medium-sized cities--have an important role to play in broadly based growth. They are less energy-intensive than large cities and require less infrastructure on a per capita basis. In summary, the industrial policy that would best complement a strong agricultural program would probably be more efficient per se than the capital-intensive policies still in vogue in many countries.

Heavy protection of capital-intensive industry must be viewed with caution in the context of a "priority to agriculture" strategy. Industry's tendency to concentrate in larger cities, its heavy use of capital and of imports, and its tendency to raise the price of manufactured inputs could all argue against such a strategy. The insatiable capital requirements of such industry frequently lead to the starving of other sectors, including agriculture.[17] Emphasis on agriculture often leads to food exports, provided that foreign exchange policy does not create disincentives, e.g., via an overvalued exchange rate. Such exports thus require that overall policy not be geared too exclusively to import substitution.

Incentives for agricultural production depend in part on the prices of agricultural goods, which is related to the protection given manufacturing and agricultural products and to the influence of national price policy on agricultural outputs and inputs. Price controls are often placed on food items because of

their importance in the budget of the urban poor. These controls can be counterproductive by discouraging output. Price supports are desirable when they can be implemented effectively, and can contribute to making price controls less necessary.

A carefully worked out food supply system, with inventory management the key to price stability, is a priority need in many developing countries (see below, "Food Buffers and Food Aid"). On the input side, it is usually hard to defend underpricing of capital or overpricing of inputs like fertilizer. Subsidies for an input like fertilizer may help to spread its productive use, and may be viewed as an acceptable way by which the government may share risks with farmers. However, any subsidy brings dangers of shortages, unequal access among different farmers, etc., and unless the arguments in favor of it are strong, it may be wise to avoid such intervention.

## Food Policy and Income Distribution

Inadequate nutrition in poor countries results from inadequate overall availability of food, unequal distribution of income, and probably to a lesser degree, a lack of knowledge about nutrition.[18] In many countries where a quarter to a half of the population does not eat well, the total supply of food is actually or potentially adequate, so that the main problem is income distribution. Elsewhere, low average income is the major problem. In many countries, national development policy during the last decade has begun to address improved distribution as a policy objective.

Food consumption and income distribution interact in several ways. First, the major rationale for pushing food production is to raise food consumption to adequate levels. Since families suffering chronic food shortages are poor families, resolution of that problem to a large extent lies in a program that will alleviate poverty. However, raising production does not automatically increase the consumption of the poor. Inadequate food consumption will be alleviated only to the extent that (1) the poor are food producers, participating in the output increases; or (2) food prices are pushed down so the poor who are not producers can buy more. Increases in production due to the use of labor-saving technology and decreased employment should not be expected to decrease malnutrition.

If there is a price elastic demand in the international market for a country's food products (more likely true for small producers than for large ones), domestic prices may not be much decreased as

output rises, unless policy intervenes to block exports or subsidized domestic consumption. The relation between farmgate prices and income distribution depends on the country. In many developing countries, most of the poorer families are farmers and holding down the prices they receive by policy intervention is likely to worsen income distribution. Export taxes would have this effect when the potential exports are produced by low-income farmers. Dumping by large countries, which destroys the export markets of small ones, has a similar effect; one contribution that the high-income countries can make is to refrain from such acts. (For a detailed discussion of this and other aspects of international trade and its relation to food supplies, see the report of Subgroup C.)

In some countries, a high share of the poor are food buyers rather than sellers, i.e., either landless workers in agricultural or nonagricultural families. High food prices, therefore, are then more likely to worsen distribution, at least in the short run.

From all this we see that the relation between increases in production and improvements in nutrition may vary widely from country to country and careful attention must be given to the structure of a given economy before valid predictions can be made or adequate policy designed.

Second, if the incomes of poor families are raised through a redistribution policy, their demand for food will rise more than the demand of richer people will fall; in other words, an improvement in income distribution will raise food needs as expressed in the market. A well-planned redistribution should predict this shift in demand and prepare for it accordingly.

Third, cognizance should be taken of the different impacts that various policies to accelerate food production may have on income distribution. Such impacts may vary widely across policy alternatives. Widespread concern has been voiced about the strategy of mechanizing large farms, on the grounds that it will lower the demand for labor and that most of the gains will accrue to those already rich. Biological improvements are generally accepted because they raise the demand for hired labor and create the possibility that much of the gains in output will take place on small farms, i.e., go to less well-off families.

In some countries, the optimal policy for raising food production also may be beneficial for improving income distribution. Where small farms can start with higher land and total factor productivity than large ones, where they can adopt new efficient technologies about as well, and where they can be "commercial" in the sense of being tied into markets for their products, a set of policies focusing on them (e.g.,

land redistribution, small farmer credit, research relevant to small farm products) may constitute good growth and good distribution strategies. However, these conditions are not typical, and in some cases political obstacles may rule out certain elements of such a strategy, especially the land redistribution. In other cases, more potential may be seen for the technological improvements that do not use labor. Some of the poorer farmers may be so removed from the market that it is hard to improve their situation much in the short run. Overall, it seems fair to say that in the past in many countries there has been a bias in favor of improvements that help larger farmers more than smaller ones, and that tend to be labor-displacing. This bias is reinforced both by the political power of larger farmers and the general presumption that larger productive units are more efficient.

In contrast to the introduction of large machines, the biological improvements that came from the Green Revolution create a much more even potential across farm sizes and tend to raise the demand for labor. Even here the impact on incomes (especially in the short run) frequently has been greater for better-off farmers. This is often due to better access to credit and inputs as a result of public policy. But even when large farms increase their incomes more than small ones, their social efficiency may remain lower if they still have less land or land and capital productivity than do small farmers. One of the so-called stylized facts about agriculture in the developing countries is the greater land productivity on small farms, even after the Green Revolution (e.g., India, Taiwan, etc.).

Fourth, some short-run poverty alleviation policies may worsen poverty in the longer run, and some policies that contribute little to the poor in the short run may be highly beneficial to them in the longer run. This may lead to fast growth and the sort of structural change that eventually makes labor scarce. For example, small farmer credit used to raise consumption without expectation of repayment may worsen poverty in the longer run if it creates an atmosphere in which subsequent credit flows become infeasible. Some policies which appear to have positive distributional effects may be counterproductive even in the short run. Thus subsidy policies, even when allegedly directed toward low-income groups, may harm them by lowering total supply while not increasing the relative access of these groups. Some groups may be very hard to help in the short run (e.g., remote subsistence farmers on poor land), and they may be better helped in the long run by the promotion of agriculture or other activites in more regions to which they will eventually migrate.

Any successful attack on poverty must lean mostly on increased production.[19] Modest attempts to impose distribution may help (e.g., increasing taxes on some groups to provide transfers or other benefits to necessarily rather small target groups), but caution must be exercised. When a country's average surplus above subsistence is small, malnutrition could probably be avoided only by an extremely efficient set of redistribution policies, with almost no disincentive effects, top-notch administration, etc. Our present understanding of income distribution is inadequate to design such policies, and administrative resources would almost certainly be inadequate to carry out such policies once designed. We must continue to study trends in distribution, the impact of output growth on it, and ways to transfer income and food efficiently.

Fifth, a program of minimum feasible needs may make a useful contribution to the solution of the poverty problem. It should concentrate on assuring that as few people as possible slip below a selected modest standard of food consumption. These approaches run little risk of creating production disincentives when well planned and executed.

## Food Buffers and Food Aid

Part of the general food problem results from fluctuations in food supply due to the natural uncertainty of agricultural production, to instability in international food markets, and to inadequate internal food distribution systems. Fluctuations in supply imply a need for stocks and, in many countries, a public policy on stocks. To design effective national policies on food inventories and distribution, one must analyze internal and world supply and price fluctuations.

The welfare problems created by fluctuations in food prices and supplies fall with special severity on the poor, who spend a greater share of their income on food and find it extremely difficult to store food on their own as a precaution. When the urban poor are affected by food shortages, they create political problems in a rather direct fashion, and therefore an incentive for government action. That incentive must be complemented by good planning to ensure that the necessary food is available. During a food shortage crisis, food distribution must not be limited only to cities. Otherwise, crises will constitute a further attraction for pulling people into the city, possibly diminishing the country's potential for food production.

The development of rural food distribution systems is of obvious importance from a welfare point of view. In many countries landless farm workers are among the poorest groups. In bad years, poorer farm operators themselves may need help. Unfortunately, some systems essentially collect food by force if necessary from the rural areas--including some poor families--and make it available in the cities. They reflect all too fully the relative political power of urban and rural dwellers. Yet past experience (e.g., in the great Bihar famine) indicates that public food distribution can be done in rural areas; the technical problems are not at all insurmountable. In some countries, an important contribution to the smoothing of supply fluctuations would be investment in and technical assistance to rural storage systems.

Apart from their direct welfare implications, fluctuations in food supplies can be quite disruptive of development efforts. They often lead to short-run, stop-go policies on imports, prices, agricultural production, etc. These are usually inefficient per se; perhaps worse, they preclude the careful thought and design necessary for policies with long-run payoffs.

International food aid can help alleviate periodic food shortages as well as promote employment and labor-intensive investment. Since this form of aid is at present politically easier to provide than aid in money, its greater use warrants consideration. This aid could act as a disincentive to local food production, but when it contributes to buffers for use in shortages or to other uses which do not significantly reduce normal demand, these side effects should be small. By contributing to the stability of food supplies, aid can contribute to the stability of overall development policy, providing developing county governments with an additional degree of freedom in their planning. And it can help reduce the incentive of such governments to extract as much food as possible from rural areas in times of shortage. Although food aid may be used mostly in urban areas, it also may have an effect on food consumption in rural areas. In short, we feel that these aspects of food distribution are important components of overall development policy; their linkages with food production policies need careful attention.

## Profile 1

## IMPROVING FOOD RESERVE AND DISTRIBUTION SYSTEMS

In the poorer developing countries where consumption levels in much of the population are close to the subsistence level, the availability of adequate food reserves and effective means of distributing them in crisis situations are especially important. An effective system frequently will require publicly managed buffer stocks. International food aid can reinforce such systems by providing some of their stocks and/or current requirements.

National public food distribution systems can serve two major directions: (1) to build and use buffer stocks to smooth total supply and price movements over time, and (2) provide food for the poorest groups on a more systematic basis. When providing food on a systematic basis is one of the objectives, the distribution system must be more complicated than otherwise. One approach for reaching the poorer groups is by means of a two-price policy using lower subsidized prices accessible only to the poorer classes. Another is to give rations to particular target groups.

Many issues remain to be resolved in the design of food reserves and distribution systems. There are various ways in which the public and private sectors can interact. Foreign food aid, when available, also can play a variety of roles.

### RESEARCH NEEDS

The following areas of research merit attention:

-- How national and international food reserves may be best used in conjunction.
-- How local food supply systems function--who the traders are and their characteristics, the extent and nature of transportation and storage services, etc.

-- Public involvement in food stocking and distribution, using both simulation analysis and, cross-country, a regional comparison of experience with different systems.

The first area of research is of special importance when, as is frequently the case, food aid has a lower political cost in the high-income countries than other types of aid. Its contribution can vary widely according to how it is used and the timing of its availability. And negative effects on domestic production should be avoided. From a country's point of view, food aid is most useful when it coincides with domestic shortages or low domestic reserves so that it can be used to stabilize those reserves. An individual country should take into account the likely relationship between availability of food aid and domestic food supplies, and techniques for injecting the food aid into the domestic system.

A better understanding of local supply systems is necessary to predict price and availability trends, in the absence of public involvement and under various types of such involvement. Of special importance is the extent and character of stabilizing storage and speculation by private traders, and the extent of monopoly power and its relationship to price movements. The private trading system must be understood to a point where the design of public involvement can complement it without suppressing its beneficial contributions.

Research on overall models or designs of public involvement must build in the exogenous determinants of domestic food supply, the pattern of availability of imported food whether commercially purchased or aid, and the functioning of the private domestic storage system. These models or designs should reflect the likely behavioral pattern of the public sector in the system, the extent to which it will resist competition from private traders, etc. When better income distribution is sought--so that there is an attempt to provide food to the low-income groups under shortage conditions--the system design must be more complete and complicated with a device to distinguish these people from others, and may require a separate public retail system.

Since collaboration among developing countries to pool buffer stocks appears to have many efficiencies, consideration needs to be given to the rules that could make such a system operative, according to which countries cooperate.

Simulation of worldwide systems also is important, among other reasons to appraise the relative costs of different distributions of stocks among countries and

between the high-income countries and developing countries.

One of the focal questions for the design of almost any public food system is: What floor and ceiling prices should trigger government purchases or sales? Another concerns optimal stock size as a function of current prices and other relevant variables. Optimal turnover depends on the perishability of the product, the size of the public system, and the pattern of price movements.

Little research on these issues has been conducted in most developing countries. The discouraging amount of public involvement appears to be based on inadequate models of the food supply system, and, as a result, it sometimes is less beneficial than it might be. In fact, it may be counterproductive. Unlike food production, effective food distribution has not been the subject of much sophisticated analysis, but there is no reason to think such analysis is not feasible or would not be quite productive.

## IMPACT

The desired outcome of this research is an understanding of exogenous determinants of food supply, private trade and storage systems, and likely public management capabilities to the point where appropriate public involvement can be defined--both in terms of the type of institution necessary and the rules of management that should be followed. Effective food supply management can have a great impact on the welfare of the populations of developing countries, especially those who are poor or who suffer from unstable food prices. Because food is the major item purchased by the poor in all countries, they suffer disproportionately when its price fluctuates, and a leveling of fluctuation would help them considerably, even in the absence of special treatment. They would benefit further if their food purchases were subsidized during shortage periods.

## IMPLEMENTATION

For the most part, the work proposed here should be done developing country by developing country. That is true not only of the empirical fieldwork, such as defining food distribution systems, but of the modelling of possible reformed systems. Reformed systems that call for important and sensitive changes in national policies will need the participation of in-

country specialists to be persuasive--and realistic. At the same time, such research can usefully share common methodologies, and, from the viewpoint of multilateral and bilateral donors, there will be an advantage in good intercountry comparability. Hence the desirability exists for a strong set of multilateral food policy research promoters, brokers, and coordinators such as the World Bank and FAO and the new International Food Policy Research Institute.

## Profile 2

## THE RELATION BETWEEN AGRICULTURAL TECHNOLOGY AND INCOME DISTRIBUTION

In agriculture, as in other sectors, the possibility of importing capital-intensive technology creates a dilemma for the developing countries. Such importation is attractive since the developing countries have a limited research and development capacity of their own. But such technologies must be expected to worsen income distribution in many instances. They use little labor and may displace considerable numbers of low-income workers. Even when they are efficient, they may lower the income levels of landless workers and small farmers. Sometimes modern technologies are introduced even when they are not efficient because low interest rates and overvalued exchange rates make them privately profitable to large farmers. Since, unlike biological technological improvements, mechanical advances have considerable indivisibilities, they are better suited to large farms and may in this way worsen distribution.

### RESEARCH NEEDS

While many specific issues and many approaches to the broad questions just outlined should receive research attention, the indigenous question of technological improvements is particularly worthy of emphasis. The processes of international technology transfer and the local development of improved varieties have received much more attention than the indigenous development of mechanical improvements, better farming systems, small-scale irrigation, and other innovations which frequently come from individual insights or small-scale experimentation. Given the potential value of capital- and land-saving improvements, and the fact that small-scale innovators are likely to be looking precisely for this sort of

improvement, a better understanding of the conditions that facilitate such innovations is important.

Research on this topic should be pursued in three general directions. First, since several countries have followed small-scale, labor-intensive strategies, their experience should be studied (Mainland China is probably the chief example). Second, many countries have developed new technologies and much can be learned by case histories of their development (e.g., tubewells in Pakistan, small-scale irrigation development in a number of countries, and small machinery innovations, etc.). These two types of research will help sort out the conditions that contribute to or impede such improvements. A third and complementary approach involves pilot projects established to develop these technologies, with associated monitoring of the process, inputs, and success of the research.

## IMPACT

Both direct support for the development of intermediate technologies and a furthering of our understanding of how such change occurs should contribute directly or indirectly to an increased flow of such improvements. The potential impact can be important and widespread; in fact, the great merit of inexpensive improvements is that their impact is not limited to a set of large farmers who can afford them. A development like the small pump tubewell in Pakistan--or, perhaps even better, the bamboo tubewell in Bihar--can affect a substantial share of the agricultural population. Potentially, the target group for such benefits may be the majority of the agricultural population in the developing countries. The main indirect beneficiaries would be the poor nonagricultural groups via the increased food production.

## IMPLEMENTATION

The first two types of research noted above are going on in some measure and will continue to be pursued by individual specialists, e.g., work on specific case histories. There is need, however, for more collaboration and concentration of such research. This might well be promoted by modest but flexible funding of selected development studies centers or institutes (preferably with both economic and engineering components) particularly in the developing countries but also in the high-income countries. The pairing of particular institutions in the developing

and high-income countries into a collaborative network might be attractive. Such research collaborations would undertake specialization (for a stated period) in: (1) gathering, collating, and distributing information about concrete, indigenous, technological, innovational experiences and experiments; (2) making their own cross-referencing and other studies in the field; and (3) commissioning and funding pieces of related research by scholars elsewhere. (Recent work by the Council of Asian Manpower Studies may offer a partial but perhaps not sufficiently institutionalized model.)

The third of the above research areas--the pilot projects--is trickier and more risky, but, since it also is more systematically lacking, it offers a higher payoff if it can be done effectively. The experimentation plainly needs to be done within the environment of the developing countries. But, unhappily, most of the established technology-research institutional structure in the developing countries has too much of a Westernized, large-scale, capital-intensive style to afford the genuinely grass roots-oriented working environment that the present proposal is seeking. Accordingly, we somewhat hesitantly recommend rather small grants to selected Western technoeconomic institutions. These institutions should be devout in their commitment to the theory of indigenous, labor-intensive, small-scale, scientifically progressive innovation. They would be commissioned in particular countries or groups of countries to search out and place small project bets on illusive, usually quite rustic, units that met such criteria. And, as nonofficial but external agents, would be exceptionally experienced and skillful in the intricate diplomacy vis-a-vis nonofficial and official in-country institutions that would be necessary. This diplomacy is necessary not only to let such externally funded experimentation go forward but to convert quickly the external funds into a catalyst for more internal (public and/or private) resources.

## Profile 3

## MECHANISMS FOR RAISING RESOURCES IN THE AGRICULTURE AND FOOD SECTORS

An increased output of food, or more generally increased agricultural output, depends essentially on improving technology and on capitalization. While financial systems make some contribution to the formation of capital in agriculture, this mechanism has serious limitations, especially in the poorest countries where farms are small and guarantees are difficult because of the precarious conditions under which farmers live. Rapid growth of capital stock in agriculture must draw on local savings. There is much evidence that farmers can save even out of quite low incomes, and, although the evidence remains very spotty, the overall savings ratio out of agricultural income appears to be high in countries with rapidly rising agricultural incomes. In many poor countries, however, rural savings are low in absolute terms and well short of the level that could be productively invested in the sector. For sectors or subsectors where financing from outside the sector is necessarily quite limited, raising local investment resources can be a key determinant of progress.

### RESEARCH NEEDS

It is convenient to distinguish savings based on individual decision making from savings based on group decision making. There is reason to believe that both types can be raised under facilitating conditions.

Individual savings in rural areas is only beginning to be analyzed. For a few developing countries, the effects on savings of such standard determinants as income levels, family size, and interest rate on assets held have been analyzed. The impact of farm investment opportunities, the availability of various types of financial assets, social obligations, and other possibly relevant factors have yet to be considered

appropriately. Particular emphasis must be placed on the effects of determinants that can be manipulated or affected by public policy, e.g., those related to the financial system.

Group savings are of particular importance in countries in which much productive investment must be carried out on a joint or community basis. Feeder roads, community irrigation systems, schools, and a variety of other investments fit this category. The means by which local leaders, government personnel, or others persuade groups to undertake useful investments of this sort need to be studied on a comparative and interdisciplinary basis. The sociology of local leadership may be particularly important here. The experience of China in generating rural savings is likely to be instructive.

Government already has some control over certain factors that probably determine rural savings and could undoubtedly increase and improve its involvement if the savings process were better understood. Understanding the effects of the financial system, the rate of inflation, and government promotion and cost-sharing of rural infrastructure investments would probably be the most directly relevant to policy.

## IMPLEMENTATION

Research into individual savings patterns calls for high quality sampling procedures, including measurement of incomes and current expenditures at a level of precision seldom approached thus far. And, relatively large surveys are necessary. Various institutional arrangements have been used in studies done to date, including national statistical offices, university survey teams, and private consulting groups. Where it is desirable to take periodic surveys over a substantial period of time, national statistical offices are likely to be the best vehicle, although in most cases some upgrading would be necessary to handle this sort of survey. In any case, the work must be done, with few exceptions, by national agencies, if only to minimize communication problems. Needed sample size also argues for this.

Financial support frequently will be necessary to induce studies of this type. Accordingly, attention should be directed to how such a support program should be organized and administered. A number of international agencies have an interest in this area (e.g., the World Bank), and many individuals, academies, and others in the developing and high-income countries would be available to participate in the analysis.

Research on the community savings process requires a different sort of empirical information, requiring the study of community dynamics. In many cases, individual efforts will contribute important analyses. The scope and complexity of the issue--where the goal is to understand what determines effective community action--may call, however, for some organization of effort, to assume that a reasonable balance of case studies are undertaken in a way that later permits effective comparative analysis. Once more, there may be a role for a somewhat formalized research structure to deal with this issue.

## NOTES

1. Abrupt and large increases in demand or reductions in supply of resources may increase prices so sharply that governments would have to resort to rationing the resources. At the time of the OPEC embargo of oil shipments to the United States, this alternative was widely discussed, although never adopted. At about the same time, the United States did ration the supply of fertilizer to foreign purchasers when the price of that commodity rose sharply, threatening the interests of U.S. farmers.

   Under these circumstances, the physical availability of energy and other resources, as well as their price, has an impact on use of these resources in the food and nonfood sectors. While such circumstances may occur from time to time over the balance of the century, we do not expect them to be characteristic of the period. Consequently, we take the price of resources as the key element defining their terms of availability to the food and nonfood sectors.
2. Revelle (1976) estimates that the total energy used in agricultural production in India in 1971 was $2.52 \times 10^{14}$ kcal, 77 percent of which was provided by humans and animals, the rest by fossil fuels, and a small amount of hydroelectric power. The amount of energy per hour worked by humans was a little less than 1,000 kcal ($2.52 \times 10^{14}$ kcal divided by 255 billion hours of human work). Energy used per hectare of gross cropped land (163 million hectares, from Revelle) was 1.546 million kcal. Steinhart and Steinhart (1974) estimate that energy use in agricultural production in the United States in 1970, not including that of humans and animals, was $5.26 \times 10^{14}$ kcal, more than twice the total enrgy used in Indian agriculture. U.S. farmers worked 5,983 million hours in 1970 (USDA 1975), indicating 88,000 kcal per hour compared with 1,000 kcal in India. Energy use per hectare of gross cropped land in the United States in 1970

was 3.9 million kcal, 2.5 times as much as in India.

These comparisons are not meant to indicate that energy use in Indian agriculture must equal that in the United States. They do strongly suggest, however, that in India, and by extension, in other developing countries as well, the growth in food production per person and per hectare needed to keep pace with rising demand for food will require very substantial increases in the use of energy per person and per hectare.

3. The review of petroleum price projections by the staff of the World Food and Nutrition Study showed that a real price 100 percent above the 1974 level by the end of the century would be in the high end of the range of projections.
4. Estimates of energy costs as a percent of total production costs for U.S. agriculture as a whole are not available. For corn, one of the most energy-intensive crops, energy costs (exclusive of the energy value of labor input) were about 35 percent of the value of corn output per acre in 1973 (USDA 1974c:37).
5. Heichel (1976) on large-scale substitution of manure for nitrogen fertilizer in the United State; National Research Council (1975a) and Wittwer (1974) on prospects for biological nitrogen fixation in legumes and cereal crops.
6. For a discussion of the issues involved in agricultural mechanization in the developing countries, with numerous references to the literature, see Stout and Downing (1976).
7. A caveat is needed with respect to potash prices. Potash production is heavily concentrated in the state of Saskatchewan, Canada, and in the Soviet Union and Eastern Europe. In late 1975, the government of Saskatchewan announced plans to take over the industry. In these circumstances, the long-run price of potash, like that of petroleum, may not reflect underlying supply and demand conditions, but rather political decisions. With respect to phosphorus, Wells (1975a:68-69, 1975b:315), after a careful review of the data and literature dealing with reserves, prospective growth in consumption, and costs of production concludes that, <u>with existing technology</u>, world reserves are adequate to meet prospective demands for roughly the next 500 years at real prices that ultimately might be two to three times the 1971 level ($50 per ton for extracting and refining phosphate rock to a level suitable for manufacture of fertilizer). Since over such a long period substantial improvements in technology can be

anticipated, the actual increase in production costs over the next 500 years likely would be less. In any case, there is little doubt that if real prices of phosphorus rise over the balance of this century, it will not be because of the pressure of demand on reserves.

8. From 1960-62 to 1969-71 land in grains (not all foods) in the developing countries increased by 1.4 percent annually (USDA 1974d:18).
9. Ceres (FAO 1974b) gives FAO data showing that in South Asia, the People's Republic of China, and the Near East virtually 100 percent of the cultivable land is already cultivated. In east and Southeast Asia, the figure is 63 percent; in Africa, 42 percent; and in Latin America, 21 percent. For the world as a whole, 59 percent of the cultivable land is presently cultivated, according to the FAO data.
10. The Dvoskin-Heady Study showed that doubling the real price of energy from 1974 levels would cause a decline in irrigated acreage of 20 to 25 percent in the United States. For the most part, this reflects the importance of energy costs in costs of pumping groundwater.
11. The argument for this assertion is developed in Crosson and Frederick (1977).
12. Agricultural and food policies are viewed here as largely overlapping and synonymous. Especially in poor countries, the great bulk of agricultural output is of food items. And many of the same issues pertain in any case to the organization and the support for food and nonfood production. In terms of the interactions discussed in this paper, it has not seemed necessary to focus on the food-nonfood distinction within agriculture.
13. In the poorest countries, production of food may account for 40 percent of the GNP; and its processing, transportation, and distribution for another 10 to 20 percent. The share of labor force so engaged can reach 70 percent in food production and another 15 to 20 percent in processing, transporation, and distribution. For the poorest people in a developing country, up to 70 to 80 percent of their expenditures typically go for food.

    These percentages become systematically lower as countries get better off, essentially because the income elasticity of demand for food and nonfood agricultural items is less than one. Accordingly, the share of additions to output and the labor force typically falling in this category is lower, perhaps on the order of one-half the average rations for fairly poor countries. The changing structure of the labor force leads to

rural-urban migration and, relatively late in the development process, to an absolute decline in the agricultural labor force.

14. One fairly typical trend is that an increasing share of agricultural output is made up of nonfood items, usually raw materials for industry (e.g., cotton, rubber, etc.).
15. Further, as noted above, some of the capital invested in agriculture could not be transferred to other sectors anyway. And in many countries agricultural growth will have a net positive effect on the balance of payments.
16. This term is used because of its popularity and inspite of its being somewhat misleading in suggesting that the only function of these centers is commerce. They will and should be loci of small-scale manufacturing as well.
17. Note that economists' extensive criticism of capital-intensive techniques in developing countries is not a negation of the desirability of increasing an economy's overall capital-to-labor ratio, which in turn permits a gradual increase in the capital available to be used with the typical worker. It rests, rather, on the fact that if--when capital is still in short supply--there may be none left for many other workers. Observation has suggested that it is better (i.e., resulting total output is higher) for everyone to have a little capital than for a few workers to have a lot and the rest none.
18. Study Team 9 is reviewing the nutrition issues.
19. This is not to diminish the role of a good food distribution system, of better-organized international trade in food (Subgroup C), and of food aid (next section), phenomena that can be vehicles for some income distribution.

## REFERENCES


Barlow, R. (1967) The economic effects of malaria eradication. American Economic Review 57(2):139-148.

Beasley, R. P. (1972) Erosion and Sediment Pollution Control. Ames: Iowa State University Press.

Becker, G. S. (1960) An Economic Analysis of Fertility. Demographic and Economic Change in Developed Countries. Universities-National Bureau Conference, Series 11, Princeton, N.J.

Bennett, H. H. (1939) Soil Conservation. New York: McGraw-Hill.

Berg, A. (1973) The Nutrition Factor. Washington, D.C.: The Brookings Institution.

Bryson, R. A. (1974) A perspective on climatic change. Science 184:753-760.

Bryson, R. A. and W. M. Wendland (1975) Climatic effects of atmospheric pollution. Pages 139-147, The Changing Global Environment, edited by S. F. Singer. Dordrecht, The Netherlands: D. Reidel Publishing Co.

Buringh, P., H. D. J. van Heemst, and G. J. Staring (1975) Computation of the Absolute Maximum Food Production of the World. Department of Tropical Soil Sciences, Agricultural University, Wagenin, The Netherlands.

Cantrelle, P. and H. Leridon (1971) Breast feeding, mortality in childhood and fertility in a rural zone of Senegal. Population Studies 25(3):505-533.

Central American Research Institute for Industry (1975) An Environmental and Economic Study of the Consequences of Pesticide Use in Central American Cotton Production. Final report, ICAITI, United Nations Environmental Programme.

Chen, L. C., S. Ahmed, M. Gesche, and W. H. Mosley (1974) A prospective study of birth interval dynamics in rural Bangladesh. Population Studies 28(2):277-298.

Chinnatamby, S. (1962) Fertility trends in Ceylonese women. Journal of Reproduction and Fertility 3:342.

Coale, A. J. (1975) The Demographic Transition Reconsidered. Paper presented at International Union for the Scientific Study of Population Conference, Leige, Belgium.

Committee for International Coordination of National Research in Demography (1975, 1976) Seminars on Infant Mortality in Relation to the Level of Fertility. Bangkok, 1975 and Paris, 1976.

Conde, J. (1971) The Demographic Transition as Applied to Tropical Africa. Development Center, Organization for Economic Cooperation and Development, Paris.

Cramer, H. H. (1967) Plant protection and world crop production. Pflanzenschutznachrichten 20(1):1-524.

Crosson, P. and K. Frederich (1977) The World Food Situation: Resource and Environmental Issues in the Developing Countries and the United States. Research Paper, Resources for the Future, Washington, D.C.

Darmstadter, J., P. D. Teitelbaum, and J. G. Polach (1971) Energy in the World Economy. Baltimore: Johns Hopkins University Press.

DaVanzo, J. (1972) The Determinants of Family Formation in Chile, 1960. R-830. Santa Monica, Calif.: Rand Corporation.

Davis, K. (1951) The Population of India and Pakistan. Princeton, N.J.: Princeton University Press.

Dumond, D. E. (1975) The limitation of human population: a natural history. Science 187:713-721.

Dvoskin, D. and E. Heady (1976) Economic and Environmental Impacts of Energy Rationing in Agricultural Development. The Center for Agricultural and Rural Development, Iowa State University, Ames (preliminary draft).

Eckholm, E. (1976) Losing Ground. Washington, D.C.: Worldwatch Institute.

Elias, R. S. (1969) Rice production and minimum tillage. Outlook on Agriculture 6:67.

Emigh, G. D. (1972) World phosphate reserves: are there really enough? Engineering and Mining Journal 173(4):90-95.

Food and Agriculture Organization of the U.N. (1974a) Assessment of the World Food Situation. World Food Conference. Rome: FAO.

Food and Agriculture Organization of the U.N. (1974b) FAO review in development. Ceres. November-December.

Freedman, R. and B. Berelson (1974) The human population. Scientific American 231(3):30-39.
Frisch, R. E. and J. W. McArthur (1974) Menstrual cycle: fatness a determinant of minimum weight for height necessary for their maintenance or onset. Science 185:949.
Frisch, R. E. and R. Revelle (1970) Height and weight at menarche and a hypothesis of critical body weights and adolescent events. Science 169:397.
Gertel, K. and N. Wollman (1960) Rural-urban competition for water: price and assessment guides to western water allocation. Journal of Farm Economics 42(5):1332-1344.
Glass D. V. and E. Grebenik (1966) World population, 1800-1950. Pages 60-138, Cambridge Economic History of Europe. Vol. VI, The Industrial Revolution and After, edited by H. J. Habakkuk and M. Postan. Cambridge, England: University of Cambridge Press.
Goeller, H. E. and A. M. Weinberg (1976) The age of substitutability. Science 191:683.
Gonzalo, S. Y. (1976) Major Factors Affecting Rural Household Consumption. Discussion Paper No. 76-13, Institute of Economic Development and Research, School of Economics, University of the Philippines.
Gordon, J. E, M. A. Guzman, W. Ascoli, and N. S. Scrimshaw (1964) Acute diarrheal disease in less developed countries. Bulletin of the World Health Organization 31:1-28.
Grant, K. (1975) Erosion in 1973-74: the record and the challenge. Journal of Soil and Water Conservation, Vol. 30, No. 1.
Gray, R. H. (1974) The decline of mortality in Ceylon and demographic effects of malarial control. Population Studies 28:205-248.
Greenland, D. J. (1975) International Institute of Tropical Agriculture. In: Proceedings: Soil and Water Management Workshop. U.S. Agency for International Development.
Hargrove, T. R. (1972) Agricultural Research: Impact on Environment. Special Report 69, Agriculture and Home Economics Experiment Station, Iowa State University of Science and Technology, Ames.
Heck, W. W. (1973) Air pollution and the future of agriculture. Air Pollution Damage to Vegetation, edited by J. Naegle. U.S. Agency for International Development.
Heichel, G. H. (1976) Agricultural production and energy resources. American Scientist 64:64.
Held, R. B. and M. Clawson (1965) Soil Conservation in Perspective. Baltimore: Johns Hopkins University Press.

Hubbert, M. K. (1972) Man's conquest of energy: its ecological and human consequences. Pages 1-50, The Environmental and Ecological Forum 1970-1971. Office of Information Services, U.S. Atomic Energy Commission, Oak Ridge, Tenn.

Ingraham, E. W. (1975) A Query into the Quarter Century. On the Interrelationships of Food, People, Environment, Land and Climate. Wright-Ingraham Institute, Colorado Springs, Colo.

Jacobs, J. J. and J. F. Timmons (1974) An economic analysis of agricultural land use practices to control water quality. American Journal of Agricultural Economics 56:791.

Kellogg, W. W. (1975) Climate change and the influence of man's activities on the global environment. Pages 12-23, The Changing Global Environment, edited by S. F. Singer. Dordrecht, The Netherlands: D. Reidel Publishing Co.

Keyfitz, N. (1976) World resources and the world middle class. Scientific American 235(1):28-35.

Kovda, V. A. (1971) The problem of biological and economic productivity of the earth's land areas. Soviet Geography, revised and translated 12(1):6-23.

Lewis, O. (1951) Life in a Mexican Village: Tepoztlan Restudied. Urbana: University of Illinois Press.

Lindert, P. A. (1974) Family Inputs and Inequality Among Children. Institute for Research on Poverty, Discussion Paper 218-74, Madison, Wis.

Makhijani, A. (1975) Energy and Agriculture in the Third World. Cambridge, Mass.: Ballinger Publishing Co.

Marshall, C. L. (1974) Health, nutrition, and the roots of world population growth. International Journal of Health Services 4(4):677-690.

Maurer, K. M., R. Radajczak, and T. P. Schultz (1973) Marriage, Fertility, and Labor Force Participation of Thai Women: An Econometric Study. R-829. Santa Monica, Calif.: Rand Corporation.

McDermott, W. (1966) Modern medicine and the demograph-disease pattern of overly traditional societies: a technological misfit. Journal of Medical Education 41:137-162.

Mincer, J. (1963) Market prices, opportunity costs and income effects. Pages 67-82, Measurement in Economics: Studies in Mathematical Economics and Econometrics, edited by C. F. Christ, et al. Stanford, Calif.: Stanford University Press.

Mosley, W. H. and L. C. Chen (1976) Health and Human Reproduction in Developing Countries. Johns Hopkins University.

Mosley, W.H. (1977) Health, nutrition and mortality in Bangladesh. Research in Human Capital and Development, edited by I. Sirageldin. Greenwich, Conn.: JAI Press.
National Research Council (1970) Biology and the Future of Man, edited by P. Handler. New York: Oxford University Press.
National Research Council (1971) Rapid Population Growth. Vols. I and II. Baltimore: Johns Hopkins University Press.
National Research Council (1974a) Productive Agriculture and a Quality Environment. Division of Biology and Agriculture. Washington, D.C.: National Academy of Sciences.
National Research Council (1974b) Rehabilitation Potential of Western Coal Lands. Cambridge, Mass.: Ballinger Publishing Co.
National Research Council (1975a) Agricultural Production Efficiency. Washington, D.C.: National Academy of Sciences.
National Research Council (1975b) Interim Report, World Food and Nutrition Study. Washington, D.C.: National Academy of Sciences.
National Research Council (1975c) Pest Control: An Assessment of Present and Alternative Technologies. Vol. I, Contemporary Pest Control Practices and Prospects. Washington, D.C.: National Academy of Sciences.
National Research Council (1975d) Population and Food: Crucial Issues. Committee on World Food, Health, and Population, Division of Biological Sciences. Washington, D.C.: National Academy of Sciences.
Newman, P. (1965) Malaria Eradication and Population Growth with Special Reference to Ceylon and British Guiana. Bureau of Public Health Economics, Research Series No. 10, School of Public Health, University of Michigan.
Newman, P. (1970) Malarial control and population growth. Journal of Development Studies 6:133-158.
Oka, I. N. and D. Pimentel (1976) Herbicide (2, 4-D) increases insect and pathogen pests on corn. Science 193:239.
Pimentel, D. (1976) World food crisis: energy and pests. Bulletin of the Entomological Society of America 22:20-26.
Pimentel, D. and N. Goodman (1974) Environmental impact of pesticides. Pages 25-52, Survival in Toxic Environments, edited by M. A. Q. Khan and J. P. Bederka, Jr. New York: Academic Press.

Pimentel, D., L. E. Hurd, A. C. Bellotti, M. J. Forster, I. N. Oka, O. D. Sholes, and R. J. Whitman (1973) Food production and the energy crisis. Science 182:443-449.

Pimentel, D., E. C. Terhune, R. Dyson-Hudson, S. Rochereau, R. Samis, E. A. Smith, D. Denman, D. Reifschneider, and M. Shepard (1976) Land degradation effects on food and energy resources. Science 194:149-155.

Pirie, P. (1972) The effects of treponematois and gonorrhea on the populaticns of the Pacific islands. Human Biology of Oceania 1:187-206.

Potter, R. G., M. L. New, J. B. Wyon, and J. E. Gordon (1965) Applications of field studies to research on the physiology of human reproduction. Public Health and Population Change, edited by M. C. Sheps and J. C. Ridley. Pittsburgh, Pa.: University of Pittsburgh Press.

Preston, S. H. (1975) Health programs and population growth. Population and Development Review 1(2):189-200.

Puffer, R. R. and C. V. Serrano (1973) Patterns of Mortality in Childhood. Pan American Health Organization, World Health Organization, Scientific Publication No. 262, Washington, D.C.

Resources for the Future (1976) Repcrt to the Naticnal Institutes of Health on the Economic, Resource and Environmental Consequences of Population Growth in the United States. Washington, D.C.

Revelle, R. (1976) Energy use in rural India. Science 192:969.

Ring, A. and R. Scragg (1973) A demographic and social study of fertility in rural New Guinea. Journal of Biosocial Science 5(1):89-121.

Romaniuk, A. (1968) Infertility in tropical Africa. The Population of Tropical Africa, edited by J. C. Caldwell and C. Okonjo. London: Longmans.

Schneider, S. H. (1976) The Genesis Strategy. New York: Plenum Press.

Schultz, T. P. (1976a) Determinants of fertility: a microeconomic model of choice. Pages 89-124, Economic Factors in Population Growth, edited by A. J. Coale. London: Macmillan.

Schultz, T. P. (1976b) Interrelationships between mortality and fertility. Population and Development: The Search for Selective Interventions, edited by R. G. Ridker. Baltimore: Johns Hopkins University Press.

Singer, S. F. (1975) Environmental effects of energy production. Pages 25-44, The Changing Global Environment, edited by S. F. Singer. Dordrecht, Holland: D. Reidel Publishing Co.

Smerdon, E. T. (1974) Energy Conservation Practices in Irrigated Agriculture. Sprinkler Irrigation Association Annual Technical Conference, Denver, Colo.
Steinhart, J. S. and C. E. Steinhart (1974) Energy use in the U.S. food system. Science 184:307-316.
Sterling Forest Conference (1974) World Food Supply in a Changing Climate. Proceedings of a conference sponsored by the American Society of Agronomy, Madison, Wis. and the Aspen Institute for Humanistic Studies, Boulder, Colo.
Stolnitz, G. J. (1955) A century of international mortality trends. Part I. Population Studies 9(1):24-55.
Stolnitz, G. J. (1956) A century of international mortality trends. Part II. Population Studies 10(1):17-43.
Stolnitz, G. J. (1965) Recent mortality trends in Latin America, Asia, and Africa. Population Studies 19(2):117-138.
Stout, B. A. and C. M. Downing (1976) Agricultural mechanization policy. International Labour Review, Vol. 113, No. 2.
Tabarrah, R. B. (1971) Toward a theory of demographic development. Economic Development and Cultural Change 19:2.
Tanner, J. M. (1968) Earlier maturation in man. Scientific American 218:21.
United Nations (1973) World Population Prospects as Assessed in 1968. Department of Economic and Social Affairs, Population Studies, No. 53.
U.S. Department of Agriculture (no date) Perspectives on Prime Lands. Background paper for Seminar on the Retention of Prime Lands, July 16-17, 1975, sponsored by the USDA Committee on Land Use.
U.S. Department of Agriculture (1965) Losses in Agriculture. Agricultural Research Service Handbook, No. 291. Washington, D.C.: U.S. Government Printing Office.
U.S. Department of Agriculture (1968) A National Program of Research for Environmental Quality. Pollution in Relation to Agriculture and Forestry. A report prepared by a joint task force of USDA and directors of agricultural experiment stations. USDA Research Program Development and Evaluation Staff, Washington, D.C.
U.S. Department of Agriculture (1971) Agriculture and the Environment. Economic Research Service No. 481.

U.S. Department of Agriculture (1974a) Our Land and Water Resources, Current and Prospective Supplies and Uses. Economic Research Service Miscellaneous Publication No. 1290.

U.S. Department of Agriculture (1974b) Testimony in hearings, Subcommittee on Appropriations, House of Representatives, Ninety-third Congress, First Session.

U.S. Department of Agriculture (1974c) The U.S. Food and Fiber Sector: Energy Use and Output. A report prepared for the Senate Committee on Agriculture and Forestry. Washington, D.C.: U.S. Government Printing Office.

U.S. Department of Agriculture (1974d) The World Food Situation and Prospects to 1985. Economic Research Service, Foreign Agricultural Economic Report No. 98.

U.S. Department of Agriculture (1975) Changes in Farm Production and Efficiency: A Summary Report. Economic Research Service, Statistical Bulletin No. 548.

U.S. Department of Health, Education, and Welfare (1969) Report of the Secretary's Commission on Pesticides and their Relationship to Environmental Health. Washington, D.C.

U.S. Department of the Interior (1975) Energy Perspectives. Washington, D.C.: U.S. Government Printing Office.

U.S. Environmental Protection Agency (1974) Strategy of the Environmental Protection Agency for Controlling the Adverse Effects of Pesticides. Office of Pesticide Programs, Office of Water and Hazardous Materials.

U.S. Natural Resources Board (1935) Soil Erosion, A Critical Problem in American Agriculture. Supplemental Report, Land Planning Committee.

Van den Bosch, R. and P. S. Messenger (1973) Biological Control. New York: Intext Educational Publishers.

Wadleigh, C. H. (1968) Wastes in Relation to Agriculture and Forestry. U.S. Department of Agriculture Miscellaneous Publication No. 1065.

Wells, F. J. (1975a) The Long-Run Availability of Phosphorus. Baltimore: Johns Hopkins University Press.

Wells, F. J. (1975b) The impasse over limits to growth. Resources Policy 1(6):313-325.

Westoff, C. F., R. G. Potter, P. C. Sagi, and E. G. Mishler (1961) Family Growth in Metropolitan America. Princeton, N.J.: Princeton University Press.

White, B. (1975) The economic importance of children in a Javanese village. Pages 127-146, Population and Social Organization, edited by M. Nag. The Hague, The Netherlands: Mouton.
Wittwer, S. H. (1974) Maximum production capacity of food crops. Bioscience 4:217.
Wolansky, N. (1972) Comments on anthropology and population problems. Current Anthropology 13:255.
Zacharias, L. and R. J. Wurtman (1969) Age at menarche, genetic and environmental influences. New England Journal of Medicine 280:868.

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