Staff Paper Series

STAFF PAPER P71-11 JULY 1971

WORLD NEEDS FOR FOOD AND FIBER: SOME ECONOMIC ASPECTS OF SCIENCE REQUIREMENTS, RESOURCE DEVELOPMENT, AND THE ENVIRONMENT

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Staff Paper P71-11 July 1971

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This paper addresses itself to three aspects of world food and fiber needs and the protection of the ecosystem. The first is to distinguish between food and fiber needs of the world on the one hand, and the production of food and fiber in developing countries as part of a long-term process of economic development on the other. The second area of attention is the role of science and technology in the process of agricultural modernization and development. Finally, we will look at a class of problems dealing with socially costly externalities associated with agricultural resource development and the use of new technologies.

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1/ Paper presented at the Conference on Expanding World Needs for Food and Fiber and the Protection of the Ecosystem, Center for the Study of Democratic Institutions, Santa Barbara, California, August 9-13, 1971.

World Food and Fiber Needs in Perspective

For nearly 175 years we have been periodically haunted by the Malthusian spectre of population growth being controlled by a limited food supply. The mechanisms by which population and food supplies are kept in balance include hunger, poverty, disease and death.

There have been five waves of scare about population and famine[2/] within the last two centuries. The first came with the publication of Malthus' "An Essay on the Principles of Population" in 1798. Cochrane[3/] presents some interesting speculation as to the origin of Malthus' thinking and why, subsequently, the Malthusian theory waxed and waned in popularity in the Western world, but has not been valid for any significant length of time. Prior to 1750 the food-population situation was truly Malthusian -- the rate of population growth was limited by the rate of growth in food supplies. In England, after 1750 the death rate began to decline, but the birth rate continued at a high level. Between 1750 and 1798 Malthus saw a rapid rise in the rate of population growth. But, he seemed to have overlooked changes in agricultural productivity which were taking place in England and on the Continent and rising food imports from the New World. These changes were to continue, more or less, for the next 175 years. "He caught one part of the dynamic scene; he missed the other part." This is an important analytical point because the same mistake was to be repeated at least twice in the twentieth century.

2/ See Merrill K. Bennett, "Population and Food Supply: The Current Scare," The Scientific Monthly, January 1949; and Martin E. Abel, "Food Production Possibilities in the High-Food-Drain Economies," American Journal of Agricultural Economics, Vol. 50, No. 5, December 1968.

3/ Willard W. Cochrane, The World Food Problem; A Guardedly Optimistic View (New York: Thomas Y. Crowell Company, Inc., 1969), pp. 60-62.

The second food scare came in the late 1890's in connection with rising world wheat prices and the German controversy about the relative merits of agrarian and industrial development strategies.

But interest in the population-food problem quickly waned and did not reappear until shortly after World War I when, for a few years, food shortages again revived Malthusian thinking.

The fourth wave of scare about population and food came after World War II. In 1948, Sir John Boyd Orr, Director General of the Food and Agricultural Organization of the United Nations "pleaded ... to help awaken the people to the fact that in the race between population and food, population was winning -- 'and we do not know how to stop it'."[4/] The same thoughts were echoed by William Vogt[5/] and Fairfield Osborn.[6/] This was also the time of the "Fifth Plate" in the United States, a way of dramatizing that for every four persons sitting down to dinner in 1950, there would be five to feed ten years hence.

As with Malthus, the seers of the late 1940's saw one part of the problem, but not the other. They did not see the role of agricultural technology in the developed countries as a persistent force which would continuously shift the agricultural supply curve to the right. Even as late as the mid-1950's, agricultural economists in the United States were debating whether the persistent growth in

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4/ Bennet, op. cit.

5/ William Vogt, Road to Survival, (New York: Sloane Associates, 1948).

6/ Fairfield Osborn, Our Plundered Planet, (Boston: Little, Brown and Company, 1948).

agricultural output was due to unusually good weather or to a constant stream of new technology. It was not until the end of the decade that the technology argument gained general acceptance.

Finally, the fifth wave of fear about famine hit with full force in the mid-1960's. This time the concern focused on the ability of the poor countries to "feed themselves." Spurious arguments became popular and emotions overrode logic. For example, one author, in discussing the accumulation of world grain stocks in the 1950's and their reduction in the first half of the 1960's as an indication of the deterioration in the world food situation, stated: "An analysis of the trends in world stocks of grain -- held almost entirely by the major exporters of wheat, food grains, and rice -- shows the emergence of some new and disturbing trends."[7/] But he did not state that almost all of these changes took place in U.S. grain stocks and were the outgrowth of a complex set of economic, technological, and political factors affecting supply management policies in the United States.[8/] The two severe droughts in South Asia in 1965 and 1966 helped fan the flames of emotion and the Paddock brothers published their book, _Famine 1975!_, full of dire predictions of the worst sort.[9/] All this and more, resulted in the President's Science Advisory Committee study, _The World Food Problem: A Report of the Panel on the World Food Supply_,

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7/ Lester R. Brown, "The World Food Problem: An Overview," in _Alternatives for Balancing World Food Production and Needs_, (Ames: The Iowa State University Press, 1967), pp. 3-18.

8/ For a good discussion of this point see Vernon W. Ruttan and John H. Sanders, _Surplus Capacity in American Agriculture_, Agr. Ext. Service Special Report No. 28, University of Minnesota, 1968.

9/ William Paddock and Paul Paddock, _Famine 1975! American's Decision: Who Will Survive?_ (Boston: Little, Brown and Company, 1967).

published in 1967, an indication of the serious attention given to the subject of world food supplies.

But once again the popularizers of the "world food crisis" theme overlooked what was happening with respect to the development of agricultural technology for the poor countries. The research work at such international research institutions as the International Rice Research Institute (IRRI) in the Philippines and the International Maize and Wheat Improvement Center (CIMMYT) in Mexico, while recognized, was not given much weight in the popular arguments. And yet it was the new seed technology in wheat and rice which, in a few short years, resulted in the "Green Revolution" and switched the attention of many people from the problems of shortages to those of surpluses.

The problem is not whether the world can produce enough food to keep ahead of population growth. This it can do for at least the next few decades with some measure of insurance.[10/] But one should not be overly sanguine about such a global prospect; one should look more carefully at the agricultural production potential among different areas of the world and, especially for the poorer countries, how growth of agricultural production can be translated into sustained economic development.

Since the surplus agricultural capacity of major developed countries is well recognized, let us focus on the poorer countries. First, those which are importers of agricultural products generally would like to reduce their dependence on imports. Second, poor countries whose economies depend significantly on exports of agricultural products would like to increase their exports. For both

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10/ Martin E. Abel and Anthony S. Rojko, World Food Situation: Prospects for World Grain Production, Consumption, and Trade, FAER No. 35, U.S. Department of Agriculture, Washington, D. C. September 1967.

groups of countries, foreign exchange considerations play a major role. Also, the added income and employment generated from more rapid growth in agricultural output is a major factor, particularly when non-agricultural employment alone will not provide their growing populations increasingly better levels of living. Finally, the major food importing, poorer nations do not see net foreign aid, particularly food aid, as either a growing or even dependable source of agricultural imports. Thus, even if there is enough agricultural production capacity in the world to take care of growing populations and improvement in incomes, uncertainties concerning the volume and terms of food and fiber transfers from the agricultural surplus (mainly developed)countries to the poorer, agriculturally deficit countries and the desire for more rapid agricultural development in the poorer countries lead to a high priority for agricultural development in the developing nations.

For such basic agricultural commodities such as cereal grains, there are conflicts among the objectives of different groups of countries which will manifest themselves in the form of unstable and generally low levels of prices in world markets. Surplus production capacity in grains will continue to exist in the developed countries. Also, the poor, grain importing countries as a group will probably succeed in lessening their dependence on food imports. Some may even become grain exporters. And, the poor, grain exporting countries have the capacity to expand production and exports. Lower world grain prices will affect agricultural development prospects in the developing countries. For the poor, grain exporting countries it will mean limited opportunities to increase foreign exchange earnings and to increase resources available to finance future development. On the other hand, it creates pressures for diversification of agricultural production in favor of commodities which have brighter international market prospects. For the poor, grain importing countries it means cheaper food which could be a stimulus to economic development. However, it is not clear how many of these developing countries will be able to expand the production and exports of other agricultural and industrial commodities in order to finance imported food grains at lower real costs.

Agricultural development can contribute significantly to the economic development of the poor countries if it yields a sustained flow of agricultural products at progressively lower real costs and provides employment and a distribution of income consistent with the relative factor endowments in these nations. Continuous reduction in the real cost of food and fiber in the developing countries will require a flow of new agriculture technology.[11/] But new technology alone will not be enough. It will have to be accompanied by (a) significant investments in resource development, particularly soil and water resources, to create physical environments conducive to the exploitation of the new technology; (b) provision of modern input markets which can provide farmers with the required modern inputs on a timely and low-cost basis; (c) improvements in product markets to efficiently distribute larger quantities of agricultural output both in domestic and export markets; and (d) the development of viable institutions and programs related to income distribution and employment which result in distributions of economic growth which are acceptable or tolerable in each country.

11/ T. W. Schultz, Transforming Traditional Agriculture, (New Haven: Yale University Press, 1964), and Yujiro Hayami and Vernon W. Ruttan, Agricultural Development -- An International Perspective, (Baltimore: The Johns Hopkins Press, 1971).

While one can consider technology as a critical "engine for change," it should be clear that significant resource, market, institutional, and program development will be required to translate the potential benefits of new technology into meaningful economic development.

Role of Science in Agricultural Development

Clearly, new technology will be an increasingly important source of agricultural output in the developing countries. Of course there will be variations among countries and regions of the world, with technology having a relatively more important role in the land-short countries of Asia compared with some countries in Latin America and Africa which have considerable potential for expanding area in agricultural production.

In this regard, the experience of India is instructive.[12/] Between 1951 and 1970 food grain production grew at an annual rate of 3.2 percent. The growth rate was the same for the periods 1951-65 and 1965-70, the latter being the period of the "Green Revolution" or "New Agricultural Strategy" in India. It would appear from the record of food grain production that the new Agricultural Strategy -- the new technology -- did not contribute much to increasing production, since there was no upturn in the historical rate of growth. But if one looks at the sources of growth in production, quite a different picture emerges.

Between 1951 and 1965 the 3.2 percent rate of growth in food grain

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12/ Martin E. Abel, "Differential Rates of Growth in Rural Incomes Resulting from Specific Government Policies Like the New Agricultural Strategy," paper presented at the Seminar on Income Distribution in India, sponsored by the Planning Unit of the Indian Statistical Institute, New Delhi, February 25-26, 1971.

production was approximately the same as that for total agricultural output, 3.1 percent per year. The latter consisted of a 1.40 percent rate of growth in gross cropped area, a 1.33 percent rate of growth in per acre productivity, and a 0.37 percent rate of growth due to changes in cropping patterns. Thus, nearly one-half of the growth in agricultural output came from the expansion of gross area under cultivation. The major expansion in cultivated area took place in the 1950's; very little new cultivated land was brought into production in the first half of the 1960's. And, cultivated area has remained about constant in the last half of the 1960's. This means that continuance of the historical rate of growth in agricultural production through the 1960's reflects a sharply increased rate of growth in productivity per acre, since essentially all of the increased output has come from higher yields, more intensive land use, and changes in cropping patterns. These observations are supported by what has happened to the use of inputs, which may be just as good a measure of agricultural progress as output. Fertilizer consumption ($N+P_2O_5+K_2O$) increased from 306,000 metric tons in 1960-61 to 1,750,000 metric tons in 1968-69. During the same period the number of electric and diesel pump-sets increased from 421,000 to 1,688,000 and the area covered by plant protection measures from 6.4 million hectares to 40 million hectares. Further, between 1966-67 and 1969-70, area under high yielding varieties of wheat went from 539.8 thousand hectares to 6,103.0 thousand hectares, and for rice from 822.7 thousand hectares to 3,234.0 thousand hectares. One conclusion is clear: the new agricultural technology in the form of high-yielding varieties, an expanded supply of modern inputs and favorable prices resulted in a rate of growth in agricultural output in India beyond what would have been possible without the new technology.

As agricultural development in the poorer countries becomes increasingly technologically based, one must address himself to the issue of how to build scientific institutions and input structures which will generate a steady stream of technological improvements adapted to local ecologicalconditions.

Hayami and Ruttan[13/] have presented a set of principles which represent the minimum requirements of a viable agricultural research system.

1. A viable agricultural research system must be capable of generating new agricultural technologies which are economically viable under local conditions. This principle applies to both mechanical and biological technologies. Variations in physical, biological, and socio-economic environments must be taken into account in the development of agricultural technologies. This means agricultural research must be conducted and the results tested and analyzed within a relatively decentralized research structure. The degree of decentralization should be conditioned, in part, by the economies of scale in research institutions.

2. There must be effective information linkages among the units of a decentralized research system to achieve optimum productivity for the system in contrast to being concerned with productivity of research units individually. As part of the linkage, national research programs should be associated with the work of international research centers

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13/ Yujiro Hayami and Vernon W. Ruttan, op. cit.

such as CIMMYT and IRRI, as well as with the work in other countries. The international transmission of scientific knowledge is an important element of a viable country research program.

3. A viable agricultural research system must be integrally involved with education and training for research. The lack of suitably trained scientific and technically trained manpower represents a serious restraint to the movement of the less developed countries to a scientifically based agriculture. Thus a research system which does not have the capacity to "reproduce itself and mutiply" cannot be considered viable.

Having outlined some necessary principles for a successful agricultural research system, one can go further and discuss certain other desirable characteristics and desirable complementary efforts, without specifying the exact structural form of the research institutions involved. As part of any agricultural development planning process there should exist mechanisms with which to (a) identify critical restraints to agricultural development, (b) evaluate these restraints with respect to the time and kinds of resources (research, investment, administrative, etc.) required to ease or eliminate them and the economic feasibility of doing so, and (c) direct the activities of various agricultural development efforts including research to the specific key restraints where and when they exist.

Such mechanisms will enable a country to move toward an optimum combination of technological, resource, and institutional based development which takes advantage of the complementarities which exist among the three ingredients. By appropriately defining agro-climatic regions which exhibit a reasonably high degree of homegeneity with respect to physical, economic, institutional and social criteria (soils, climate, topography, cropping patterns and intensity of cropping, investments in fixed capital and infrastructure such as irrigation and transport facilities, population density, and certain key aspects of social organization and institutional development), one can get better congruence between problems and the resources required to deal with them. This, in turn, would lead to more efficient use of scarce developmental resources--capital, research talent, and administrative skills.[14/] It would also help in the planning of international agricultural research. Areas in different countries with similar technological problems could be more sharply delineated. Sharper focus could be given to international research efforts and exchange of research and developmental experience among countries would be facilitated.

To date, the major research and production focus has been on individual crops like rice and wheat. This type of research will and should continue for food crops and nonfood crops as well. However, a new dimension is being added to research in agricultural development which is the combination of crop (and livestock) enterprises which can lead to an intensification of agricultural production particularly in areas where land is one of the most limiting factors. In part this will involve some modification of the production environment. (This aspect of the problem is discussed in more detail in the next section). In large measure, however, it will envolve the improvement and adaptation of several crops to a particular environment. The focus of this work goes beyond increasing yield of individual crops and includes the

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14/ A more detailed discussion of the concept of planning agricultural development on the basis of agro-climatic regions and key restraints to production and employment can be found in Martin E. Abel and K. William Easter, Agricultural Development Planning and Program Evaluation With a Focus on Regional Restraints, paper presented at the Rice Policy Conference, International Rice Research Institute, Los Banos, Philippines, May 9-14, 1971.

development of viable cropping patterns which increase productivity per unit of area. Among other things, this research may include shortening the growing season of some crops, developing ways to conserve soil moisture and using it more efficiently, and introducing new crops into rotations and areas and the attendant development of markets for them. In short, there will be more effort to deepen and broaden agricultural development.

As agricultural development becomes based more on technology and less on the use of traditional resources there occurs a growing need for the development of institutions which will permit the exploitation of the new technology and distribute its benefits in ways which result in a tolerable distribution of income, minimize social and political tensions, and permit a reasonably orderly process of development. This will not be easy to do in most cases because of inherent social and economic inequities of long standing. These inequities inevitably get highlighted by rapid change based on new technology. As Ladejinsky has stated about India:

> "It is not . . . the new technology which is the primary cause of the accentuated imbalances in the countryside. It is not the fault of the new technology that the credit service does not serve those for whom it was originally intended; that the extension services are not living up to expectations; that the panchayats are political rather than developmental bodies; that security of tenure is a luxury of the few; that rents are exorbitant; that ceilings on agricultural land are notional; that for the greater part tenurial legislation is deliberately miscarried; or that wage scales are hardly sufficient to keep soul and body together." 15/

15/ Wolf Ladejinsky, "Green Revolution in Bihar--The Kosi Area; A Field Trip," Economic and Political Weekly, Vol. IV, No. 3, September 27, 1969.

Bringing about institutional changes that provide cultivators with needed inputs, handle expanded outputs, and provide new technologies in ways which also result in a tolerable distribution of the benefits of such change will not be easy. Yet, unless a country wants to completely reject the development and use of new agricultural techniques, which would have its own dire developmental consequences, the institutional problems of technologically based agricultural development will have to be faced. For many developing countries, the rapid growth of agricultural production at progressively lower real costs is a necessary condition for successful economic development.

Technology, Resource Development and the Environment

One of the signal characteristics of the new high-yielding varieties of food grains is their sensitivity to the physical (and economic) environment in which they are grown. The new varieties of wheat and rice were bred to achieve a high yield response to heavy applications of fertilizer. A related factor in the realization of the high yield potential of these varieties is the availability of water in correct amounts and on a timely basis. This means improving the degree of water control involving both controlled application of water and drainage systems capable of removing excess water. In addition, disease and insect problems will have to be made manageable whether by means of external control or by developing better inherent resistance in the plant.

In a study of the performance of the high yielding varieties of rice and wheat in Asia, Barker concludes that:

"Data have been presented to support the hypothesis that differences in environmental conditions and not farmer's ability or knowledge have been responsible for the outstanding performance of the new wheat as compared with the new rice varieties. The typical environmental conditions under which the two crops are grown differ markedly. The production functions suggested that the potential response the high yielding rice varieties is equal to that for the new wheat varieties under the same environmental conditions. However, given the difference in growing conditions for dry climate wheat and rice as compared with rice in the monsoon not only the degree of response but the year-to-year variability in response must influence the farmers willingness to apply inputs. The wide differences that can be observed in production gains to date give support to the importance of the environment.

Acceptance of the above hypothesis has important policy implications for Asian countries. Sustained gains in rice production can be achieved principally by reducing the risk and uncertainty facing farmers. Continued effort will be required to improve and expand irrigation and drainage facilities. At the same time, more attention will need to be given to improvement of production potential under rainfed and upland conditions. It will be necessary to invest adequate research funds in the development of insect and disease resistant varieties. Resistant varieties for the long run appear to offer a more fruitful approach than emphasis on insecticides which for the individual farmer are expensive and offer uncertain benefits." 16/

There are two major problems in resource development and improving the production environment which many developing countries face. First, new technology can call for different levels and intensities of resource use. Previous investments, such as the traditional flood irrigation one finds in much of South and Southeast Asia, may not enable the full exploitation of new technological potentials. But even worse, most new investments are being made along traditional lines even with knowledge about the availability and characteristics of the new

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16/ Randolph Barker, Environmental Factors Influencing the Performance of New High Yielding Varieties of Wheat and Rice in Asia, International Rice Research Institute, Los Banos, Philippines (mimeo).

technology. There is a considerable inertia which needs to be overcome, as the present situation represents a considerable squandering of investment resources. Second, some investments required to improve the production environment involve significant divergences between social and private costs and returns; certain externalities are inherent in these resource developments. Generally, developing societies are not aware of these situations either because of a lack of technical information or an understanding of the economics of the investments involved. Even in cases where they are recognized, the societies may be unable to exercise the type of regulations (controls, taxes, pricing policies, etc.) which can be used to eliminate the discrepancies between private and social net returns.

One particular area of investment in which these problems are found in abundance is soil and water resource development, so important in exploiting the yield potential of the new high-yielding varieties of cereal grains. These problems can take many forms and I would like to discuss a few of them. I will draw primarily upon my knowledge of and experience with Indian agricultural development, although the examples of the problems I give can be readily found in several other countries.

The new high-yielding varieties of wheat and rice have increased the demand for water available in adequate amounts and with a high degree of control in its use on individual fields. In some of the wheat areas, it has taken the form of rapid growth in the use of private tubewells. Both the social and private returns have been high. However, several problems are beginning to emerge.

In many areas ground water resources are being exploited with little knowledge of the nature of these resources. There is preciously little information about the size of the ground water resource, its quality, rates of recharge, etc. Continued, unregulated growth of private tubewells could lead to serious overexploitation of ground water resources resulting in rising costs to all producers in an area.

Many areas which can be irrigated by tubewells either have canal irrigation or the potential for it. Yet, little has been done to plan for the conjunctive use of surface and ground water. The canal systems generally are poorly designed and managed in relation to the controlled water needs of the new high yielding varieties. Thus, even with the presence of canal water, farmers prefer tubewell irrigation. Thus, canal water is not being used efficiently. Integrated planning for the use of both surface and ground water could lead to significant improvements in water use. However, a necessary component of better use of water is the improved design and management of canal systems.

Another problem related to canal irrigation (and hydroelectric power as well) is the loss of irrigation potential as a result of silting of reservoirs and irrigation canals. In many of the hilly areas which are the watersheds for canal irrigation systems, there is a great deal of soil erosion. This results from a relatively high population density in the hill areas and pressure to grow subsistence crops--mainly cereal grains--requiring annual cultivation of the land. The soil erosion problem of the hills become an important external cost to the people dependent upon canal irrigation and power. So far, this problem has not been seriously dealt with.

In drier areas there are also serious problems of overexploitation of resources. Unregulated grazing of animals and relatively intensive cropping have led to a great deal of water and wind erosion of the soil. The loss of soil productivity is substantial. Here to, some regulated forms of land use are required, as are new sets of production technology.[17/]

In all of the above examples of problems in the soil and water domain, three areas seem to be of great importance. The first is more information about and a better understanding of the technical (physical) relationships involved. The second is a better understanding of the type of technological innovations which can help to solve some of the problems and possibly also deal with some aspects of the externalities involved. Finally, and in the long run possible most important of all, is the creation of institutions which will permit collective action in dealing with these externalities. These institutions could (a) be regulatory in nature such as controlling the density of tubewells in an area or the intensity of grazing; (b) facilitate cooperative management of resources such as water-users associations for the collective management of canal irrigation systems; or (c) facilitate the implementation of economic policies such as pricing of resources, taxes, and subsidies which would narrow or eliminate differences between private and social net benefits. Considerable improvement will have to take place in information, research, and training systems to provide a basis for rationally bringing about improvements in each of the above areas.

17/ For a good discussion of problems involved in developing agriculture in arid areas of India, see N. S. Jodha and V. S. Vyas, Conditions of Stability and Growth in Arid Agriculture, Agro-Economic Research Centre, Vallabh Vidyanagar, 1969

The development of forest resources represents another neglected area in many developing countries. For many countries more intensive and systematic development of forest resources would provide additional employment opportunities and the opportunity to earn greater foreign exchange either through import substitution or expanded exports of forest products. In addition, forestry can play an important role in implementing sound programs of land management. In some areas forest resources have been over exploited resulting in serious problems of soil erosion, silting of reservoirs and canal irrigation systems, and flooding. Some of hill areas of India and Nepal offer excellent examples of these problems. Programs of reforestation in these areas offer a partial solution. However, such programs will have to be part of a more comprehensive development plan for these areas. The present problems resulted in large measure from heavy population pressure on a scarce land resource for food, fuel, and timber. This pressure will have to be eased in order to have successful reforestation or improved forest management programs.

Attention will have to be given to the income and employment potential of a combined agriculture and forestry base for a region. And, where these two sectors do not provide sufficient opportunities, sources of nonagricultural employment will have to be developed to allow a more extensive and yet socially more desirable use to be made of some of the land resource. But even with the development of nonagricultural employment, there still may not be sufficient income producing activities in some regions. In such cases three alternatives exist. First, people may move out of the area into nonagricultural jobs. This, however, is not a promising possibility in many developing countries because of the already high rates of under-and unemployment in the nonagricultural sectors. Secondly, a sufficiently rapid rise in agricultural production of a labor-using type in other areas could provide employment opportunities requiring people to move out of the hilly areas with poor resource endowments. In some situations, this could be a major secondary contribution of rapid technological advance in agriculture of an appropriate type.[18/] Finally, one could consider a program of income transfers from areas affected by certain negative externalities to those areas generating them as a means of eliminating the problem. Certainly, it would be worth something to farmers in the valleys or on the plains not to have their irrigation systems silted as a result of poor soil and water management in the hills. A transfer of resources from the farmer area to the latter could be used to improve soil and water management practices, including paying farmers a subsidy to alter land use practices. However, means by which to effect such transfers are not readily at hand.

Insect and disease problems represent another area of serious concern, particularly in tropical and semi-tropical regions where crops are produced during most of the year. There is a need for plant protection policies and the basic scientific and economic information on which they should be based. The present general approach to the problem is to genetically build in resistance to insects and diseases in the plant. This approach has considerable merit. First, many of these

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18/ In the United States the combination of rapid technological advance in the agricultural areas with good natural resources and rapidly rising nonagricultural employment reduced the pressure for people to continue to exploit marginal lands. Thus some of the soil, water, and forestry problems which we encounter in the hilly areas of India and Nepal, and elsewhere either did not emerge or were made manageable in the United States more as a result of general patterns of economic development than as a result of programs designed to deal with them, although the impact of the latter were by no means insignificant. I am indebted to Vernon W. Ruttan for bringing this point to my attention.

problems cannot be effectively controlled through application of plant protection materials applied by individual farms. In areas of numerous, relatively small farms the action of an individual farmer tend to be negated by the inaction of some surrounding ones. Second, trying to control these problems on a large-area basis is costly and, in some cases, potentially hazardous. An effective disease and insect warning system would be required which for some years to come is beyond the administrative and technical skills available in most developing countries. Without such a system, plant protection materials would have to be applied routinely and this greatly raises costs. Further, in agricultures characterized by small land holdings, there is little separation of plant and human populations. The exposure of large numbers of people to plant protection materials (say from an aerial spraying program) could be hazardous to the human population. Finally, much of the plant protection material has been developed in the rich countries and is directly transferred to the poor ones. Some of it works, but much of it doesn't in the new environment.[19/] Emphasis on the use of plant protection materials in the develping countries would have to involve the extensive development of indigenous research capacity and chemical industries, which would also be costly. Only in this way can we be sure of developing plant protection materials which are highly and selectively effective in combating the disease and insect problems in the developing countries. It is not clear that this approach is economically superior to breeding for resistance.

19/ It is the case that certain chemical substances which degrade slowly in temperate climates and are, therefore, environmentally undesirable may be both effective and desirable products in the tropics because they degrade sufficiently rapidly under tropical conditions and pose no threat to the environment.

In addition to the physical environment in which agricultural production takes place, we should also look at the institutional environment which has already been alluded to as well as key economic policy issues. There is a close relationship between the policy and institutional environment and appropriate directions for technological and resource development.

In almost all developing countries, particularly those in Asia, a major consideration is how to enable the small farmer to participate in agricultural development. A companion consideration is how to increase rural employment more rapidly to provide better employment and income opportunities for the landless labor and small landowners who rely on wage labor for part or all of their incomes. Briefly, there are at least three reasons for being concerned about the income and employment opportunities of the small farmers and landless laborers. First, extremely uneven distributions of rural income can result in explosive social and political instability which undermines orderly economic development. Second, the future food and fiber needs of most countries cannot be met unless the small farmers increase their output and productivity. Finally, improving the incomes of small farmers and landless laborers creates a demand for the products and services of the nonagricultural sector and contributes to the growth of these sectors. An important aspect of the latter point is that the goods typically demanded by the rural poor can be produced with labor intensive techniques, thereby contributing to more rapid growth of employment in nonagricultural sectors.

The participation of the rural poor in the development process is something which will not automatically happen. A variety of policies and programs will be required. I would like to mention briefly some of the important actions required.

First, in many developing countries capital is underpriced and labor overpriced in terms of their real values in production. This type of factor pricing works in the direction of employing capital intensive forms of production in situations where just the opposite should be encouraged. Adjustments in factor-pricing policies would be an important step toward improving the distribution of income and employment.

Second, investment and pricing policies governing resource development, particularly the improvement of land and water resources, should permit the small farmer to benefit from these developments. This means that the design and management of these investments should be at least neutral with respect to farm size.[20/] Irrigation and drainage prospects should not favor large over small farmers, and soil and water conservation measures should be available to farms of all sizes.

Third, small farmers should, on the one hand, have ready access to new technologies, and on the other, their technological needs should be a significant part of agricultural research efforts. This requires an agricultural research and extension structure which is motived (or compelled) to generate economically viable techniques suited to the needs of small farmers and capable of getting these research results out to them.

Fourth, small farmers should have equal access to farm input (including credit) and product markets. They should not be discriminated against because of their size, tenurial status, or social characteristics.

20/ It is recognized that it may not be possible to avoid discriminating against certain very small holdings in many resource development efforts.

Finally, and governing several of the above points, small farmers should have the same legal rights and political representation as the large ones. For without this they can't have security of tenure on the land and their interests given due representation in the institutions which serve agriculture.

It follows from these now generally accepted points that while science and technology will represent the "engine for change" in the process of agricultural development in the poor countries, translating it into a real force for economic development will require drastic social, political and institutional changes. New technologies of the biological and chemical type (seed and fertilizer) generally are in themselves neutral with respect to scale. However, where these technologies are highly productive and profitable they will (a) highlight inherent inequities of long standing in social and political structures and (b) simultaneously create the demand for a large variety of changes. With advances such as the new high-yielding varieties of cereals, farmers, particularly the smaller ones, will demand improvements in water resources because water is now a more productive input; they will demand more credit because purchased inputs are essential for the production of the new varieties; they will want access to the new inputs; and they more than ever will desire a tenurial status under which the legal system in fact treats them as equals and with which they can participate equally in factor and product markets and in the institutions which collectively manage provision of inputs and the disposal of outputs.

Conclusions

There are several other points which emerge from this assessment of future agricultural development in the poor countries. There will be a high payoff to the further development of national, regional, and international research programs capable of generating a continuous stream of economically viable agricultural technologies; capable of generating information on and analyses of the needed directions for scientific advancement and the developmental (economic, social, and political) consequences of alternative technological changes; and capable of determining the directions which economic policies should take in order to sustain developmental efforts through allocations of resources which are consistent with factor endowments and social goals. Considerable investments will also be required in resource and institutional development needed to realize the benefit of the new technologies. And, on the resource side, problems of externalities will probably become relatively more important.

There are opportunities for development assistance organizations to help in achieving these objectives. However, careful attention should be given to the professional quality and form of such aid so that it is productive in the short-run and in the long-run leads to viable research and information institutions in the developing countries.

It would also seem that many of the future agricultural development problems in the poor countries are social, political, and organizational in nature and foreign financial assistance (the support of research aside) cannot "buy" the desired results. These are problems which the poor countries will have to solve themselves. Development assistance organizations should recognize this point. They should not promote assistance in amounts and forms which perpetuate undesirable economic policies such as financing unnecessarily capital intensive investments. On the other hand, they could emphasize investments contributing to increased agricultural output, increased employment, and improved distributions of income and, in the process, effect and support improved sets of economic policies in the developing countries.