Agricultural Development
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FOREWORD

For the past quarter of a century a number of international agencies, development assistance agencies of the more-developed countries, and several private institutions and organizations, including The Rockefeller Foundation and the Ford Foundation, have been providing extensive help to the developing countries. These programs, designed to foster economic and social development, have included grants and personnel for technical assistance, and extensive development loans. Despite this external aid and the efforts of the developing countries, the gap between the developed and the developing nations has been widening rather than narrowing. There has been progress in economic and social development in the developing nations, but the rate continues to be less rapid than in the more-developed nations.

In recent years we have become increasingly aware that in the underdeveloped nations, most of which are predominantly agrarian, agricultural development must precede or at least be concomitant with industrial and other economic and social development. We now understand, better than in the past, that a modern industrialized society cannot be built on the quicksand of a traditional subsistence agriculture, particularly in nations where 75 to 85 percent of the people are engaged in agriculture. We now realize that if the developing nations are to catch up with the developed nations, they must make massive strides in increasing the productivity and efficiency of their agricultural sector.

Many of the programs and projects of assistance provided to the developing nations over the past 25 years were concerned with agriculture, but in most cases the results of these programs have been disappointingly small. In the developed countries—represented by Europe, North America, Japan, and Oceania—there have been substantial increases in productivity per acre of crops and animals. All or almost all the increases in agricultural production in these countries have come from increased yields per acre, the total amount of cultivated land having actually decreased in most of these nations since 1950. In contrast, increased production in the developing countries has come almost entirely from the cultivation of additional land; the yields per acre have, in most cases, remained static.

Meanwhile there has been deepening concern about the food gap in the face of rapidly expanding numbers of people. Increases in food production in the developing countries have hardly kept pace with growth in population, so that in most countries there has been no increase in per capita food production and in several, in fact, there has been a sharp decrease. Since it is in these developing countries that the most critical food shortages already exist, the decline in per capita food production exacerbates an already serious situation.

Some authorities, viewing the lack of success of past efforts to achieve agricultural development in the developing countries, have expressed despair regarding the possibility of increasing agricultural production rapidly enough to keep up with the growth in human population over the years ahead. One eminent scientist and writer has, in recent months, expressed pessimism about the possibility of avoiding a collision between a soaring population and a limited world food supply. He foresees the beginnings of local famines in 1975-80 and a world engulfed in a sea of famine by the century’s end unless, he says, there is a concerted assistance effort by the rich countries, massive effort by the poor countries to revolutionize their food production, and a reduction in population increase throughout the world.

In the past two or three years there have been, however, strikingly encouraging developments in ag-
gricultural productivity increases in a few countries. These results generate optimism regarding the possibility of increasing food production rapidly enough to close the food gap over at least the next two or three decades, and thus buying time for population programs to reduce the rapid rate of population growth. In such critical countries as India, Pakistan, and the Philippines there have been striking increases in production of the major cereal grains—rice, wheat, maize, and sorghum. In 1967-68, the Republic of the Philippines became, for the first time in this century, self-sufficient in rice. West Pakistan produced enough wheat and almost enough rice to meet its current needs and is beginning to worry about surpluses. Kenya had a surplus of maize. India's 1967-68 food harvest exceeded by 10-15 million tons the best previous crop, and the wheat crop was 50 percent higher in that year than it had ever been. The facts and figures of this agricultural revolution—frequently called the green revolution—have been reported and commented upon so many times that it seems hardly necessary to repeat more of them here.

The Rockefeller Foundation believes that there are lessons to be learned from these recent successes and from the failures of the past. Accordingly, it invited the officials who determine policies and programs of the major international, national, and private development agencies to a meeting at the Villa Serbelloni, Bellagio, Italy, for the period April 23-25, 1969, to consider the implications of these recent events and to discuss needs, potentialities, and priorities of programs designed to sustain and to extend the agricultural revolution. A list of participants is included in this publication.

The program, planned by officers of the Rockefeller and Ford Foundations, provided minimal structuring in the interests of encouraging participants to concentrate on major issues and of allowing them the greatest opportunity to exchange information and views. A major topic was scheduled for discussion during each of the five half-day sessions, and resource papers were commissioned on each topic. These papers were distributed in advance of the conference, and each paper was summarized at the beginning of the appropriate session by the author or an official of the agency that prepared it. The remainder of the session was available for discussion of the topic by the participants and the consultants.

This was intended to be an off-the-record meeting, and therefore no formal record was made of the discussion and no official conclusions were developed. One of us prepared a summary, which was presented orally at the end of the final session. The comments of participants were considered in the preparation of the final draft of the summary. It is believed to reflect the principal conclusions and concepts developed during the conference. It was not, however, presented to the participants for adoption and cannot, therefore, be considered a formal report of the conference.

Requests by agency heads—both during and after the conference—for additional copies of the resource papers and of the summary prompted the publication by The Rockefeller Foundation of this document.

W. M. Myers

Will M. Myers, who is vice-president of The Rockefeller Foundation, joined the Foundation staff in 1965 as an associate director for agricultural sciences. Formerly, he was dean of the Office of International Programs at the University of Minnesota, and, from 1952 to 1963, head of the Department of Agronomy and Plant Genetics. Dr. Myers has served as a member of the Agricultural Board and as chairman of the Latin American Science Board of the National Academy of Sciences.
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AGRICULTURAL DEVELOPMENT
WORLD NEEDS AND POTENTIALS IN AGRICULTURAL PRODUCTION

Food and Agriculture Organization of the United Nations

Analysis of world needs and potentials in agricultural production clearly shows the correctness of the view that more emphasis must be given to agriculture within the context of balanced economic development. This increased emphasis will need to center in the developing countries where population growth combined with increase in incomes is rapidly pushing up the demand for food. In the developed countries, production capacity in agriculture is expected to continue to grow faster than production needs, but the contribution of this capacity to solving the food problems of the developing countries will continue to be limited by the lack of foreign exchange in these countries for commercial imports and the hardening of concessional terms.

Fortunately, however, the potential for food production in the developing regions now appears to be in a stage of transition, giving grounds for cautious optimism. After a long period in which production per caput in developing countries has risen so slowly as to present a most unfavorable prospect for the future, it now seems that the potential exists for a much more rapid increase. Long years of patient activity in such fields as research and extension and long-term investments in water development, agricultural institutions, and infrastructure, as well as the much greater emphasis on agricultural development than before, have begun to bear fruit. The high-yielding varieties of cereals represent an important aspect of this breakthrough.

The difficulties in transforming these potentials into solid achievements must not be underestimated. Increased production will come largely from increased yields, which will require large increases in supplies and use of purchased inputs and water resources. Drastic changes in agricultural technology and price and production patterns will also be essential. More rapid agricultural development thus will require increased efforts, increased investments, and improved production, price, and trade policies. Besides the foreign exchange for import of the needed inputs, it will require improved administrative organization and institutions. Consequently, the ability of the developing countries to meet the rapidly growing demand for food and other agricultural products must still be regarded as a hope rather than a reality.

If, however, the opportunities now offered can be seized, there is real prospect for a more rapid improvement in the food situation and the achievement of a less precarious equilibrium between population and food supplies. Continued uncontrolled population growth could, however, still cause these hopes to be dashed. It is necessary, therefore, to redouble efforts to slow down the growth of population. At the same time it must be recognized that, for a variety of reasons, results from such measures are slow. Such policies are not likely to affect food demand significantly for another decade or so, while the effect of the current rapid population growth will continue to pose employment problems for a long time to come.

FOOD DEMAND

The increase in food requirements of the developing countries will amount to between 3 and 4 percent per annum over the next couple of decades. Population growth is expected to account for at least two-thirds of this increase in food demand. The growth in per capita income will increase the demand for protective foods (vegetables, fruit, and, in particular, livestock products). Thus, while the overall growth in food demand is of the order of 3 to 4 percent per annum, that for livestock products is expected to be 5.5 percent per annum at constant prices. Since it is the consumption of such products that makes for an overall improvement in the nutritional balance of the diet, there is a compelling reason to satisfy this additional demand. In addition to satisfying commercial demand, a crucial need exists in these countries for welfare policies for relieving malnutrition and hunger.

The Food and Agriculture Organization of the United Nations was established in 1954. The aims of the organization are to raise the levels of nutrition and standards of living; to secure improvements in the efficiency of production and distribution of all food and agricultural products; to better the conditions of rural populations; and to thus contribute toward an expanding world economy and humanity's freedom from hunger.
The rapid pace of urbanization will require production for the market to be expanded even more rapidly than total food production. It is estimated that between 1962 and 1985 the urban population in developing regions (excluding mainland China) will increase by about 420 million, representing a growth of about 160 percent. Particularly striking is the anticipated threefold increase in urban population in Africa south of the Sahara, which will necessitate an increase in marketed output for the domestic market of approximately 6 percent per annum as against an increase in agricultural output as a whole of about 3.3 percent.

More or less the same development can be expected to take place in many of the other developing countries. Increased production for the market on this scale would call for adequate economic incentives to the farmer and improvements in price policies, storage, transport, and marketing.

The prospects for increasing production in the context of prospective demand can be usefully discussed in relation to (a) cereals, (b) other food crops and livestock, and (c) the traditional export crops.

**Cereals**

In a number of developing countries there are signs of a substantial acceleration in the rate of growth in cereal production. The pilot review, undertaken by FAO in 1968, of the medium-term food outlook in 21 developing countries indicated that in most of these countries a considerably more rapid rate of growth than in the past was expected in the 1966-71 period. Countries where production is likely to reach growth rates of more than 4 percent included India, Pakistan, the Philippines, Malaysia, Turkey, the United Arab Republic, Tanzania, Senegal, and Venezuela.

Several of these countries appear likely to reach approximate self-sufficiency or have export availabilities in one or more of their major cereal commodities by 1975 or before. While the levels of grain production of the traditional exporters can be expected to be within the limits of what each can sell in domestic and foreign markets, it is apparent that substantial reserve capacity will continue to exist in these countries. Consequently, the pressure on world markets may well be intensified. A number of developing countries will therefore need to anticipate whether production should be expanded to produce grains for export, or the resources that could be released used for producing other agricultural products to meet expanding needs for protein and other foods of nutritional importance. This will involve important shifts in price, marketing, and storage policies to support the diversification of production.

In the longer term, the studies of the Indicative World Plan indicate that the production potential exists for increasing cereal production faster than in the past and faster than the growth in demand for human consumption in the developing countries. These potentials reflect the breakthrough in the use of modern technology in cereal production, of which the most striking illustration is found in the use of the new varieties of wheat and rice. The package of new seeds and increased use of other inputs has frequently doubled yields per hectare. The new varieties can have their greatest impact in the food-deficit countries of Asia and the Far East over the next two decades. Estimates made for the Far East regional study of the IWP, for example, indicate that in the eight countries covered at least half the total cereals' area could be devoted to high-yielding varieties by 1985, as compared with 10 percent in 1967-68. This would imply the provisional conclusion that there could be sufficient rice, wheat, and maize available for export from surpluses within Asia to exceed the import requirements of deficit countries in the region. The improved outlook for cereal production thus can have considerable impact on patterns of world trade. Potentials in other regions, despite some notable exceptions, do not seem to be as dramatic.

The new varieties transform the production situation by substantially altering input-output relationships and greatly raising the yield ceiling for profitable application of fertilizers, water, and other inputs. Because of the increased requirements for pesticides and fertilizers, the continued extension in their use will require massive increases in the use of purchased inputs, which may be a limiting factor. Large investments in research, irrigation works, fertilizer plants, and machinery also will be needed, as well as the use of foreign exchange to import the production requisites that cannot be produced locally.

Developments in the technology of cereal production can have a striking impact in important countries and regions, affecting both trade patterns and consumption levels. They offer the promise of substantially alleviating the problems of ensuring adequate consumption of cereals, the staple food of the majority of the world population. These developments also can furnish increased feed concentrate supplies for livestock to produce more protein in some countries, provided prices of cereals can be reduced and there is an improvement in the price relationship between feeds and livestock products.
But the developments in cereal production will not by themselves resolve the world food problem. There has so far been no comparable breakthrough in the production of high-protein foods, which alone can resolve the problem of widespread malnutrition and will experience the highest rates of growth in demand. Cereal crops, because they are a main source of protein, can make a contribution through increased yields and by permitting the release of land; the development of cereal varieties with a higher protein content can also be important. But major attention will need to be given to the expansion of the production of pulses and certain oilseeds, especially groundnuts and soybeans. The IWP regional study for Asia and the Far East envisages a substantially high rate of growth, of about 9 percent per annum, in pulse and oil-crop production in the period 1962-85. The attainment of this growth rate is dependent on greater effort being devoted to research and related programs to produce and distribute improved varieties, as well as on price policies for these crops vis-à-vis cereals.

LIVESTOCK PRODUCTS

It is in meeting the demand for livestock products in the developing countries that the most challenging problems of production may arise. In the past, livestock production in the developing countries has hardly shown an increase of more than 1.5 to 1.7 percent per year, much below population growth. Studies carried out for the IWP indicate that, as against a projected rate of growth in demand of 5.5 percent per year for livestock products in the period 1962-85, the targeted growth rate in production is only about 3.4 percent per year. The technical and institutional constraints on faster growth of the livestock industries are the main reason why production growth falls short of the projected domestic demand in all the developing regions except South America. To meet the entire deficit in livestock production by imports would impose a great strain on the balance of payments of most of the developing countries. Nor will there be enough supplies of meat in the world market to do so, for import demands are likely to increase in the developed countries as well.

Even if the maximum rate of growth that seems feasible is achieved, the prices of livestock products are likely to rise substantially. Some rise in livestock prices is indeed essential to provide the incentive to the producer. However, this would impose a greater hardship on the lower-income groups in the population and thus widen the disparity in protein intake between income groups. Closing the gap between production and demand will require radical changes in price and other policies to encourage the use of feed concentrates, increase the production of forage and pasture, improve productivity, and reduce barriers in international trade, including those resulting from animal diseases. According to the regional studies of the IWP, the use of feed concentrates alone would have to grow by more than 4 percent per annum between 1962 and 1985.

To overcome the protein deficiency expected in the developing countries, greater intake of vegetable protein also would have to be aimed at. This lends added emphasis to the need to increase the production of pulses and oilseeds. At the same time, non-conventional sources of protein must be explored and, where economically feasible, exploited. Consideration might also be given to partially shifting the emphasis of food aid from supplying calories to providing protein and other protective foods.

TRADITIONAL TROPICAL EXPORT PRODUCTS

While for livestock products the major problem is production, with regard to the traditional tropical export products—oilseeds, sugar, coffee, cocoa, tea, etc.—the major problem for the developing countries is to find a market outlet. Here the trade and, in some cases, production policies of the developed countries will play a crucial role. There is the need to lower or remove restrictions such as excise duties and import controls on the consumption of tropical beverages. A change in production policy is needed in the developed countries, aimed at reducing the level of self-sufficiency in respect of sugar, in the production of which many developing countries have a comparative advantage. Similarly, in respect of vegetable oils and oilseeds, the developing countries are in a position to export more if a more liberal import policy, especially regarding processed products, is followed by the developed countries. But even with improved policies, expansion in exports seems likely to be slow in view of the only modest rate of overall growth in import demand in the developed countries, especially for tropical beverages. This is due to the slow rate of population growth and low income elasticity of demand for these products in developed countries. The expansion of import demand for agricultural raw materials (cotton, wool, jute, hard fibers, and rubber) in the developed countries is also limited by increasing competition from synthetics and other substitutes.

These factors would adversely affect especially those developing countries which depend for the bulk of their foreign-exchange earnings on export of one
or two commodities. While diversification of their economies is desirable, there are difficulties in implementing such a policy in view of specific ecological conditions, lack of substitutability between crops, and lack of research on diversification. Greater emphasis would therefore have to be placed on raising the level of efficiency of production, from planting to processing.

AGRICULTURAL INPUTS AND INVESTMENTS

The regional growth rates in gross value of total agricultural production considered feasible by the IWP studies over the period 1962-85 range between 3 and 3.8 percent per annum. Even to attain these modest growth rates, the use of purchased inputs would have to expand substantially; the consumption of chemical fertilizers would have to increase more than tenfold, from about 3 million tons in 1962 to about 33 million tons in 1985, and mechanization would have to develop at a rapid pace to increase the productivity of land and labor. Considerable investments would have to be made in irrigation, land improvement and development, agricultural mechanization, fertilizer and pesticide plants, and in grain storage; the bulk of the investments, as indicated by the regional studies of the IWP, would be on irrigation and farm mechanization.

Financing development in agriculture depends not only on tax and savings policies in the developing countries but also on their capacity to meet the foreign-exchange component of the investment requirements. Apart from aid which might increasingly be directed to supplying production requisites, an enlightened trade policy on the part of the developed countries would contribute significantly to foreign-exchange earnings required for achieving the level of investment called for.

In the preparation of the Indicative World Plan the emphasis has been placed on achievable targets, but these targets presume that the necessary trade, investment, institutional, and price conditions can be effected. In agriculture this will be critically dependent on dynamic macro-economic considerations. The capacity of the developing countries to organize and finance the necessary agricultural development programs will be a basic factor. Equally important will be the avoidance of further deterioration in the terms of trade for export products. Finally, the monetary and aid policies of the developed countries and the investment policies of public and private organizations will need to permit an expansion in the outside resources available to the developing countries.

AGRICULTURAL EMPLOYMENT AND INCOMES

A basic purpose of development is to increase incomes and standards of living. This is particularly important in agriculture, which includes a large part of the population having the lowest incomes. But obtaining substantial increases in farm incomes may prove to be one of the most difficult problems. A rate of increase of less than 2.5 percent a year in overall agricultural income per head during the period covered by the IWP suggests the likelihood that the already wide gap between agricultural and nonagricultural income will continue to widen in most countries.

The main factor influencing income potentials will be the change in the number of people engaged in agriculture, which will depend upon the rate of population growth and the extent of nonfarm employment attained. In most developing countries the increase in employment in other sectors will not be sufficient to provide for all the increase in rural and urban populations. Agricultural population will continue to increase in absolute terms, and in many of these countries agricultural development will consequently have to take place in the context of a decline in the average area cultivated. In the past, the developing countries were able to increase their agricultural production mainly by extending the area under cultivation. In many countries, particularly in Asia, there now remains very little leeway to bring new land under cultivation, and greater reliance will have to be placed on increasing productivity per hectare.

Now that there is a better chance of assuring basic food supplies, it is becoming possible to pay more attention to such problems. However, there is no doubt that problems of rural unemployment and underemployment will loom very large in the coming years. There is also the danger that disparities in income may widen within the agricultural sector itself. The rural areas of most developing countries will, for a long time to come, contain large numbers of farmers with little economic opportunity beyond the production of their own subsistence needs. The persistence of such groups will be prolonged by the continuation of rapid population growth, as well as by policies of concentrating scarce resources on more favored areas. Labor-intensive methods of production should obviously be encouraged where feasible. A better balance must be struck between the need to concentrate on the more advanced producers, so as to obtain the most rapid increase in urban food supplies, and the need to develop more productive em-
ployment opportunities for all farm people. The growth in agricultural input and processing industries can be a means for providing increased employment opportunities.

SUMMARY

Because of the rapidly expanding demand for food, faster development of agricultural production will be required for economic development in the developing countries. Faster development of production will increasingly require investments by the cultivators, by the governments, and by international public and private enterprises. Not least of the problems will be the supply of trained manpower to staff the institutions, which themselves will have to undergo radical changes. Whether the necessary investments will in fact be forthcoming, in total and of the right kind in the right places at the right times, is by no means certain. Equally important is the need for dynamic adjustment of the agricultural sectors in all countries—a selective expansion of agricultural output to meet national and international changes in demand. In this context, liberalization of trade has a key role to play. Finally, the development of food production potentials, through the application of new technology, will need to be obtained in such a way as to bring increased per capita income in the agricultural sector.
INTRODUCTORY NOTE BY THE DIRECTOR-GENERAL

The following paper sets forth the FAO viewpoint on the significance and the possibilities for developing countries of the recently developed high-yielding varieties of cereals—the most exciting breakthrough in tropical and subtropical agriculture for a great many years. While it has been drafted primarily for circulation to governments, I believe that the analysis it contains will be of general interest to participants in this conference.

I would like in this introductory note to draw particular attention to the following lines of attack which, in our opinion, need to be emphasized both by aid-givers and by aid-receivers if future progress is to live up to present expectations.

RESEARCH

The success of the high-yielding varieties of wheat, rice, and other cereals is a remarkable vindication of the policy of the Rockefeller and Ford Foundations in giving long-term financial and technical support to major research efforts in the developing areas themselves. I hope that this will encourage the “official” aid programs to give increased backing for such research; support needs to be given without expectation of, or pressure for, quick and spectacular results. The foundations are continuing and intensifying their work, but the needs are vast.

Further research is urgently required at both international and national levels. Internationally, the available high-yielding varieties are not suitable for all areas. Those participants in this meeting who are also involved in the current moves to establish a West African Rice Association will recall, for instance, that the rice varieties evolved in the Philippines have not performed effectively under West African conditions; new varieties need to be developed. More important, the current high-yielding wheat varieties must, in most developing countries, be grown on irrigated land. Improved varieties suitable for rain-fed agriculture could bring even wider benefits—to both the farming communities and the general economies of many developing countries. I would also mention the need for improved varieties of other food crops, as set forth in the following paper. At the national level, the valuable character-

istics of the local varieties, which are adapted to prevailing agro-climatic and biological conditions and suited to local tastes, need to be incorporated in the available high-yielding varieties. Continuous research is needed to breed new varieties: Such “genetic diversification” is indispensable for reducing the risk of a widespread catastrophe from disease.

THE SEED INDUSTRY

It is easy for a country to import a few thousand tons of improved wheat seed from Mexico, but often much more difficult to conserve—over successive harvests—the quality of the seed when multiplied and distributed within the country. Genetic and other forms of deterioration can set in rapidly in the absence of proper controls over multiplication, certification, seed testing, and facilities for processing and distribution. In many developing countries that have started, or are about to start, programs for the introduction of high-yielding varieties, existing arrangements are clearly inadequate. We regard this, indeed, as potentially the most serious weakness in the whole high-yielding varieties effort.

The answer, in our opinion, is a major effort to develop the seed industry in these countries, with the cooperation of the larger and more internationally-minded seed firms from the developed areas. Financial assistance under aid programs will also be necessary.

STORAGE AND MARKETING

There is no point in increasing production unless the extra grain can, in fact, be marketed and sold. Serious strains on the marketing system have already been reported from some countries as a result of progress with the new varieties. In some circumstances this can be the most important single bottleneck, and its impact should not be underestimated. I have, for instance, recently seen quoted a remark made by the outgoing managing director of the Food Corporation of India. He said that “unless the present primitive methods of agricultural marketing in India are modernized, [the country] cannot support the increased agricultural production. Steps to modernize agricultural production will have no meaning
if there is no corresponding modernization of marketing.” While much of the work involved in improved marketing is of an institutional nature and depends mainly on decisive action by the government concerned, a key element is the provision of adequate storage capacity and also, in some instances, the expansion of transport facilities. These two sectors—storage and transport—may often need international financial assistance, and I hope the importance of such help will be recognized.

A different set of problems is posed by governments that decide, on the basis of high-yielding varieties, to enter the export trade. Here much caution is required. If everyone aims at becoming an exporter, it is unclear, to say the least, who will do the importing. A number of governments may well be currently nursing ambitions that will prove impossible to realize. The results achieved through the new varieties may perhaps have encouraged a tendency for planners to move from one extreme to the other: In the development drama, agriculture is suddenly promoted from the neglected stepchild to the deus ex machina. We must encourage the middle course of realism, the selection of practical and attainable objectives.

PREPARATION OF INTEGRATED COUNTRY PROGRAMS

The needs of a successful high-yielding varieties program are diverse. Besides the specific elements mentioned above, the availability of water, fertilizer, and pesticides is absolutely fundamental. Any one of a number of elements may be the limiting factor in a given country or area. If progress is to be made in an orderly and rational manner, integrated action programs must be drawn up at the national level. The planning process itself is an area in which FAO can provide assistance to governments if required; this is not a major problem. The two points which I do wish to bring to the attention of participants in the conference are (a) that projects connected with high-yielding varieties should normally form part of an integrated action program, since progress is usually necessary on several fronts simultaneously, and (b) that a project designed to cope with the “limiting factor” in a given situation may govern the success of the whole program, and should thus be looked at, not in isolation, but in the whole context of progress with the new varieties.

A final caveat: I trust that this paper will be read in conjunction with the separate document submitted to the conference by FAO on world food needs and potentials. There we have emphasized that agricultural development involves not merely increasing production but also coping with a wide range of social problems relating to employment and standards of living. It may be theoretically possible in some countries to meet all market requirements, notably for wheat, from high-yielding varieties grown on irrigated land that represents only a minor part of the total arable area. But, obviously, this would not be in the interest of the economic and social progress of the country as a whole. We must remember the need to devote an adequate share of attention and assistance to those cultivators—often representing the mass of the peasantry—who cannot now benefit directly from high-yielding varieties.

The advent of the new varieties has brought great new opportunities, and work in this sector is one of the five areas selected by FAO for a special concentration of effort. The simplicity of the concept of high-yielding varieties conceals, however, the complexity involved in realizing the full potential of these varieties. Close cooperation is needed between all the agencies working in this field.

A. H. Boerma

Addieke H. Boerma is director-general of the Food and Agriculture Organization of the United Nations. In 1938 he entered government service in the Netherlands, serving from 1946 to 1948 as Commissioner for Foreign Agricultural Relations. He joined the FAO in 1948 as regional representative in Europe and served as director of the Economics Division and as assistant director-general before becoming director-general in 1968. Mr. Boerma was executive director of FAO’s World Food Program from 1962 to 1967.
In the past few years, new high-yielding varieties of food crops—mainly of cereals and particularly of wheat and rice—have begun to transform the food production picture in a number of developing countries. Used in suitable combinations with other inputs, these new varieties have frequently doubled yields per hectare.

Emboldened by their success, these countries are increasing the areas planted to the new crop varieties at as high a rate as their resources permit. Other countries, encouraged by their example, are getting ready to take up the new varieties.

If these countries can realize their ambitions, the first consequence will be a rapid improvement in the diets of people who today are not getting enough food of any sort. Over the long term, however, the consequences of success with the new varieties will extend over a much wider field:

1. By making it possible to build up food reserves, they will enable governments to plan their development with greater boldness.

2. By reducing the developing world’s needs for food imports, they will free scarce foreign exchange for spending on development needs.

3. By freeing marginal lands for animal production and by making grains available at low enough prices for stock feeding, the new cereal varieties can make a significant contribution to animal protein supplies.

4. By increasing the farmer’s return on his land and labor, they will bring greater prosperity to the farm economies of the developing world and thus avert a deterioration of rural society, which endangers many of the developing countries. At the same time they will make peasant farmers more receptive to modern agricultural methods.

But the promise of the new varieties is not an unqualified one. Much effort, a lot of money, and swift and comprehensive planning will be essential if the promise is to be kept.

While a number of remarkable varieties are already in use, new varieties must be developed to meet local ecological situations and to counter epidemics of plant disease that may occur in the densely packed, genetically uniform stands in which these varieties are generally grown.

Supplies of pure certified seed must be produced continuously, tested, and distributed to farmers if yields are to be maintained.

The new varieties demand substantial supplies of fertilizers, good water management, and considerable improvements on traditional methods of cultivation and plant protection. Their use will call for massive investment in production inputs, as well as substantial improvement in distribution and storage facilities to get the inputs to the farm and to protect the greater production that will result.

Other supporting services, such as credit and extension, will have to be expanded, and modification to the land-tenure system may be needed in some countries.

Solution of all the problems of introduction of the new varieties will bring in its train fresh problems and possibilities. Incentives to cereal producers, for instance, must be maintained without encouraging the emergence of unsalable surpluses and without discouraging the production of other crops.

In fact, the new high-yielding cereal varieties, by increasing the profitability of farming and by reducing the areas of land needed to meet demand for the staple foods, have increased both the need and the possibility for diversification of crop production.

The early successes achieved with high-yielding varieties programs in a handful of countries are not a call to abandon other activities. Rather they point up the need to examine new and continuing programs in every field of agricultural development to see whether the new varieties will have a part to play. The public interest excited by the high-yielding varieties has no technological weight, but it is a strongly positive element in programs for their introduction and will give strong backing to other programs for agricultural development.

FAO, after careful study, considers that member governments in the developing world have much to gain from undertaking programs to introduce and promote these varieties. If all the necessary measures are taken, countries can achieve rapid improvements in the food situation and give impetus to general economic development.

Member governments are therefore urged to acquaint themselves with the nature of the new varieties available and examine the possibilities of including high-yielding varieties programs in their plans for agricultural development. FAO and other international and private agencies will be able to assist with this examination and subsequent replanning and with technical assistance in carrying out the programs.

RECENT EXPERIENCES WITH HIGH-YIELDING VARIETIES OF CEREALS

The use of improved seeds obtained through breeding and selection has a long history. They can transform the production situation in these areas by
substantially raising the yield ceiling at which the marginal rate of return to additional applications of inputs becomes unrewarding.

*Wheat*

The development of fertilizer-responsive, disease- and lodging-resistant varieties of wheats was begun by The Rockefeller Foundation in Mexico in 1943. The main characteristic of these varieties is that their fertilizer response is expressed in more tillers and more grains per plant without increased length of straw and consequent lodging. Combined with a great expansion in fertilizer use and better water management, they raised average wheat yields in Mexico from 0.9 ton per hectare in 1948-52 to 2.6 tons in 1964.

Mexican varieties of wheat have since been introduced and tested in a large number of countries in the Near East and elsewhere. The first import of Mexican seed for pilot production in India and Pakistan was as recent as 1964, but by 1967-68 2.7 million hectares of irrigated land was planted to these varieties in India and 1.2 million hectares in Pakistan. Their average yields in 1966-67 in Pakistan were 2 to 3 tons per hectare, or more than twice those of local varieties, while yields of 7 tons per hectare were obtained in experimental fields and those of progressive farmers.

The Mexican varieties are now being multiplied and modified in India, Pakistan, Turkey, Afghanistan, Lebanon, Iran, and Iraq. In the United Arab Republic and Iran some locally developed, rust-resistant varieties compete favorably with the Mexican varieties.

*Rice*

Work on high-yielding varieties of rice has been conducted in a number of Asian countries and at the International Rice Research Institute, which was founded in 1962 at Los Baños in the Philippines with Ford and Rockefeller Foundation support. As with wheat, these varieties are characterized by stiff straw and high response to fertilizers. They have successfully disproved the belief that the tropical rice varieties, grown and consumed in most countries of Southeast Asia, were inherently incapable of the high yields of the temperate-zone varieties adapted to the more northerly countries of Asia. The variety IR8 has shown wide adaptability in the tropics and subtropics and has given yields of 6.5 to 10 tons per hectare; in a trial involving three crops in a year, a total yield of 20.2 tons per hectare has been reported. However, apart from the Philippines (25,000 hectares in 1967-68), there has been little large-scale production of this variety. Its acceptance has been limited by its susceptibility to bacterial leaf blight and blast disease, two of the worst diseases of rice, and its poor palatability and milling quality.

Other high-yielding, fertilizer-responsive varieties, usually having a lower yield ceiling than IR8 but often earlier-maturing and with better disease resistance and grain quality, have been developed at IRRI (IR5, IR127, IR160, IR332) and in Ceylon (H4 and H8), India (ADT 27), Indonesia (Syntha), and Malaysia (Malinja and Mahsuri).

*Maize*

Hybrid maize originated in the United States as long ago as the 1930's. It was later successfully introduced in Mexico, where The Rockefeller Foundation began breeding programs in the early 1940's, and in certain European and African countries. Generally, however, its spread to developing countries has been slow. This is not only because the necessary complementary inputs were not available, but also because of the complex problems of seed production resulting from the need for the yearly renewal of hybrid seed.

Emphasis in maize breeding in developing countries is now shifting to open-pollinated composite varieties, whose seed can be produced cheaply and needs to be replaced only every three or four years. In Pakistan, for example, it is planned to plant almost all the irrigated maize area (0.5 million hectares) with such a variety in 1968-69. The yield potential of these synthetic varieties is more than double that of local varieties, but less than that of the hybrids.

*Millet and Sorghum*

Hybrid varieties of millet and sorghum, based on male sterility in one parent, have been developed in the United States and India. The technology of seed production is more complex than with wheat, rice, and even maize. The direct introduction of the United States hybrid sorghums in developing countries has not as yet proved successful, because of disease and quality problems. The Indian hybrids (C3H-1 and -2) are reported to be suitable for nearly two-thirds of the country's sorghum area, and in 1967-68 were planted on 0.7 million hectares. They yield 60-80 percent more than the local varieties but are more susceptible to insect damage.
THE FUTURE APPROACH

Crop diversification and alternative uses of land taken out of cereal crops must be developed for countries where the promotion of high-yielding varieties has been successful. The crops to be considered must depend to a large extent upon the food habits of the people, but every effort should be made to introduce cheap sources of high-quality protein to improve the general standards of nutrition.

An FAO secretariat working party, which has made preliminary studies of the strategy of introduction of the new varieties, reached the conclusion that second priority in crop production, after introduction of the high-yielding cereals, should be given to grain legume and oilseed crops. Progress in producing high-yielding varieties of these crops has so far been rather limited, but with raised yields through better cultural practices they can provide an urgently needed quality element to human diets, and they can play a valuable part in crop rotations based on the new cereals.

Third priority should be given, in the secretariat group's view, to extension of pasture and fodder crops, of which some high-quality varieties have already been produced. Work in the first two priority areas should contribute substantially to improvement of animal nutrition through increasing supplies of food grains and pulses and of by-products from oil extraction. Pasture and fodder crops are, however, essential to economic production of ruminants.

Next highest priority should be given to vegetables and fruit crops and then to roots and tubers, the secretariat group concluded. High-yielding varieties of cassava, potatoes, sweet potatoes, and other tubers have already been produced. In some countries, however, higher priority might be given to introduction of roots and tubers, which have a high calorie output per unit area and also value in rotation.

PLANNING FOR ACTION

Possibilities exist for immediate and future action in many countries. The nature of action will depend upon the desire of countries to make use of the high-yielding cereals that are available, the stage of agricultural development they have reached, and their willingness to provide large investments in the agricultural sector of the economy. It is necessary to emphasize that a national program for food production from high-yielding varieties is a much vaster undertaking than may appear at first sight, and careful technical and policy planning and objective evaluation of a country's stage of agricultural development are necessary. FAO believes that nearly 20 percent of developing countries could undertake full-scale national programs, and that many more could embark upon less ambitious programs with significant effects upon food supplies and even export earnings.

Many levels of action are possible in national programs. In larger countries, differences in degree of agricultural development between areas will need to be reflected in differences in level of action. A flexible, multi-level plan must therefore be adopted, and it is probably true to say that no two countries would have identical high-yielding varieties programs. By generalizing from previous experience, four very broad stages of high-yielding varieties programs can be described in terms of existing agricultural development. These stages do not provide blueprints for national high-yielding varieties programs, but serve to indicate what action is possible within national or local patterns of development. The final plan for a country might well contain elements from each of these stages, combined to suit the different needs of different localities.

The Ground-Breaking Stage

Countries in this stage still require considerable development of their physical and human resources. Soil potentialities are poorly known, and water supplies cannot be assured or adequately controlled. Farmers are only beginning to make regular use of the agricultural inputs of fertilizers, plant protection chemicals, and agricultural machinery. Farmers' cooperatives are nonexistent or inoperative, and the village square is the market outlet. Major take-off on high-yielding varieties is still for the future. The main levels of action are in testing high-yielding varieties for local suitability and the development of resources and agricultural inputs. Appropriate pre-investment projects on development of resources and agricultural inputs can be used in an exploratory way to introduce high-yielding varieties and the improved farm practices and management that must accompany them. In some areas—for example, where a new irrigation scheme is to be initiated—small-scale, production-oriented projects can be used to combine all the inputs required for high-yielding varieties programs. These programs provide information for larger-scale activities and stimulate farmer and public awareness to future possibilities.

Pilot Food-Production Stage

Countries that have been steadily developing natural resources and agricultural inputs in several
areas, and countries that possess considerable areas of virtually unused or well-watered agricultural land should consider the adoption of pilot food-production programs. Suitable high-yielding varieties should already have been identified and can be made available, if necessary by importation. Farmers should be aware of the benefits of fertilizers, even if they have not been able to obtain these inputs regularly, and can be induced by financial incentives to improve their agricultural practices. The main objectives of pilot food-production programs should be local self-sufficiency in grains, immediate reduction in malnutrition, and decrease in food imports. Projects covering areas of 5 to 15,000 hectares will achieve these aims and bring about the improvement of and experience in the technical, economic, and social services that are needed in national high-yielding varieties programs. These projects will also help improve the technical agricultural services of extension, credit, and marketing, and give governments added experience in price structure development and planning for future agricultural development. They will also reveal what consequential problems in land tenure and use, transportation, and storage and implications for the economy as a whole are likely to occur in larger programs.

**National High-Yielding Varieties Programs**

Countries where a serious food gap exists or threatens, and countries that have been able to achieve substantial agricultural development over the past decade should consider the possibilities of undertaking national high-yielding varieties programs. Many technical, economic, and social issues must be taken into account, because the program will have significant effects on the national economy and well-being. The size of the program that is desirable and can be financed, and the role of private enterprise must be determined. A decision to aim at national self-sufficiency or at exportable surpluses will determine the scale and orientation of the program and its associated price, marketing, and storage policies.

Governments undertaking such programs must recognize that many ministries will need to be involved and that resources will not be sufficient to achieve nationwide coverage of all parts of the program. Hard decisions must therefore be made on the areas where the efforts will be concentrated. These must be selected because the soils are suitable, adequate, controllable water resources are available, the services for distributing seeds, fertilizers, pesticides, and credit are adequate or can quickly be developed, and the land-tenure and farming patterns can be adapted to what is essentially large-scale intensive production. If national seed production is inadequate, arrangements must be made to import supplies of certified seed. Because fertilizer needs of these programs are large and may draw heavily upon the country’s foreign-exchange reserves, some system of rapid soil or tissue analysis should be instituted as soon as possible to determine actual fertilizer needs with reasonable accuracy. All available extension workers should be used in the program, not as advisers to the farmers but as expert field workers and demonstrators, and a widespread, continuing educational program aimed at the farmer and at the suppliers of inputs and credit must be put into effect through whatever communications media are available. Price incentives will be necessary to get the program started, and price stabilization will be essential to its ultimate success.

Countries should anticipate that a successful production program will produce local and even national surpluses of grain. Drying, storage, and processing facilities will need to be provided, and transportation assured to bring the grain from the farmers to the facilities. If the program is aimed at export, market research will need to be undertaken and facilities for export developed. If it is intended to utilize the grain entirely within the country, the use of surplus grain must be developed.

**The Post-Program Stage**

Experience gained by the few countries that have recently undertaken national high-yielding varieties programs reveals that new needs arise. Of first importance is maintaining the ability to produce the varieties by the development and testing of new varieties for use in future years. Reserve areas must be set aside where the old varieties are maintained, particularly if they have desirable characteristics such as resistance to diseases and pests, consumer acceptance, or processing quality. If seed production and certification facilities are not strengthened and maintained, the purity of seed will quickly be lost and yields will decline to previous low levels. Price policies to be adopted in this stage must be determined by economic policy decisions on the continuing aim of the program, that is, whether local self-sufficiency in food or feed grain is the aim or whether exportable surpluses are to be encouraged. It is certain that permanent changes in farm management and organization will be required, and governments must be prepared to adopt policies that will encourage efficient farm operations on good lands and remove marginal lands from exploitative use.
Smaller areas will suffice to produce the grain necessary for self-sufficiency, and even for export, and alternative uses for the remaining land must be explored and developed. Animal production and plantation forestry are possible uses that must be considered.

A country that has successfully stimulated cereal production may wish to undertake similar programs in the production of other foods, particularly grain legumes and similar crops that improve the protein content of the diet. The conditions for such programs will be similar to those for cereals, except that varieties with widespread ecological adaptation and high-yielding capacity are generally not yet available.

**FAO CAN HELP**

**In Planning for Action**

FAO stands ready to assist member governments determine what type and size of high-yielding varieties program they should undertake. Through its regional representatives, country representatives, headquarters secretariat, and statutory bodies, FAO is able to help obtain and provide the information needed to assess the level of agricultural development attained by a member government, to help determine pricing policies, export possibilities, and the general economic impact of the program, and to assist in drawing up the strategy for high-yielding varieties programs and for continuing development at the conclusion of these programs.

The medium-term food outlook reviews and the Indicative World Plan are particularly suited to assist in planning programs because they have been designed to analyze trends for 3-4 and 10-15 years ahead, respectively, in food production and supplies and expected changes in pattern of food consumption, imports, exports, and trade prospects.

Several intergovernmental and private agencies are known to be interested in assisting developing countries to utilize high-yielding varieties. Through regular and systematic contact with these organizations, FAO expects to act as a clearinghouse for information on high-yielding varieties programs, assisting member governments to determine how these other agencies can help them and helping investigate sources of external financing through multilateral or bilateral aid where this is required. Through this clearinghouse activity, FAO will also assist interested agencies and donor countries to determine where their efforts and contributions could be made to best effect.

FAO is also able to assist with formulating and implementing field projects for immediate and future action. These projects will be similar to, and may in some cases be modifications of, existing pre-investment and investment projects, but will generally need to be more comprehensive in scope to cover the requirements of high-yielding varieties programs.

**In Immediate Field Action**

Modification of existing field projects to include high-yielding varieties represents the best approach to immediate field action. UNDP Special Fund projects operated by FAO should be of particular value for this purpose. Many Special Fund projects are directly involved in crop or seed production and are of sufficient size to enable adequate trials and demonstrations of high-yielding varieties to be conducted. Furthermore, the UNDP has set up its own committee on high-yielding varieties and has already requested that these varieties be included in several projects at present under consideration. The Freedom from Hunger Campaign fertilizer program has field operations in many countries where high-yielding varieties are already in use. Program modifications are possible in these countries to include high-yielding varieties.

To determine the opportunities for these projects to introduce high-yielding varieties, member governments should re-evaluate them with the assistance of the representatives of appropriate United Nations agencies. The re-evaluation should give due weight to the potential usefulness to the country of the high-yielding varieties available, the stage of development already reached by a high-yielding varieties program, if any, the availability of complementary inputs and supporting services, and the possible price and trade problems.

Projects planned or in the pipeline could also be examined for the possible inclusion of high-yielding varieties. Where such inclusion appears warranted, the project should be appropriately redrafted.

**In Formulation and Implementation of Long-Term Projects**

Projects to develop land and water resources will be required for countries in early stages of high-yielding varieties programs, because suitable land resources and adequate and controlled water supplies are essential to success with high-yielding varieties of cereals. Where governments are considering large-scale investment projects in irrigation development, these should be designed to include high-yielding varieties to ensure an adequate return on capital.
Particular attention should be paid by all countries undertaking high-yielding varieties programs to projects for seed production certification and distribution. The seed industry is one in which the necessary combination of technical knowledge and business organization is often lacking in developing countries. The association of seeds firms from developed countries with government or semigovernment agencies and local entrepreneurs in developing countries may be a useful means to obtain the necessary development.

Projects to develop farm use of fertilizers, plant protection chemicals, and agricultural machinery will be needed by countries able to undertake the pilot food-production stage. For more advanced countries, investment projects will be necessary in facilities to distribute and provide credit and marketing services for these agricultural inputs. Because massive supplies of fertilizers are required for the new varieties, domestic production may also need to be considered through projects for the development of agro-industrial complexes.

The implementation of production-oriented projects will be possible when all the requisites for successful food production can be supplied for limited and carefully chosen areas of a country. These projects help determine what changes must occur in farm management and organization in converting from extensive forms of production to modern, intensive agricultural practice. The results provide information for larger-scale production.

Projects to develop storage and processing facilities and equipment are required by countries undertaking national high-yielding varieties programs to deal with post-harvest problems. With major problems of malnutrition overcome, consumer preference at home and export quality abroad will require not only changes in varieties grown but also expansion and diversification of processing industries.

The adoption of nationwide programs and the maintenance of production in the face of apparent surpluses by countries in the post-program stage will need efficient action by the support communication services. Lines of communication must be established and maintained with large numbers of simple rural people. Information and advice must also be made available to the suppliers of inputs and services. Because the communications media available vary widely from country to country, FAO communications specialists could be enlisted in advisory missions to countries considering undertaking high-yielding varieties programs.

Research and training projects will be a continuing requirement for countries in all stages of development. Plant breeding research must provide new varieties to replace those that have been in use for several years. Research on soils, water, plant nutrients, and the many other factors of crop production and management must be continued to provide new and more profitable solutions to the crop production equation. Centers to train extension workers in the practicalities of crop production from high-yielding varieties must be set up. The training functions of specialized regional programs such as the Near East Wheat and Barley Improvement Project can be used for this purpose.

**APPROACHES TO FINANCING**

Member governments undertaking these programs will need to commit substantial financial resources to them. Foreign exchange will be required in most countries to purchase the massive amounts of fertilizers and substantial quantities of plant protection chemicals and agricultural equipment required. Rural banks and cooperatives will need financial assistance and direction to enable farmers to obtain the credit they need to purchase farm supplies at reasonable terms. Continuing agricultural research is of high priority to the maintenance of these programs, and must be adequately financed. External assistance in financing will therefore probably be required, particularly in the early stages of development.

Small-scale preinvestment projects may be financed with assistance from multilateral or bilateral sources. Larger-scale programs will often require investment by the international and area banks. FAO, through its recently created Investment Center, will be able to assist member governments in investigating international sources of financing for high-yielding varieties programs.

Latterly, for example, FAO has been involved in the preparation of projects for investment in seed production and irrigation development by the World Bank group, and expansion of this type of activity will be an important feature in future developments. All the agencies named, the regional banks, and countries offering bilateral aid are anxious to foster these types of development as well as the provision of other essential inputs.

**HIGH-YIELDING VARIETIES WILL AID ECONOMIC DEVELOPMENT**

Some of the new varieties have been described as miraculous by their more enthusiastic proponents, and, to the farmer who sees his harvest doubled in a
year, the word would not seem extreme. Combined with the substantial material results of successful introduction of the new varieties, this aura of the marvelous which has come to be associated with them can be a very potent force in the whole field of agricultural development. The extra income for the farmer, allied to a new faith in the possibility of improving his life through advanced agriculture, can have consequences extending far beyond an increase in staple food supplied.

It has been reported from India that the added income obtained by farmers from successful high-yielding varieties programs is creating an increased demand in rural areas for transistor radios and bicycles. On quite a simple level these prestige items thus represent, not only the beginnings of a consumer economy, but also the first steps in the development of better communication in rural areas and of an increased awareness among farmers of the market possibilities for their produce.

After most careful study and serious consideration, FAO believes that the opportunities exist for many member governments to use high-yielding varieties of cereals in their strategy of development. The financial investment needed for a high-yielding varieties program is large, and the participation of many people must be obtained. Most of all, however, the highest levels of government must be committed to the program, and show a determination to use resources and resourcefulness to make it a success.
Mankind now has the capability, given the will, to meet food needs for two or three decades and, in doing so, to stimulate widespread economic and social development in agrarian areas wherever agricultural productivity remains low and static. But realization of such comprehensive progress will require proper and massive investment of men and money, organization or reorientation of a great number of activities, and coordination of effort of national and international agencies far beyond that achieved in recent years.

The combined experiences of agencies represented here reveal clearly that accomplishments of the scope envisioned are indeed possible. Mexico, which a quarter-century ago had a population of 21 million and major food-crop deficits, now is in a surplus situation despite a population climb to 47 million, and is turning its attention to greater involvement of the large number of farmers with small landholdings. India, primarily through its High-Yielding Varieties Program, is now increasing both production and average yields of wheat, rice, corn, sorghum, and millets. Pakistan, particularly the Western Wing, has made dramatic progress in acceleration of output of wheat, rice, and corn. Kenya has moved from a deficit to a surplus situation with corn, largely because of increased yields on small farms. Utilizing new varieties and other technology developed by the International Rice Research Institute, the Philippines produced a surplus of rice in 1968. Thailand, faced with dwindling exportable surpluses of rice in recent years, soon should be able to reverse that trend. Many farmers in the coastal regions of Turkey were able in 1968 to achieve wheat yields double or triple those of previous years.

There are a few dramatic new developments involving uneducated farmers with small landholdings. In El Salvador, some 8,000 such farmers in the hill regions are now realizing corn yields three or four times greater than ever before and are overcoming a very serious hunger problem, both through greater direct human consumption of cereals and by greater on-farm production of poultry and pork. In the vicinity of Porto Alegre in Brazil, some 10,000 farmers are greatly accelerating output of the basic food crops. In the Valley of Puebla in Mexico, through the combined efforts of the International Maize and Wheat Improvement Center and local agencies, corn yields on some farms are being raised from a traditional average of 800 kilograms per hectare to 4,000 kilograms or more per hectare—and this in an area where 50,000 families attempt to derive a livelihood primarily from 120,000 hectares of unirrigated maize. Still other examples could be mentioned.

Behind each of these examples of progress has been a determined effort to bring science to bear on local problems. In each case, agricultural technology has been specifically and imaginatively tailored to local needs by public agencies. Behind each effort there have been men of vision and scientists of substantial talent. But unfortunately, the achievements that can be listed represent only a tentative and feeble start toward solution of a massive problem involving all of the world's food and fiber crops—animal or plant—and millions upon millions of farmers whose yields and incomes are low and static. The job remaining is immense: High-yielding technology must be developed for every crop and animal species, for every season, in every region of every nation; systems of supply of manufactured inputs and of transportation, marketing, and storage must be devised; institutional capabilities, national and international, must be created to initiate and then sustain accelerated economic and social progress. Most of the effort must be made by the individual nations, for only they can set the policies, establish or reorient the institutions, and train the numbers of people needed to reach their own farmers. Outside agencies can assist, and must, but that is all.
While the scientific capability exists to effect the sweeping changes needed, still lacking at this time are coordinated effort and widespread understanding by political and scientific leaders of the means by which change can be set in motion.

This paper attempts to identify the fundamental factors responsible for progress wherever it is occurring, to explain why these are important, and to describe, in part at least, the action that should be taken by national and international agencies, by scientific and educational institutions, and by private industry.

**BASIC ASSUMPTIONS**

Before consideration of the strictly agricultural problems facing the world, it is important that certain assumptions, on which evidence seems to be overwhelming, be stated for the record.

First, there is urgent need, now, for rapid acceleration of agricultural output (food supply) in those agrarian nations or regions of nations which have existing or impending food deficits and, in some instances, already face very unfavorable man:land ratios. Perhaps a dozen nations of substantial size, plus a number of smaller countries, fall in this category. Most are in the tropics or subtropics. Characteristically, their yields per unit area or per animal unit are low and static; past increases in output have resulted primarily from increases in land area utilized, rather than from increased yields. In many other nations, particularly in Latin America and Africa, food crises are less imminent because pressure on the land is not yet so great; however, even in these countries, the existing institutions and trained people characteristically are so inadequate for the complex task of development that little time can be lost in initiating needed programs.

Second, expansion of food production and stabilization of population growth rates must be attempted simultaneously. While the prospects are good that agricultural output can be substantially increased in the decades ahead, improvements in food supply and income per person can occur only if population growth rates are contained at, or reduced to, levels that nations' resources can support in comfort and dignity. Present agricultural progress in India, Pakistan, the Philippines, and elsewhere is only buying time for desperately needed population-stabilization efforts.

Third, neither accelerated agricultural output nor organization of effective population-stabilization programs can occur without a reasonable degree of peace.

Fourth, in the poorer agrarian nations, agriculture is a basic industry and must be treated as such by the nations themselves and by assistance agencies. Millions of rural dwellers, many of whom have small acreages and still operate on the barter system, can and must be assisted to increase their agricultural output and income, and thereby to participate in the market economy. To increase their farm output, these people must be enabled to purchase production inputs and to sell to more distant markets. They must contribute to the creation of the wealth needed to finance improvements in education, public health, and transportation. Unless rural dwellers increasingly become consumers of products of urban-based industry, economic development of the nation cannot proceed at an accelerated pace.

Fifth, improvement in the diet of most of the poorer people in the developing countries can occur only if their incomes are increased. Gifts of food, which only buy time, offer no permanent answer to the problem of hunger. Furthermore, while some farm dwellers can and should be assisted to grow a greater variety of products, for many of them this would provide a solution during only part of the year, and the needed assistance efforts would be relatively costly.

Increasing agricultural output—and thereby, farm income—in agrarian nations is a prerequisite to all other forms of economic and social development. It must therefore be given as high priority, both by nations and by outside assistance agencies, as any other economic activity that will contribute an equal amount to income per dollar invested.

**FROM TRADITIONAL TO INTENSIVE AGRICULTURE**

For an understanding of the combined forces that permit crop and animal yields to move from traditional low values to modern-day highs, it may be helpful to examine the factors that limit productivity under traditional (or subsistence) systems, to recall the technical and other advances that now permit the elimination of such constraints, and to consider the concepts and characteristics of intensive (or modern) agriculture. It is, of course, realized that there are gradations from the simplest forms of agriculture, such as the harvest of wild game by the hunter, through traditional forms of sedentary subsistence agriculture, to the high-yielding, present-day systems of the developed nations.

*Traditional Agriculture*

As late as the turn of the present century, virtually all the world's agriculture was still of the tradi-
tional type in several respects. Yields depended in large part on the inherent fertility and other qualities of the soil; consequently, agriculture tended to flourish where soils were rich and where moisture was adequate or irrigation and drainage could be controlled. There was little the farmer could do about changing the fertility or chemistry of his soil other than to rotate crops to include soil-building legumes, to return animal or human waste to the field, or to rotate fields as in the very primitive "slash and burn" culture.

The only varieties of crops available to the farmer were those that had survived centuries of natural selection for ability to produce dependable but modest yields on soils of low fertility. These varieties had also become adapted to the usual conditions of minimum management employed by many farmers, particularly the practice of spacing cultivated plants wide apart so as to achieve maximum yield per plant (to minimize hand harvesting operations) and allow plants to draw nutrients from a fairly large volume of soil.

As civilization spread and man settled new areas, he took with him the crops on which he had come to depend. And in each new area his crop varieties were forced to become adapted, again largely through the process of natural selection, to a new set of soil properties and perhaps to a different day-length and to new temperature regimes; particularly, they had to develop resistance to disease organisms or to insect pests peculiar to the new locality. With the evolution of varieties, each with specific adaptation to one of the multitude of specific sets of environmental conditions, there arose great diversity of germplasm. Man aided in the elaboration of this diversity as he selected types that suited his own fancy, thus giving rise to stabilization of specific grain, fruit, or foliage characteristics. These combined forces contributed to the present-day diversity of germplasm, of which the 250 described races of maize in the Western Hemisphere and the International Rice Research Institute's collection of 8,000 rice strains are examples.

Despite all the diversity that existed, a traditional farmer could do little about improvement of yield by changing varieties. True, he could and did, over time, improve yields by some selection of his own—by saving the better types; or, from time to time, he replaced his own variety with another in his locality that demonstrated greater resistance to diseases or insect pests. Though the great diversity of germplasm was of little benefit to traditional farmers, it now constitutes one of the world's important scientific resources. Even though most native types are adapted to conditions of low soil fertility, many of them do have resistance to specific insect pests or disease organisms or have plant characteristics useful in the development of high-yielding types.

Crops in traditional farming systems could be protected against the ravages of insect pests and diseases only through replacement of susceptible types by more resistant ones or by altering dates of planting to escape heavy onslaughts. But there was little more that the farmer could do.

The power available on the traditional farm was limited to that of the farmer's own muscle plus that of his family and sometimes of neighbors, supplemented in more advanced systems by that of farm animals. The limitation of power restricted the options of the farmer with respect to depth of planting and amount of cultivation. It likewise restricted the land area that one family could dominate, as it still does in those areas where other forms of power are not yet available.

Most produce, furthermore, was used for home consumption or for sale or trade for services or other products within the area of the farmer's mobility. There was a minimum of exchange of products with distant markets.

Traditional farming was and is a relatively simple matter, by modern standards. The production system involved man, his land, his seeds, and his farm animals. There was little or no need, and little or no desire by farmers, for intervention by either government or private industry.

Recent Innovations

Since the early 1900's, many scientific discoveries and innovations plus elaboration of business and organizational techniques have, if properly utilized, allowed drastic changes to occur in agricultural productivity.

Fertilizer and soil amendments. With advances in chemistry, physics, engineering, and business, man has learned to manufacture fertilizers containing the major and minor nutrients required by crop plants. Soil and crop scientists have learned the symptoms of deficiency or excess of individual plant nutrients. Interactions among certain elements are now understood. Means of correcting soil acidity or alkalinity are known, as are techniques for improvement of soil structure. Scientists now know how to determine the specific combinations of fertilizers and soil amendments needed to make most soils productive. But they still do not know the specific combination required in many production areas; this
information must be determined on the spot and for each crop involved.

Concurrent with the development of chemical fertilizers and means for their mass production at reduced cost, there has developed an increasing understanding of the nature of soils, and substantial progress has been made in characterizing and mapping them. Most of the world’s major soil groups are known, so that scientists attempting to identify the specific combinations required in any particular area can do so with a minimum of delay. The very recent availability of chemical fertilizers does not seem to be well understood by many institutions concerned with improvement of agriculture; consequently, some of the developing countries are criticized for their seeming tardiness in the use of fertilizers and other amendments. According to the FAO, fertilizer consumption on a world basis, but excluding mainland China, rose gradually from 2 million tons (total for nitrogen, phosphoric acid, and potash) in 1905-06 to 4 million tons just before World War I. There was little change in total consumption in the war years, but in the early 1920’s the figure rose steadily to over 7 million tons. At that point, the world economic depression caused a temporary reduction to about 5 million tons; with recovery, however, production climbed steadily, reaching about 9 million tons in 1938-39. Little information is available for the period of World War II, but consumption has since risen steeply. Starting at 7.5 million tons in 1945-46, it tripled in the next ten years to about 22 million tons in 1955-56, and during the next ten years it almost doubled again, reaching about 40 million tons in 1965-66. Total availability in 1968 was about 55 million tons, and most types of fertilizer were in surplus supply.

Since fertilizer is a purchased input, it normally can be used only in a cash market system. For this reason the earlier limited supplies were primarily utilized on cash crops such as cotton and tobacco in the United States, or on the tropical estate crops for which production and marketing were organized by business interests. More recently, as fertilizer costs were lowered and as scientists developed crop varieties specifically designed to convert high levels of fertilizer to harvestable product, the use of fertilizers has spread to the lower-value food crops.

High-yielding varieties. The native varieties of most crops, having evolved over centuries of natural selection on soils of low fertility and under conditions of minimum management, developed certain specific traits that made them unsuited for use in systems involving high levels of fertilizers and intensive management. Many of these indigenous varieties generally are very efficient at extracting the limited quantities of nutrients available in impoverished soils; few recently developed improved varieties equal them in this regard. Generally, the unimproved types also possess great plant vigor, a characteristic vital in agricultural systems where weed control is imperfect if practiced at all. Most of the indigenous cereal crop varieties respond to high levels of soil fertility or applied fertilizers by producing luxuriant vegetative growth and high individual plant yields if plants are widely spaced so that all leaves are fully illuminated. Such excessive vegetative growth, however, often makes the plants top-heavy so that they fall over (or lodge) long before harvest, with overall reductions in grain yield. Excessive vegetative growth in the dense planting needed for high yields also causes shading of lower leaves, which reduces rates of photosynthesis and hence yield.

Since the turn of the century, scientists have learned through advances in genetics and plant physiology to design crop plants that are capable of converting high levels of applied fertilizers to harvestable product rather than to excessive foliage. In the case of the cereal crops, such as rice and wheat, plant types have been devised that are short and stiff-stawed, with narrow, erect, dark green leaves and with grain:straw ratios of about 1:1. These are the characteristics of the semidwarf wheats from Mexico, developed cooperatively by scientists of Mexico and of The Rockefeller Foundation, and of the dwarf tropical varieties of rice now emanating from the International Rice Research Institute. Scientists have learned in the case of some crops to create varieties having insensitivity to day-length (as has been done with the Mexican wheats and the IRRI rice varieties), whereby greatly extending the range of latitudes at which these can be grown successfully. Plant pathologists and entomologists have learned the essential life-cycle characteristics of many of the world’s major disease organisms and insect pests. Plant pathologists and plant breeders have devised systems for identification of crop-plant resistance to specific organisms and for incorporation of such resistance into otherwise high-yielding types of plants. Geneticists have devised breeding methods for rapidly tailoring crop plants for use in high fertility, intensive management systems, and even for sophisticated mechanical harvest.

The creation of new varieties tailored to a predetermined set of needed characteristics—a process now becoming known as “biological engineering”—
is a highly sophisticated endeavor, requiring direction by highly capable scientists. In many of the developing countries, unfortunately, the responsibility for varietal improvement has been placed in the hands of mediocre or poorly trained people, a situation which must be corrected.

Not generally understood is the effect on crop productivity of the interaction between fertilizer levels and varietal characteristics. As mentioned earlier, indigenous varieties have characteristics that permit only minimum economic benefits from applications of fertilizers, and use of high levels often will reduce yields severely (Figs. 1, 2). On the other hand, high-yielding types such as the rice varieties IR8 and Taichung (Native) 1 and the Indian sorghum hybrid CSH-1 may yield no more than the old indigenous varieties under conditions of low soil fertility; they only demonstrate their superiority and give maximum returns to fertilizer use at high fertility levels.

In the writer's opinion, one of the major factors contributing to the lack of effective demand for fertilizers today is the absence of suitable varieties of most crops for areas where they are urgently needed. Except where hybrids can be developed and marketed, these varieties must be produced by public agencies, because there is little opportunity for commercial seed companies to be profitably engaged in the development of crop varieties if the farmers can save their own seed.

It is now possible to create high-yielding varieties of crops anywhere in the world, given the availability of interested and capable plant scientists and of continuing support of their work. The farmer can be emancipated from the restrictions on yield imposed by his native varieties. But this requires a massive and well-directed effort in the public sector.

New means of plant protection. In recent decades an increasing array of chemicals of ever greater specificity has become available for use in the control of particular disease organisms or insect pests. Literally hundreds of such compounds are now available, and the limitations on their safety and use are reasonably well known. But this does not mean that scientists know which compound to use against a specific organism in a specific environment on a specific crop. The identification of the proper compound and the determination of the ways in which it should be used must be determined on the spot, and this remains to be done for many crops in many regions of many countries. Much of it must be done by public agencies until private industry is well established.

There have been many attempts during the past two decades to introduce the use of pesticides on farms where indigenous varieties were being grown without application of fertilizers. While certain of the chemicals may have given protection against the organisms to be controlled, the restrictions on total yield caused by the indigenous varieties and the low soil fertility made the use of the plant protectants unprofitable. This has been discouraging to many of the companies marketing agricultural chemicals. On the other hand, as high-yielding varieties are used in combination with high levels of fertilizers, adequate plant protection becomes imperative and pays handsomely (see Fig. 3). Furthermore, farmers are demonstrating that they are willing to use such measures when it obviously is profitable to do so.

The farmer is no longer limited in protection of his crop to the age-old systems of crop rotation, selection of date of planting, or choice of indigenous variety. Science can now remove these obstacles to production, but these innovations will be used—as a general rule—only in combination with high-yielding varieties, high levels of fertilizer use, and intensive management.

New power sources. During this century a multitude of new sources of power have become available that allow a farmer many options nonexistent under the traditional system. Now, a tremendous range of farm implements permits land-leveling, drainage, preparation of a desirable seedbed, precision placement of seed and fertilizers, application of plant protectants, and rapid harvest. Soils can be plowed to greater depths. In Asia, where the carabao does not develop enough power to pull an implement through a dry soil, planting and cultivation of crops during the highly productive dry season is now possible, given the use of machinery and of irrigation. A farmer no longer need be limited in his farm operation by the extent of his own power, that of his neighbors, or that of his farm animals. Means are also available now for development of a wide range of irrigation schemes, from massive systems to individual tubewells, which become increasingly attractive as varieties, fertilizer-use technology, and techniques of disease and insect control permit irrigated plantings to become highly productive and profitable.

Processing, storage, and credit. Concurrently, innovations have occurred in the processing, storage, marketing, and transport of agricultural products. Also, there have been innovations in the supply of credit with the appearance of a great variety of credit institutions, ranging from local rural banks.
FIGURE 1. Response to nitrogen of the rice varieties IR8 (improved) and Peta (tall tropical indica variety). IRRI.

FIGURE 2. Response to nitrogen of the improved sorghum hybrid CSH-1 and a local sorghum variety. Dhone, India, kharif, 1965.

to national and regional banks and the World Bank.

The evolution of intensive systems. In the highly developed nations, including those in North America and Europe, the process of change has occurred relatively slowly, with considerable acceleration since World War II as the fertilizers, specific plant protectants, high-yielding varieties, and self-propelled farm machinery of greater capacity all became available. Because of the relative slowness of the process (at least in its initial stages), there was time for simultaneous elaboration of systems of processing, storage, marketing, and transport, with credit availability at any stage in the system. Concurrently, a substantial improvement took place in the level of education of farmers and in communications systems for transmitting knowledge to them. While there have been stresses accompanying the change, these have been minimized by the relative slowness and orderliness of the process.

Intensive or Modern Farming

Individuals vary as to their concepts of intensive or modern farming and, in the writer's opinion, it is important that the differing points of view be acknowledged.

In the industrialized nations, the degree of modernization is determined not only by yield level attained but also by output per unit of human time. Thus, in affluent countries, degree of mechanization or even of convenience becomes an important criterion. Some forms of machinery, however, do little more than replace human labor and are therefore not directly related to "intensification" of production—intensification in this case meaning increased yields per unit land area per unit time. To the extent that machinery permits precision placement of fertilizers and seed or the supply of irrigation water, mechanization contributes to yield. In other words, some forms of mechanization permit increased yields, while other forms are relatively irrelevant to yield but permit domination of greater areas by man or contribute to his convenience.

There are other concepts of modernization or intensification. A 10-ton rice yield, which approaches record level, is modern whether produced on one hectare, by a farmer using hand methods or animal power, or on a highly mechanized farm of large proportions. Use of high-yielding varieties of the most modern type, coupled with high levels of fertilizer application and appropriate plant protectants, is modern, regardless of the tools used in the process.

In the opinion of some, consolidation of landholdings is a necessary and modern practice, although, in reality, intensification of agricultural production is not necessarily related to size of landholding at all. The experiences of Japan and Taiwan offer useful examples of the fact that intensification of agriculture can be achieved on small landholdings as well as large; indeed, consolidation of landholdings and mechanization in these countries may reduce average yields as it becomes impossible to "garden" or individually tend each plant in the field.

The intensification of agriculture is a complex and sophisticated matter, requiring the intervention of three new sets of individuals and institutions not particularly involved in the affairs of the subsistence farmer. First, scientists working primarily in the public sector must develop the new varieties, the fertilizer-use practices, the means of disease and pest control, and the crop or animal management practices; and for maximum benefits, and often for any benefit, all changes must be introduced at about the same time.

Second, industry must supply the necessary inputs and at a reasonable price, and often must participate in the processing, storage, marketing, and transport of the harvested product.

Third, the national government is involved in market development, the establishment of price policies, the organization and support of research, extension, and education, and the arrangement for supply of inputs either by business or by public agencies.

Whereas in traditional agriculture the farmer and his family essentially controlled the whole production system, in a market-oriented system four sets of individuals and institutions become involved; if any one of the four fails in its contribution, intensification fails.

CONCEPTS IMPORTANT IN AGRICULTURAL PLANNING

General

As national governments and assistance agencies consider the action that must be taken to accelerate agricultural output and economic development, a number of now well-founded concepts become highly important. Agricultural technology is location specific. Unlike the technology of engineering or medicine, that of agriculture must be tailored—for optimum productivity and profitability—to the specific conditions of individual farms or farming areas, with their unique combinations of soil factors, moisture, day-length, temperature, complexes of strains of disease organisms and insect pests, and patterns of human
preference. This means that much, although not all, of the development of agricultural technology must be undertaken in the regions and under the conditions for which it is designed to be used. Thus, by implication, at least the final stages of the research process must be accomplished over years in each season of each region of each nation—and for each commodity of interest.

Crop varieties must be developed, or at least tested, in each locality; the same applies to techniques of fertilizer placement, timing, and amount, to measures for disease and insect control, to quantity and timing of irrigation, to feeding, management, or health protection of animals, and to any other variable affected importantly by environment. Consequently, agricultural technology suited to one environment has very limited transferability to others that differ significantly in any major respect. Particularly, it has been learned that much technology developed in temperate-climate regions is not applicable to the tropics; this should not be surprising since scientists of the highly developed nations have long accepted the need for combinations specifically designed for each season of each locality within their own countries.

Scientists are making some progress in extending the transferability of technology. Well-known examples include the new varieties of rice and wheat that have flowering mechanisms uninfluenced by day-length (photoperiod). Such advanced types have two important advantages: (a) they can be grown successfully over a wide range of latitudes, and (b) at any location within this range they can, if other growing conditions permit, be planted at any time of year with the knowledge that the crop will mature in a fixed length of time. In the rice areas of the tropics, this latter advantage is of special importance since some farmers (with irrigation) can now schedule plantings for harvest at any desired date. Rice is thus coming on the market throughout the year, with a consequent minimizing of the occurrence of periods of surplus and deficit during the year and of accompanying over- and underpricing.

Although technology must be developed for and tested in each environment, the underlying science is transferable. Capable scientists, properly supported, can quickly determine anywhere the applicability of available technology and fill the important gaps.

*Improvement in biological technology is the major catalyst of intensification of production.* Yields of most food crops and animals in the less-developed nations have been at traditional low levels throughout the period of recorded history, being limited by levels of soil fertility, characteristics of indigenous varieties or strains of animals, inability of the farmer to control diseases or insect pests, and other factors. Furthermore, until relatively recent times, human population density in most nations was sufficiently low that total needed output of food and fiber could be achieved by planting ever greater areas. That option is rapidly vanishing in all or large parts of some developing nations, including India, Pakistan, the United Arab Republic, and Indonesia.

The need in some nations to increase yields per unit area or per animal unit has long been recognized, and there have been many attempts to effect change. These have variously relied on intensive extension efforts, price supports, appeals to farmers by political leaders, land reform, comprehensive community development programs, or piecemeal introduction of either fertilizers, supposedly high-yielding varieties from technically advanced nations, pesticides, or irrigation. Most have proved disappointing in their effect on yields. It now is increasingly realized that failure frequently was inevitable because one or more of the technical barriers was left unaltered. And, too often, local scientists have claimed—quite erroneously—to have solutions to technical problems, and their claims have been accepted as valid by naive economic planners. Such errors in judgment can and should be avoided in the future.

Every case known to the writer of rapid increase in average yield of any commodity in a developing (or developed) nation—including those mentioned early in this paper—has been set in motion by development and demonstration by capable scientists of "complete packages" of technology, adapted to local conditions, which permitted twofold or greater increases in absolute yield. By "complete packages" is meant high-yielding varieties, plus appropriate fertilizer-use techniques, plus adequate means of control of diseases and insect pests, plus necessary planting, cultivation, and irrigation techniques—any and all of which, combined, permit the high yield. Or, in the case of animals, it means proper strain, nutrition, and management—all at once, with nothing important left out.

In the case of crops, at the heart of the agricultural revolution, wherever it is occurring, are the high-yielding varieties that effectively convert high levels of fertilizers to marketable product. These new "biological converters" must combine inherent yielding ability with resistance to important disease
organisms, with qualities acceptable to consumers, and with numerous other qualities.

As scientists have developed packages of practices that permit high and profitable yields, farmers have demonstrated their willingness to change. National leaders of some countries, upon seeing the dramatic results, have been quick to mount nationwide production campaigns; important examples are India’s High-Yielding Varieties Program, designed in 1965 to cover 32 million irrigated acres by 1970-71; West Pakistan’s concerted and successful effort with rice and wheat; and President Marcos’ campaign for “Rice, Roads, and Schoolhouses” in the Philippines. Since high yields cannot be obtained by edict, or by piecemeal use of manufactured products, or by extension of practices of “better farmers” (whose superiority may be due to soil factors or better techniques for their particular situations), it remains for scientists to develop needed technology and clearly demonstrate the new yield levels; when this is done (and only scientists can do it), the problem of low production is moved from the scientific to the political and economic arena, where non-scientists can then be effective in arranging and stimulating change. At this point, and usually not before, the demand arises for new policies, for supply of manufactured inputs, for storage and marketing and credit. And these factors are as necessary as the technology, for without them the technology is largely useless.

Each factor in the intensive production system is important, and none should be overlooked by planners. Failure to meet any particular need adequately reduces the net effect of all.

Of all factors, the availability of complete, highly productive packages of practices is the catalyst, the important prerequisite to progress. And development of such catalysts requires scientists capable of putting together complete technical combinations. Unfortunately, such efforts are being undertaken only with a very few crops in a few locations in a few places. Inexpensive technical assistance, so badly needed so widely, is not being provided.

Needed change can now be dramatic and quick. Contrary to the opinion of many, rapid and even abrupt improvement of conventional agriculture is now possible with many commodities, particularly those crops for which seed can be rapidly increased. The reason given for the contrary opinion often is that the developed nations of Europe and North America have experienced relatively slow advances in national average yields of some crops. While this is generally true, it is in these nations that the many new production inputs (agricultural chemicals, machinery) have gradually been developed. And these nations have neither experienced recent food crises nor had other reasons to press for accelerated output. Many believe, the writer among them, that most technically advanced nations could still greatly increase output, were there a demand for it.

In nations with low yields—given availability of manufactured inputs, credit, the complete technology required for high yields, and demand—production on individual farms can now move abruptly from the traditional low yields to modern-day highs, as farmers abandon traditional practices in favor of present-day ones. National average yields can be markedly and quickly affected; for example, the national average yield of wheat in India moved from 925 kilograms per hectare in 1965 to 1,286 kilograms in 1968, as acreage under high-yielding varieties and associated practices rose from about 1.3 million to over 6 million acres.

It is not necessary that farmers, or even nations, move slowly up the yield and productivity scale. Rather, science, government, and industry—working in concert—often can bring about quick change, when demand and proper technology exist.

Investments in appropriate agricultural research and training provide high returns. As agrarian nations and assistance agencies consider the relative attractiveness of various investments, data reported by T. W. Schultz may be helpful (Table 1). In answering the question, “What is the rate of return to investment in organized agricultural research?” Schultz states:

“On this question there are some studies with some hard facts. . . . The available evidence strongly supports the inference that organized agricultural research has been a most profitable investment. The pioneer work by Zvi Griliches begins with his study of hybrid corn. He found that the accumulated past research expenditures on hybrid corn research, private and public, as of 1955, came to $131 million on which, for each dollar, the social return came to $7 annually or a 700 percent rate of return. Costly? Yes. Payoff? High indeed.”

The data of Dr. Schultz should not be interpreted as indicating that investment in agricultural research, per se, will be profitable. Much of the world’s present agricultural research probably is not, because it is conducted by poorly trained people, or by capable people without adequate support, or by competent people who unfortunately are little concerned with urgent needs of the regions served. In such cases, research may in fact be a useless eco-
<table>
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<tr>
<th>Type of study</th>
<th>Social rate of return</th>
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<td>A Returns at end of year above a 10% discount rate</td>
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<tr>
<td>1. Particular U.S. farm products</td>
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<tr>
<td>a. Hybrid corn research, public and private, as of 1955&lt;sup&gt;a&lt;/sup&gt; and internalized over 1910-1955</td>
<td>700</td>
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<td>b. Hybrid sorghum research, public and private, as of 1967&lt;sup&gt;c&lt;/sup&gt;</td>
<td>360</td>
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<td>c. Poultry research, public, 1960 and internalized over 1915-1960&lt;sup&gt;d&lt;/sup&gt;</td>
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<td>(1) Feed efficiency</td>
<td>178</td>
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<td>(2) Total productivity</td>
<td>137</td>
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<td>Public and private agricultural research and extension adjusted for excess capacity&lt;sup&gt;e&lt;/sup&gt;</td>
<td>300</td>
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<tr>
<td>a. Public agricultural research and extension&lt;sup&gt;f&lt;/sup&gt;</td>
<td>54.57</td>
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<tr>
<td>b. Adjusted for private research&lt;sup&gt;f&lt;/sup&gt;</td>
<td>46.48</td>
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<td>4. Agricultural research in Mexico</td>
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<tr>
<td>a. Wheat research, 1943 to 1963&lt;sup&gt;g&lt;/sup&gt;</td>
<td>750</td>
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<tr>
<td>b. Corn research, 1943 to 1963&lt;sup&gt;g&lt;/sup&gt;</td>
<td>300</td>
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<tr>
<td>c. Total agricultural research in Mexico, 1943 to 1963&lt;sup&gt;g&lt;/sup&gt;</td>
<td>290</td>
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<tr>
<td>5. Japanese agriculture, 1880-1938</td>
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<td>Predominantly investment in education, for example, in 1880, education 23.6 million yen, and agricultural research and extension, 0.3 million yen; and in 1938, 185 and 21.5 million yen, respectively, lower bounds&lt;sup&gt;h&lt;/sup&gt;</td>
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<sup>a</sup>Estimate A is obtained by applying a 10 percent discount rate to the flow of cost incurred over time accumulated and, also, to the flow of benefits obtained over time accumulated. The 10 percent discount rate is assumed to be a reasonable proxy for the rate of return on alternative social and private investment.

The use of estimate B, the internal rate of return, may attribute an inordinately high value to a dollar spent in the more distant past. For example, in the case of hybrid corn, the internationalized rate of return attributes a value $2,300 to a dollar spent in 1910 in developing hybrid corn. (See Griliches’ paper cited in footnote c, p. 425, on why this is an objectionable procedure.)

<sup>b</sup>Estimate B is that rate of return which equates the flow of costs and flow of returns over time; it thus distributes the net benefits equally over the entire period measured in terms of the internal rate of return. Estimates A and B are different ways of interpreting the same set of cost and benefit facts.


conomic burden to the nation, rather than a profitable investment. This must be changed.

For high return to investment to be assured, research must (a) be directed against all technical barriers to productivity of a given commodity, with clear national production and farm-level yield targets; (b) be led by highly competent and dedicated scientists, with major responsibility assigned to one individual, for sufficient years to obtain measurable results; (c) be conducted by interdisciplinary teams of scientists capable of simultaneously attacking all major problems; and (d) be adequately supported with both men and money, so that results from central experiment stations can be widely tested and promoted on farms.

Where technology can be quickly put to use with a minimum of additional adaptive research, as with the use of the dwarf wheat and rice in Pakistan and India, returns should be many fold higher than the dramatic figures reported by Schultz for the United States or Mexico.

Investment by agrarian nations in well-directed agricultural research and training will result in very high returns.

Farmers, large or small, respond to profit opportunities. It is being increasingly realized that most farmers are rational, economic men, whether their holdings are large or small and whether they themselves are well educated or illiterate. The literature of the past two decades is filled with accounts of nonadoption of recommended practices by poorly educated farmers with small holdings. Such farmers have often been criticized for their unwillingness to change, the cause often being identified as either lack of education, conservatism, laziness, or superstition. However, there are now enough results in from Kenya, Mexico, India, Pakistan, the Philippines, El Salvador, Brazil, Taiwan, and Japan to suggest that nonadoption probably occurs because of the incompleteness or unprofitability of the recommended technology, or because of the farmer’s inability to take advantage of useful technology owing to unavailability of inputs, unfavorable prices, or lack of access to a dependable market.

Thus, when farmers fail to adopt new practices, the fault will lie most often, not with them, but with the scientists, the economists, the national leaders, and private industry. The farmer is willing to change, if potential profit is substantial.

Agricultural research and training are primarily public-sector activities. Most of a nation’s continuing agricultural research, from the solution of major problems by interdisciplinary scientific teams at central experiment stations through regional and local experiment station testing, must be done by public agencies—usually the ministry of agriculture or colleges. The reason: There is little if any opportunity for private enterprise to become profitably engaged.

The Rockefeller Foundation has recognized this principle for the past 25 years, and this has led to its active participation in the development of national research systems such as Mexico’s National Institute of Agricultural Research (INIA), the Colombian Institute of Agriculture (ICA), Ecuador’s national research agency (INIAP), the Agricultural Research Institute of Chile, and the all-India coordinated crop improvement schemes for corn, wheat, rice, sorghum, and millets. Each of these national organizations operates a nationwide system of experiment stations, with research organized by commodity and with experimentation and testing under way in every region where any important crop is utilized.

Still, there are occasional vocal advocates of the idea that research and training in the developing nations should be handled by private companies. Certainly, as a nation’s agriculture progresses in intensification, private companies will play increasingly useful roles in the development and marketing of hybrids, in the refinement of techniques of insect and disease control and fertilizer use, and in the development of machinery to meet unique conditions. However, most companies find it impractical to become so engaged until there is reasonable assurance that a substantial market for their products will become a reality; this usually means there will be a time-lag between initiation of public-sector activities and entrance of private enterprise. It is unrealistic to expect private companies to undertake with their own resources the massive task of development of technology and training of the technical personnel required to accelerate a nation’s agricultural output. Many of them could contribute immensely but would need financial support; certainly private industry can become involved long before general development is reached.

On Research

Needed agricultural research is highly sophisticated, even if practical and applied. One of the fundamental weaknesses of technical assistance in agriculture in past years has been that persons with inadequate training and experience in research have been given responsibility for technical programs in developing countries. And, to compound the diffi-
cultivates, such persons have often been given periods of assignment far too short to permit any chance of real success. Experienced leaders of most of the major assistance agencies now are in agreement on this point.

One of the unfortunate results of the success of the semidwarf Mexican wheats developed cooperatively by Mexican and Rockefeller Foundation scientists, and of the "miracle rice" varieties such as the famous IR8 developed by the International Rice Research Institute, is that too many people are now assuming either (a) that the research job with wheat and rice is finished, or (b) that the development of such varieties is an uncomplicated matter. Both ideas are extremely dangerous and totally wrong.

It may be useful to review briefly the development of high-yielding technology for tropical rice by the International Rice Research Institute in the Philippines.

Rice is the basic food crop of 60 percent of the world's population and is by far the most important crop in Asia. Yet average yields in this area have been low and static for centuries. Throughout Southeast Asia, yields have averaged little more than 1 ton per hectare, with harvests of 2.5 to 3 tons on irrigated lands. In Japan, Australia, Spain, and the United States, national average yields range from about 4 to about 6 tons per hectare.

Impressed by the obvious differences in yields between tropical Asia and the technically advanced nations, many people and agencies have in the past attempted to increase rice yields in the tropics, often through introduction of the technology from Japan or the United States.

On a number of occasions, Japanese rice farmers have been taken into the tropics to raise yields using the "Japanese system" of farming, either with Japanese or tropical varieties. Generally, they have failed, by a wide margin, to reach the yield levels of Japan.

Extension programs have been mounted by bringing in extension or production specialists from the technically advanced nations to try to introduce throughout a region the techniques and varieties used by the better local farmers. Generally, such efforts have been disappointing.

There have been innumerable past schemes to get farmers in the tropics to use nitrogenous and other fertilizers on their indigenous varieties. Occasionally this has been helpful, but frequently farmers have not responded. Similarly, efforts to introduce pesticides to control the rice stem borer have been unsuccessful; the practice simply did not pay at the yield levels in the tropics at that time.

From such failures it often was concluded that the farmer in the tropics is unwilling to change, is indifferent, or is illiterate and cannot learn. But evidence accumulated during the past five years indicates that the fault was not the farmer's, but rather was due to lack of proper varieties, practices, and adequately trained technical personnel.

The International Rice Research Institute, established in 1960 by the Ford and Rockefeller Foundations in cooperation with the Government of the Philippines, is about 40 miles southeast of Manila and is adjacent to the College of Agriculture of the University of the Philippines. By the time its facilities were completed in the spring of 1962, it had assembled some 20 major agricultural scientists, representing eight nationalities, to work on the problems limiting rice production in the tropics. This team of carefully selected scientists first set out to raise rice yields on the Institute's own station, and immediately ran into a myriad of difficulties. Using the best of the available tropical varieties, they tried close spacing and high levels of fertilizer, only to find that these reduced rather than raised yields.

The rice stem borer took a heavy toll, but all attempts at control using conventional dusts and sprays failed because of almost daily rains. By 1963, virus diseases were wiping out entire experiments. The blast disease, which infrequently caused losses under traditional methods of rice growing, was now serious as high levels of nitrogenous fertilizers were employed.

The Institute's scientists were convinced that higher amounts of fertilizers would be required if yields were to be increased, and they immediately initiated a comprehensive research program to determine what was wrong. The following are but a few of the developments during the period 1962-65 which contributed to present successes with rice in the Philippines, Vietnam, Malaysia, India, Pakistan, and elsewhere.

The scientists found that the tall, leafy indigenous varieties are vigorous and grow rapidly, which they must to compete with tropical weed growth and to tolerate varying depths of water. However, when heavily fertilized and given good management, these varieties became extremely tall and leafy. In high density plantings, each plant shades its neighbors, cutting down the rate of photosynthesis of the lower leaves. At high rates of nitrogenous fertilizer use, the taller, leafier plants lodge long before harvest, and yields are thus drastically reduced.

The plant breeders initiated the development of
varieties with a short, stiff straw, similar in outward appearance to those used in Japan and Taiwan. By growing three experimental crops a year, they were able to release by 1965 the first short, stiff-straw varieties that would respond to nitrogen applications by producing grain rather than foliage. But many other plant characteristics were required. Grain dormancy, not present in the Japanese varieties, was needed to prevent sprouting of the grain in the panicle during rainy harvest seasons. Insensitivity to day-length was needed to provide broad geographical adaptation and a constant duration of growth regardless of time of year that plantings are made. Resistance to the blast disease was particularly important since it was known that high levels of nitrogen would routinely be applied by farmers using such varieties. Commonly, consumers in the tropics prefer a long, slender grain with "dry" cooking qualities, as contrasted to the short, sticky grain types of Japan and Taiwan. Leaves were to be slender and dark green to permit light to penetrate into the canopy and to assure high rates of photosynthesis. The development of these varieties required a team effort involving plant breeders, plant pathologists, organic chemists, agronomists, and engineers. The Institute's scientists demonstrated that, with such expertise on the team and with the advanced state of science, the job could be done.

The entomologists searched vigorously for means of controlling the rice stem borer and within two years had found safe insecticides that could be broadcast in the irrigation water and, when taken up by the plant, would control this difficult insect. However, by 1965, as tests were initiated in outlying regions of the Philippines, it was found that the insecticides first identified at IRRI would not work in other regions; there were different strains of the insect, and for these, entirely new insecticides had to be identified.

The virus diseases, which hit in 1963, are transmitted by leafhoppers and planthoppers—minute insects for which either chemical controls or crop plant resistance would be required. Prior to 1963, there had been few reports of virus diseases in the tropics, and no provision had been made for a virologist on the Institute staff. When it became obvious that a virus disease probably was involved, the Institute obtained the services for 18 months of Dr. Tosi Take Iida, one of Japan's authorities on the subject. Working with the Institute's pathologists and entomologists, he found that there was not only one but a complex of four virus diseases. Through intensive work, the four were sorted out and the insect vectors for each determined. These results permitted the plant breeders and entomologists to go to work on the development of plant resistance while the entomologists also searched for means of chemical control, which they soon found.

The plant pathologists found that *Piricularia oryzae*, the organism causing the rice blast disease, comprises a tremendous number of strains and substrains or races. Working in cooperation with leading scientists of Japan and the United States, they developed rapid means of testing experimental varieties for resistance to groups of strains. Through such cooperative work, the Institute scientists have been able to incorporate into the hundreds of IRRI experimental varieties resistance to major groups of races and to determine the regions of Asia in which each new experimental variety can be grown with relative safety.

Simultaneously, the agronomists worked on techniques for use of fertilizers, including amounts, rate and date of application, and proper placement. In cooperation with U.S. specialists, a comprehensive research program on weed control was initiated. Techniques were sought for successful direct seeding of rice in the tropics, with the hope of replacing the backbreaking transplanting method which has been practiced for centuries.

The Institute's collection of over 8,000 strains of rice was thoroughly screened, repeatedly, for specific characteristics of value in the breeding program, particularly for resistance to the stem borer, the blast disease, the leaf blight disease, the virus diseases, and for insensitivity to length of day.

Throughout Asia, and now in Latin America, certain of the new experimental varieties from IRRI are giving yields double and triple those obtained with local varieties, when heavily fertilized and properly managed. With the built-in insensitivity to day-length, these new varieties can be planted safely at any time of year. With irrigation, three crops a year can be grown and over 20 tons of grain per hectare have been obtained in a 365-day period. However, such high yields cannot be obtained unless the dry land can be tilled, and this presented a problem to the agricultural engineers: The carabao, the native work animal, cannot pull a plow through dry soil.

Today, high yields of rice are being obtained with the new varieties, with close spacing, high levels of fertilization, and intensive management. The same techniques that failed so completely with the native varieties in the earlier years of the Institute's work are finally being successfully employed.
The experience of the Institute demonstrates dramatically that the rice technology and the varieties of Japan, the United States, and Australia were not applicable to tropical Asia. This know-how was not available for tropical rice.

The Institute’s experience also illustrates clearly that scientific competence can be exported, that teams of capable scientists, properly oriented to the problems of a region, can make fast progress if given adequate support and enough time.

The improvement of technology for tropical rice was not a simple matter; rather, it was highly complex and demanded the attention of an interdisciplinary team of highly competent scientists. One must expect that similar competence and support will be needed to achieve similar progress toward the solution of other agricultural problems of developing nations.

The Institute has demonstrated that yields in the tropics can be fully as high as those in Japan, Australia, or the United States; but its findings do not solve the problems for all the tropical rice regions. Interdisciplinary teams of scientists must be at work in each of the nations where rice is important; for in each nation there are unique biological problems, distinct sets of environmental conditions, and distinct consumer preferences as to grain quality. The gall midge is a serious insect pest in Thailand and certain other nations, but it is not present in the Philippines and consequently the Institute scientists cannot work on it there. In Thailand, East Pakistan, and parts of India, deep-water rice is grown at depths ranging from a few inches to 20 feet. Interdisciplinary teams now exist in both Thailand and India, but in most nations they are yet to be formed. The Institute’s technology has little applicability to parts of Africa, and interdisciplinary teams must be established there if similar progress is desired.

A good start has been made in developing advanced technology for the tropical rice regions, but it is only a start. The effort must be extended to all important rice-growing regions and must be continued until strong national programs are in place in most of the major rice-growing nations.

*Technology can be tested; the measure is absolute yield.* A quick and substantial payoff from agricultural research can occur only if the research is directed against problems that are seriously limiting productivity. Obviously such limiting factors were present in the tropical rice areas, because yields simply were not of the same order of magnitude as those being obtained elsewhere. Had scientists in the tropics been achieving harvests of 10-12 tons (world record levels) repeatedly, there would have been little or no need for the IRRI research effort.

The adequacy of available technology can be tested for any crop in any region through use of maximum yield trials conducted by scientists who are familiar with or have access to the best of the world’s scientific contributions. Such testing is clearly a job for well-informed professionals. If properly conducted, it can often save precious time in initiating sound production campaigns. A recent example is provided by the quick transfer of the high-yielding wheat varieties and accompanying technology from Mexico to India, Pakistan, and the coastal areas of Turkey. By 1960, the semidwarf, day-length-insensitive, spring-wheat varieties from Mexico were producing very high yields at high levels of fertilizer usage and under regimes of intensive management; they were beginning to attract international attention. Young wheat scientists from Pakistan and India were brought to Mexico in the early 1960’s for in-service training, and, when they returned to their own countries, they were permitted to take with them seed of the new varieties. As a result of this in-service training, they now knew how to grow and test them. The results of the first year of tests were dramatic; yields were as high as in Mexico.

Dr. Norman E. Borlaug, The Rockefeller Foundation’s wheat specialist in Mexico, who had been in charge of the program since 1944, went to Pakistan and India to see these tests and confirmed the reported results. Immediately, a more extensive network of tests was installed and again the yields were high. By 1965, there was a sound scientific basis for moving ahead immediately with production campaigns in both Pakistan and India; as a result, both governments took the necessary action. In Pakistan a wheat production campaign was mounted with the assistance of Dr. Ignacio Narváez, head of Mexico’s cereal improvement program, who moved to Pakistan to work with his Pakistani colleagues. The Ford Foundation contracted with the International Maize and Wheat Improvement Center (CIMMYT) to assist Pakistan with technical aspects, while the Foundation’s own staff in Pakistan helped the nation to plan and organize its efforts. The Ford Foundation and CIMMYT have both helped to guide Pakistan from its deficit food-grain position to one of self-sufficiency.

In India, Minister for Food and Agriculture Subramaniam launched that country’s High-Yielding Varieties Program in 1965, again based in part on the dramatic results of the initial tests with the
Mexican wheat varieties, the rice varieties from the International Rice Research Institute, and corn, sorghum, and millet hybrids developed in India with assistance from The Rockefeller Foundation's Indian Agricultural Program. In the case of wheat, India set in 1965 a target of some 12 million acres to be planted with the Mexican wheat varieties by 1970-71. It recently has been estimated that some 10 million acres already will have been so covered during the 1968-69 wheat season.

In 1965 and 1966, Turkey tested the Mexican wheat varieties for the first time in the coastal regions, with results as promising as those obtained in Pakistan and India. Consequently, Turkey imported some 22,000 tons of wheat seed from Mexico in the summer of 1967 and launched a very successful wheat production campaign in the coastal areas, with highly effective support from the U.S. Agency for International Development.

In Pakistan, India, and Turkey, the tests of the utility of the technology developed in Mexico paid off handsomely. Those nations did not wait for the formation and upgrading of interdisciplinary scientific teams; rather, with expatriate leadership, they embarked immediately on bold national production campaigns that also provided training for their own scientists on the scene through participation in the dynamic national efforts.

Now each of these nations, quite properly and necessarily, is undertaking a major wheat improvement program aimed at production of varieties of greater local acceptance and with resistance to the ever-threatening and devastating rust diseases. And they still must develop complete packages of technology for the drier and colder regions.

The tests of the wheat technology in India, Pakistan, and Turkey were feasible because there were standards of performance elsewhere against which the test results could be compared. There was confidence in the test results because in each case the trials had been seen and judged satisfactory by acknowledged specialists such as Dr. Borlaug or Dr. Orville A. Vogel of the U.S. Department of Agriculture, stationed at Washington State University.

The national agricultural research system comprises activities from central experiment stations to individual farms. A major difficulty encountered in the organization of effective research, training, and production programs in developing nations is the general lack of appreciation of the scope and depth needed in the research system. That agricultural research must be undertaken at central experiment stations or in the laboratories of national research organizations or colleges of agriculture is well understood; frequently, however, the further steps of identifying and testing packages of technology in each distinct farming region of a nation and finally at the ultimate experimental site—the individual farm—are erroneously excluded. Too often, scientists as well as extension leaders consider that activities leading to adoption by farmers are not the responsibility of the research establishment. Until this erroneous idea is overcome, progress will be slow indeed.

particularly during the past three decades, science has provided an increasing array of new technologies—varieties, fertilizer-use practices, means of insect and disease control, improved methods of land preparation, crop maintenance, and harvest, credit mechanisms, new fertilizers and other agricultural chemicals, vaccines, techniques of animal herd improvement, means of balancing animal rations, and a host of others. A veritable smorgasbord of new technology of constantly increasing specificity and diversity is available. These new production inputs and techniques are being turned out at universities in the developed nations, in the laboratories of commercial companies, by action agencies of both developed and developing nations, and by other institutions. Few would question the high degree of sophistication involved in the creation and perfection of such materials and techniques.

Scientists in developed nations and the institutions that support them have generously attempted to make new knowledge and materials freely available to the public. In agriculture, this has been done through a multitude of devices, including use of technical publications, farm bulletins, newspapers and farm magazines, radio and television coverage, and short courses organized by the institutions. Additionally, particularly where agricultural progress has been most rapid, regional and even farm-level tests and demonstrations have been systematically organized and pursued, (a) to permit the research scientists to evaluate technology more fully and (b) to allow the interested individual producer to see for himself the most recent advances in technology.

In the highly developed nations, the above system has worked admirably in that many of each nation's farmers have become aware of technology and have adopted it, with resulting increases in productivity and profitability of production. Unfortunately, such a system, good as it is, is not benefiting all farmers. Rather, benefits have accrued primarily to the well-educated agricultural entrepreneur who not only understands the great array of materials and techniques but can also, through trial and error (experi-
mentation), identify the outstanding combinations of technology for the specific conditions on his own land. Not generally realized is the fact that such experimentation, such trial of combinations of practices at the farm level, also is a highly sophisticated endeavor, requiring a comprehensive knowledge of available technology and an understanding of how the individual technological components interact among themselves and with characteristics of soil, rainfall, and other factors. Sophisticated? Yes.

Because of the high degree of sophistication required to devise appropriate combinations of biological, managerial, and economic inputs for specific environmental situations (the individual farm), the relatively uneducated farmer cannot participate on his own initiative. Because of his lack of education and often because of his remoteness from centers of scientific activity, such a farmer may be unaware of the availability of some or all of the technical and other inputs. Were he aware of them, he would probably find their complexity bewildering. He is incapable of putting together the productive and profitable combinations for his own farm. He is bypassed by science. He need not be.

In the highly developed nations, agricultural extension services disseminate the findings of research and promote their use by farm producers. To the extent that such services have dealt with the highly educated entrepreneurs, they have been highly successful. Increasingly, extension agents have become communications specialists whose primary function is to make the farm producers aware of the availability of technology. But such personnel do not cooperate with scientists in experimentation at the farm level to assist in the identification of proper combinations of materials and practices.

In the less-developed nations, one commonly finds extension services manned by personnel who have limited education (even by local standards) and are inexperienced in technical farming. Often they are in organizations administratively separate from the research establishment. Because of their lack of training and limited access to new technology, they are relatively useless in promoting intensive agriculture.

If the uneducated farmer in remote areas is unable to put together the proper combinations of advanced practices for his own farm, and if the extension agents have neither the training nor the access to technology to do it, then who can? Must this farmer's participation in the increase of needed agricultural output await the day when he and others like him have greater education? The answer is emphatic No. The research scientists—and only the research scientists—can remedy the situation, and do it they must.

The national agricultural research system in any developing nation must now be visualized as comprising (a) interdisciplinary research efforts at the central experiment stations, be they facilities of agricultural colleges or the ministry of agriculture, (b) experimentation and testing at centers in each farming region, and (c) necessary experimentation, testing, and demonstration on farms in each locality to be served. This total research system must be headed by highly capable scientists dedicated to advances in the farm areas. Personnel at all levels of the system, even the village-level workers who are expected to assist farmers to increase crop and animal productivity, must be considered as part of the research system. This means that they must be trained in the essentials of technical agriculture, including the use of modern inputs, and in the techniques of experimentation and demonstration needed at the local level. This, in turn, means that such personnel must be trained at the central or regional experiment stations where they can become familiar with modern technology and its use and become acquainted with the research scientists and the facilities from which will flow their continuing supply of new and better information and materials. They must personally demonstrate to the farmer, particularly the uneducated farmer, how to use new technology, not simply convey written or spoken information to him. They must be able to diagnose farm problems and prescribe remedies on the spot. They are the equivalent of the medical doctor, who becomes a qualified practitioner only upon completion of final technical training (internship) at a central hospital under the guidance of qualified professionals. As in the case of medicine, internships for agricultural specialists will require full-time service at the central experiment stations for periods usually of a year or more. Fortunately, such people can, during their period of internship, contribute to the progress of the research program as they themselves are trained, so that costs of research and training can be kept at minimum levels.

The above principles have been recognized by The Rockefeller Foundation throughout the 25 years of its activity in agriculture. For example, during the years 1943 to 1961, the Foundation cooperated with the Government of Mexico in developing that nation's research system, particularly as it involved the basic food crops. In 1943, average yields of all food crops were very low and Mexico was importing
heavily. As reported previously, field programs were initiated with wheat and corn, then expanded to include other crops such as field beans, potatoes, sorghum, vegetable crops, and forage crops, as well as work with poultry, dairy and beef cattle, sheep, and swine.

The pattern was similar for each project. A specialist was brought in. He built up a modest staff of young Mexican college graduates who were trained as the research was done. Each specialist was faced with a similar mandate: increase agricultural production (and profitability). Existing varieties from all over the world were brought together, tested, improved, and released to farmers. Complete and profitable packages of practices were worked out for each season in each important region for each crop. There were specialists in soils, entomology, plant pathology, farm management, and communications to assist in securing information and getting it out to farmers.

For each crop, success was to be measured by the impact made on the nation's agricultural output; with such a yardstick, the scientists worked on those problems limiting production, avoiding academic pursuits unrelated to production goals.

Emphasis was placed on the training and testing of men: By 1963 over 700 young Mexicans had served for one or more years as interns under the guidance of the Foundation’s specialists in the Office of Special Studies of Mexico’s Ministry of Agriculture.

As men and information and improved varieties became available, the program was expanded to more regions and lines of work. Price policies were changed by the government, and extension services were broadened with the young, trained agriculturists. As it became evident to private industry that higher yields could be obtained with their products, their interest and services increased. Irrigation facilities were improved, farmers’ associations strengthened. By 1963, Dr. Harrar was able to write:

"The impact of this cooperative program on the agriculture of Mexico has produced demonstrable results. In general, it can be said that food production has doubled. Wheat production has more than doubled, corn harvests are up almost as much, bean production has doubled, broiler production has tripled, eggs have increased two and a half times, and the end is not in sight. Mexico could stop importing wheat in 1956, when harvest balanced demand for the first time in history, and corn is no longer in deficit supply.

"Twenty years ago, Mexico’s 21 million people averaged 1,700 calories a day. Today [1963], Mexico’s 37 million people have reached 2,700 calories, and a more varied diet that increasingly includes animal proteins."

The outstanding individuals among the 700 interns were given opportunities to undertake graduate studies at universities in the United States and elsewhere to qualify them to assume leadership of Mexico’s institutions and programs in 1961. Mexico has only begun its era of agricultural progress and much remains to be done. There will be still more dramatic improvements if Mexico maintains a strong and well-oriented program.

On Extension

Conventional extension methods are inadequate. For reasons given in the paragraphs just above, it is essential that extension programs in developing countries be reoriented, where necessary, to permit their involvement in the regional and local experimentation, testing, and demonstration. Those personnel involved in such activities must become a part of the nation’s research system, either administratively or functionally, and the entire system must be under unified leadership so that responsibility for both orientation of research and success at the farm level can be clearly assigned. There must be no evasion of such responsibility. In some circles; there is now a strong belief, with which the writer is sympathetic, that the term “extension” is outmoded, that it should be replaced with the term “production” to avoid misinterpretation of mission. This change has already been accepted by the International Rice Research Institute which has a major program for the training of production specialists—personnel who elsewhere might be considered extension agents. The International Maize and Wheat Improvement Center in Mexico trains wheat specialists and corn specialists, the implication being that such people will, upon completion of internship, understand all important aspects of intensified production of the crops.

Earlier explanations in this paper demonstrate that production (or extension) programs cannot be successful unless the complete packages of technology first have been developed and demonstrated to be highly productive and profitable to the prospective producers. The research must come first; but as it proceeds, production specialists, as well as additional research scientists, can be trained locally to permit the elaboration of the research system and the initiation—with trained people—of production campaigns wherever they are most needed.
On Education

Colleges of agriculture must be instruments for economic development. One of the most glaring weaknesses in world agriculture, and in particular in the developing countries, relates to the nature of agricultural colleges. With very few exceptions, assistance agencies are taking very little action to assist these institutions to meet the most urgent need of the regions they serve. The agricultural college has three important missions, only one of which has generally received serious attention.21

First, substantial numbers of the nation’s or region’s youth must be educated and trained for the career opportunities which will be opened to them during their productive years. There is little disagreement, except on details, on the need for education in the basic sciences, language, history, economics, mathematics, and in the subjects of the student’s chosen field of specialization. Presently, significant numbers of agricultural colleges in many developing nations are being assisted to upgrade faculty through scholarships for study in the developed nations, to improve curricula and business organization, and to make arrangements for handling the demand by increasing numbers of students for collegiate or university education.

Second, through its faculty and its library, the agricultural college must bring together, conserve, and make easily available the world’s information and materials which are potentially valuable in the drive for cultural and economic development of the region served. Libraries are receiving some attention, but, too frequently, faculties are either uninterested in or incapable of searching out the scientific information and material of relevance to the region’s immediate or impending needs. Some are unable to enter the mainstream of scientific thought and activity because of academic isolation; there is a lack of available publications, little opportunity to participate in conferences on important subjects and problems, and minimum opportunities for travel even intranationally. The faculty member who apparently is uninterested in the needs of the college’s constituency remains a major barrier to progress. Frequently he attaches greater importance to the topics of current interest in the developed nations, and equally frequently he disclaims leadership in economic development as a college responsibility.

Finally, many faculty members are incapable of bringing together significant information and materials because their own training or experience is inadequate for the task. It takes years for any agri-

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would be concerned with field research during the summer months only, and would thus have a long winter period in which to teach and prepare for the following summer's activity.

What, then, should be the nature of the activities of an agricultural college, and how should its success be measured? It would seem that at least two criteria would be useful: (a) the student's proficiency in the use of the knowledge and understanding gained through his university experience, and (b) the impact of the college's research program on the nation's economic development.

Each central agricultural college should have on its staff a number of specialists who, through years of dedicated experience, have emerged as authorities in their fields. At a good college in the tropics, one should expect to find authorities on each crop or animal species of major importance or potential importance in the region served. One should also find specialists on the major animal and plant diseases and on major insect problems, as well as specialists in economics, agricultural engineering, and other fields.

Each crop or animal specialist should be providing leadership for important components of the overall research program for the area served, whether this be a province, a region, or a nation. His program should be closely integrated with those of the action agencies of the ministry of agriculture, and with extension agencies that may be administered separately. There must be a minimum of administrative barriers between the central experiment station and the farmer. If leadership of major research activities has been vested in a different research organization, then university personnel still must contribute significantly to the total effort.

One of the critical problems facing an agricultural college in the tropics is that of leadership for its research programs. Direction of each crop or animal program, or of research on major problems in other fields, must be placed in the hands of the most competent and dedicated scientists available, who must then be left in these positions of leadership for extended periods of time. This suggests that at agricultural colleges these specialists, these authorities, should be given research professorships and their teaching loads kept at a minimum. They should contribute to the educational program primarily through guidance of student research problems.

As mentioned earlier, students at agricultural colleges in developing nations usually have little opportunity while in college to develop a real proficiency in crop, soil, or animal management. It also is not unusual, for example, to find that a college faculty member who is teaching a course in crop management is not himself able to grow a good crop. The reason: He has never been trained to do so; because of the absence of dynamic, crop-oriented or animal-species-oriented programs at the college experiment station, he had no chance to obtain experience while in school. This lack of crop or animal programs may in turn be traceable to an absence of the continuing leadership, either national or external or both, that is required to develop comprehensive programs ranging from research through extension to the farmer.

The medical profession usually requires that a candidate for the M.D. degree spend a substantial period of time as an intern under the guidance of qualified professionals. Agricultural colleges might well require a year's internship in a dynamic research program as a prerequisite to graduation. This, however, would require crop- or animal-oriented research programs—well-equipped experiment stations with staff members working on critical problems in the region served—which in turn would require the presence of effective and continuing scientific leadership.

Many agricultural colleges do have provision for agricultural practice built into the curriculum. In some cases students are required to spend a specified number of hours in the field or a certain number of months on a farm. All too often, however, the students put in their hours of practice weeding crops or doing other menial tasks that do not contribute to their understanding of advanced agriculture. This would be the equivalent of allowing medical interns to spend their internship mopping out hospital corridors. Students really need to gain experience with land preparation, planting, maintenance and harvest of the crop, fertilizers and their application, plant protection, and seed production—or to gain equivalent understanding with respect to the animal sciences.

In developing countries, there is one additional and urgent training problem. Large numbers of educated but untrained college graduates already may be occupying positions at the experiment stations, on seed farms, on the faculties of agricultural colleges, or in the extension service—persons who have gained college degrees in the past but who still lack proficiency in technical agriculture. Considerable attention is being given today to the retraining of such young men at experiment stations with dynamic research programs. These technicians serve
as full-time staff members (interns) and thereby become proficient in modern agriculture. But this demands that there be such action programs on the experiment stations, complete with effective and continuing technical leadership and adequate support by government.

If assistance agencies will support the development of comprehensive and relevant programs of research at the major agricultural colleges of developing nations, widespread agricultural and economic progress can be stimulated. But it will be the nature of the research effort, as well as the magnitude of it, that will determine success.

Professionalism in agriculture: Lack of standards presents difficulties. In agriculture, no formal standards of either education or experience have ever been established for such titles as agronomist, plant breeder, or economist. One holding such a position may have a doctorate, a Master of Science degree, or (in Latin America) an Ingeniero Agrónomo degree, or he may have even less education.

At the time that the International Rice Research Institute was being established in 1960-62, the writer had an opportunity to visit many of the major rice research installations of Asia. In Japan, the agricultural scientists were highly educated and highly experienced. In another nation, the research program on rice, its most important crop, was headed by a man with a Master of Science degree—the only person in the national rice improvement program who had advanced training. In still another, the rice improvement work was under the direction of an able young man with only two years of college. Activities of the principal cereals research institute in a major country were headed by a plant breeder with a high-school education. Fortunately, some of these deficiencies either have been or are being remedied.

One also finds a great range of education and experience among individuals sent to the developing countries by assistance agencies. Because of the lack of standards in agricultural professions, assistance agencies face unusual difficulties in identifying persons properly prepared technically to undertake sophisticated professional assignments. Too many people qualify by title; too few qualify by virtue of education, experience, and dedication. Technical incompetence of its overseas staff has plagued some assistance agencies.

Because of these difficulties, assistance agencies and others will find it useful to have candidates for professional assignments judged by other professionals in whom the agencies have confidence.

One other source of serious error in assistance programs in past years has been that the worth of agricultural technology in developing countries has too often been judged by persons incompetent to make such judgments. Few agricultural economists are capable of judging the quality of a plant breeding program, but such evaluations have often been made; in principle, neither should a plant scientist try to judge the quality of an animal science or an economics program. There is abundant truth in the idea that the only person a professional cannot fool is another experienced professional in the same field.

On Organization and Focus

Basic food crops are still neglected. The basic food crops of the world comprise rice, wheat, corn, sorghum, the millets, the grain legumes (soybeans, cowpeas, chickpeas, peanuts, field beans, and lentils), the root crops (cassava, potatoes, sweet potatoes, yams), and some others. Except for the work that has been done on such crops in the technically advanced nations—much of it not applicable to the environmental conditions of the developing nations—there has been little investment in their improvement. The situation is equally bad in the case of fruits and vegetables. The estate crops have been given some attention both by government and by commercial companies. Food crops, however, remain neglected in vast and numerous areas where millions of farmers depend upon them for a livelihood. Economic development in these regions must await the improvement of these crops.

The Ford, Rockefeller, and W. K. Kellogg Foundations have recognized the need for intensified work on certain of these crops, and this has led to the establishment of the International Rice Research Institute in the Philippines, the International Maize and Wheat Improvement Center in Mexico, the International Institute of Tropical Agriculture in Nigeria, and the International Center of Tropical Agriculture in Colombia. These centers have joined or will join other, already established national and international institutions in contributing to the acceleration of work on certain of the crop and animal species, plus associated problems, and in training scientific specialists. These and other institutions must be adequately supported to permit them to be effective in solving those problems on which they are particularly qualified to work by virtue of staff competence and geographic location. It is nevertheless obvious to the foundations that the four new international centers, together with all other national and international institutes, represent only a start.
toward the network of world, regional, national, and local centers of technical activity that is needed if the benefits of science are to be brought to all of mankind in the shortest possible time and at minimum cost.

**Production-oriented, coordinated, commodity programs are keys to success.** Wherever rapid progress is occurring in the acceleration of production of basic food crops, it is being achieved through production-oriented, coordinated, commodity programs. Activities are organized by commodity with specific production or acreage targets; this allows success or failure to be measured. It also causes scientists to concentrate on all of the technical problems inhibiting increases in yield, none of which they dare leave unsolved. Responsibility for success can be clearly fixed.

By “coordinated” is meant joint and planned efforts by all institutions and disciplines that must participate if the total program is to be successful. In some of the larger nations, the idea of coordination raises some fears in the minds of scientists and institutional leaders at state or provincial levels that a federally coordinated program will dominate their own activities. Such domination should not and need not occur; central agencies should assist the organization and funding of work on nationwide or interstate problems, but the subordinate units should in addition have their own streams of support for intensive activities on problems in the areas under their jurisdiction. Coordination and cooperation must be sought, while dictation and restriction are to be carefully avoided.

There are a number of national commodity programs known to the writer. Among these are the all-India coordinated crop improvement schemes for maize, wheat, rice, sorghum, and millets. For each of these there is a federally supported, central research and coordinating unit at a strategically located experiment station, plus federally supported activities at cooperating state institutions which serve as regional and zonal centers. This arrangement is permitting the elaboration of a nationwide complex of interlocking cooperative activities. Pakistan has mounted major programs with wheat, rice, and corn. In Thailand there is a national corn and sorghum program headquartered at Farm Suwan, the major experiment station of Kasetsart University; it is jointly staffed by the university and the Ministry of Agriculture, and regional activities are under the auspices of the ministry. The Philippines is now developing a national uplands crop program involving corn, sorghum, and soybeans; at the University of the Philippines College of Agriculture there is a central interdisciplinary research effort on these crops, supplemented with work at four regional stations (of other agencies). Kenya’s national corn improvement program also has been soundly developed.

The wheat improvement program in Mexico illustrates the possible impact of organized national programs. In 1944, Dr. Norman Borlaug went to Mexico at the invitation of Dr. Harrar to head the cooperative work on wheat. Wheat yields were low, about 11 bushels per acre. Varieties were highly susceptible to stem rust; they were tall, and use of fertilizers usually did not pay since the varieties would become overly tall and leafy and would fall over. Mexico was importing half the wheat it consumed.

By 1964, wheat yields in Mexico had climbed to 39 bushels per acre as a national average—a three- and-a-half-fold increase.

Eight important components of this successful program can be defined:

1. **Ambitious objectives were established.** The program was designed to eliminate Mexico’s substantial wheat deficit of the early 1940’s—which it did in spite of a sharp rise in Mexico’s population during this 20-year period. Every effort was made to raise production in the shortest possible time. Measures of success were increases in average yields and increases in total national production.

2. **There was initial and continued emphasis on research.** In 1943 most of Mexico’s wheat was grown during the dry season, under irrigation, to escape the ravages of stem rust. New varieties were developed, and continue to be developed, which were rust-resistant, had short, stiff straw to permit profitable use of high levels of nitrogenous fertilizers, and were insensitive to photoperiod, a characteristic adding considerably to their range of adaptation. Soil management, weed control, and irrigation techniques were developed. By use of two and sometimes three generations or crops a year, the research program made fast progress. Although Mexico had to produce its own wheat varieties from scratch, it did so; and by 1954, only ten years later, 70 percent of Mexico’s wheat acreage was planted with varieties developed, tested, increased, and adopted by farmers. Research was clearly a prerequisite to increased production in Mexico, as it still is today with most crops in most developing nations.

3. **In-service training was emphasized.** Some 700 nationals were locally trained to a point of proficiency in crop production. Over 40 graduates of Mexico’s colleges of agriculture were given one or
more years of local experience working as members of the staff of the wheat project. They learned about wheat and how to improve and farm it. Only a small fraction of these men stayed in research, but over the years many others accepted positions in extension, teaching, and seed production or with agricultural banks and industrial firms. The important point is that a large number of trained wheat men were infused into Mexican agriculture. And as they learned, these men helped with the job of research, seed production, and extension, so that the cost was kept minimal.

4. Leadership was continuous. The wheat program was initiated by Dr. Harrar and Dr. José Rodriguez Vallejo, with the counsel of Dr. E. C. Stakman. Shortly thereafter, Dr. Borlaug assumed responsibility for the project. Borlaug stayed with the program during the next 20 years, until Mexico’s own scientists were prepared to assume leadership in 1961. And a number of the Mexican scientists who joined the project in its early years are still with it. Continuity of leadership, both by nationals and by specialists supplied from abroad, is essential.

5. Outstanding and dedicated young wheat men—graduates of Mexico’s agricultural colleges, most of whom had received the additional field experience—were sent abroad for advanced study, primarily to United States universities. This permitted Mexico to develop the competent leadership needed to assume the direction of its own wheat improvement work.

6. As trained men became available, the research program was systematically broadened to include all important wheat-growing regions; seed production was intensified through private growers and on government farms; and extension of varieties and practices was accomplished effectively by young men who had become proficient in wheat production techniques.

7. Research and extension were combined. As the research team solved the problems limiting production, they demonstrated repeatedly—at field days and on private farms, to national leaders and to farm groups—that higher yields could be obtained, and they showed how to do it. There was little separation of research and extension; there was instead one program that began on the research station and ended with use of the varieties and practices by the farmers.

8. Government and private-sector services and policies aimed at encouraging wheat production were improved. Price supports were provided, farm credit became more widely available, extension services were expanded, and supplies of farm ma-


cinery, fertilizers, and agricultural chemicals were increased. Wheat farming became profitable. Without the interest and support of leaders of the Mexican government, this record of unusual achievement could not have occurred.

The small farmer can be reached. Agrarian nations with inadequate food production face at least two problems: They must increase national totals to meet urgent needs and eliminate dependence upon other nations, and they must encourage production in geographical areas of greatest deficit and by large numbers of farmers with small and often remote landholdings.

The first objective, that of quickly meeting urgent total national needs, is receiving serious attention by some nations with deficits. Naturally, efforts focus on maximum increases in minimum time. Generally, the large and quick increases are being obtained on better lands, where rainfall is good or irrigation possible, with those few crops for which adapted, high-yielding varieties exist, and through efforts of progressive farmers whose landholdings tend to be relatively large. But as national output increases, and as some farmers benefit while others do not, attention turns to the plight of the large numbers of uninvolved farmers with small landholdings, many of whom are in areas of local food deficit. Can they be benefited? In some cases, hopefully in many cases, the answer is Yes.

The Puebla Project in Mexico is attempting to assist some 50,000 families who subsist primarily on the production of 120,000 hectares of unirrigated corn in an isolated valley of the State of Puebla. Scientists of the International Maize and Wheat Improvement Center, of the Graduate School of the National School of Agriculture at Chapingo, and of Mexico’s National Institute of Agricultural Research joined forces with state and federal agencies to determine whether corn yields could be quickly increased—substantially and profitably. The first year, a comprehensive series of experiments was installed on lands of cooperating farmers. These involved: (a) tests of seven levels of nitrogen fertilization, with plant population and phosphorus supply kept high (26 locations); (b) tests of seven levels of phosphorus, with plant population and nitrogen supply kept high (26 locations); (c) tests of plant populations, ranging from the traditional 15,000 plants to about 60,000 plants per hectare, with both nitrogen and phosphorus supply kept high; and (d) tests of about 60 different improved varieties, hybrids, and local strains, with plant population and both nitrogen and phosphorus supply kept high.
Industrial leaders are beginning to realize the interdependence of individual sectors. Demand for fertilizers, for example, will depend on the availability of crop technology produced by public agencies and people trained by them; on the availability of pesticides, of adequate prices and markets, and of needed machinery. Machinery or pesticides will not be purchased until other inputs are available, etc.

Expansion of markets in developing nations for all manufactured inputs is heavily dependent upon prior development of technology and training of personnel by public agencies. An awareness of this interdependence of science, government, and industry—and of the interdependence of sectors within industry—led, in part, to the formation of the Agribusiness Council in the United States, an organization that will seek orderly involvement in agricultural development of all relevant and interdependent public and private entities.

ACTION RECOMMENDED

Acceleration of world agricultural output can be fostered by the formation of a worldwide, interlocking complex of national and international scientific institutions, programs, and projects designed to produce the scientific information, materials, and manpower required to intensify agricultural production wherever needed. Provision must be made for immediate attention to all areas where agricultural productivity is still low and static and where man:land ratios are most unfavorable, and to control of many internationally serious diseases and pests. The underexploited tropics and certain arid areas can and should be brought into use as required.

Development of such a network of institutions and activities will require that national and international efforts be cooperative and coordinated to the extent possible. Toward this end, increased and periodic dialogue among appropriate leaders should be established, to identify neglected, high-priority needs and to foster cooperation wherever indicated.

It would be beyond the capabilities of the writer to identify all the necessary components of the international network, but the following are listed and described as a basis for further discussion.

International Centers

Comprehensive research and training institutes, strategically located, competently staffed, and adequately supported, can and must serve as catalysts of progress by individual nations by undertaking the following unique types of activities:

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1. The solution of technical problems of major international importance that (a) cannot be handled by existing research centers in developed or developing nations and (b) require in-depth interdisciplinary research by highly trained specialists with a full range of scientific facilities.

2. The establishment of new standards of productivity of specific crop or animal species in the region served, against which performance elsewhere can be compared. (As late as 1963-64, yields of 3 tons of rice in the Asian tropics were considered very good, until work at IRRI demonstrated that yields under 6 tons were mediocre, and that good yields should be 6-8 tons since top yields were 9-10 tons. Suddenly, work on rice at many places in the tropics was reoriented to try to match the IRRI pace.)

3. The design of agricultural systems—sequences or combinations of crop and animal production practices—that permit maximum output and profitability per unit land area or animal unit per year or per man-year. (Dr. Richard Bradfield's work at IRRI, discussed more fully in F. F. Hill's resource paper, is an example.)

4. The provision of a reliable source of specialized information and materials to which any individual or institution can easily turn for assistance. The library attempts to bring together the world's information on subjects of institute specialization, then to make it freely available to cooperators anywhere. Conferences of world specialists, focusing on specific problems, permit the great amount of obsolete or incorrect technical information to be identified as such and eliminated, leaving a useful residue of reliable and relevant data and ideas. Over time, the institute staff become acquainted with the capabilities and limitations of most of the important institutions and individuals in the scientific fields of specialization; information and evaluations of this kind are of particular value to assistance agencies.

5. The organization and, where necessary, leadership of cooperative work among interested scientists and institutions on problems of common concern, so as to move all work by cooperators to advanced levels, avoid overkill on problems, minimize duplication, and permit the imagination and capabilities of all cooperators to be effectively utilized in joint attacks on selected problems. By remaining apolitical (at least, not managed by governments), such institutes can organize work on a scientist-to-scientist basis, thereby achieving a degree of professionalism not readily possible when government officials choose delegates or cooperators.

6. The provision of direct technical assistance to developing nations in the organization of research, training, and production programs. Such centers can supply leaders or guidance during the years required for training of nationals; they can also furnish advanced biological materials.

7. The training of large numbers of specialists for national or international organizations.

The Ford, W. K. Kellogg, and Rockefeller Foundations, the Government of Canada, and the U.S. Agency for International Development, together with the governments of the host nations, have cooperated in various combinations to establish four such centers:

The International Rice Research Institute (IRRI) in the Philippines, which serves primarily tropical and subtropical Asia and whose work is limited to rice and to multiple-cropping systems involving rice.

The International Maize and Wheat Improvement Center (CIMMYT) in Mexico, whose work is limited to corn and wheat but is worldwide in scope.

The International Institute of Tropical Agriculture (IITA) in Nigeria, which will focus on tropical food crops and soils, and will serve primarily the African humid tropics. Initially, crops will include corn, soybeans and cowpeas, cassava, sweet potatoes and yams, forage grasses and legumes, and rice.

The International Center of Tropical Agriculture (CIAT) in Colombia, whose research will focus on agricultural systems for the humid tropics, primarily in the Americas. An animal science (primarily beef) program will cover forage crops and animal nutrition, health, and herd improvement, and will include a small Inter-American Swine Improvement Project. Crop work will center initially on rice, corn, grain legumes, and root crops, much of this in cooperation with IRRI, CIMMYT, and IITA.

Even with the establishment of these four institutes, there still will exist no comparable center of activity, accumulated expertise, and assistance for tropical vegetables, tropical fruits, sorghums, millets, or oil crops. Centers focused on arid-land agriculture and on irrigation and drainage are also needed.

One or more acknowledged centers of knowledge and activity, with responsibility for service internationally, are needed for every commodity of any importance, including many not mentioned above.

Programs at the initial four centers should now be strengthened until they function fully as outlined above. Simultaneously, attention should be given to means of organizing additional centers, preferably near colleges that offer postgraduate degrees in agriculture.
Support for international centers should be by outright and continuing grants from assistance agencies so that the centers can remain apolitical, function with businesslike efficiency, and be guided by representatives of assistance agencies together with distinguished and informed intellectual leaders from interested nations.

**Regional Research Centers**

For present purposes, regional centers are considered to be institutions established for the purpose of leading the development of specific ecological or geographical areas, e.g., the llanos of Colombia, and/or Venezuela, the campo cerrado of Brazil, the Gangetic plain, and East Africa. Such centers usually will be components of a national system, and should be supported in large part by local governments. To be successful, such centers should: (a) be responsible not only for research but also for progress at the farm level, with well-defined production goals; (b) have an interdisciplinary staff, with at least one senior specialist for each important commodity and each supporting discipline; (c) be given long-term support; (d) be under direct or indirect supervision of those national leaders who are responsible for planning, finance, and agriculture; and (e) maintain close links with other national and international activities that could be helpful.

Such centers of research, extension, and production efforts, properly staffed and oriented, can be very wise investments, and international banks or other agencies should find them particularly worthy of consideration for loans for equipment, expatriate leadership, and even support of operations.

Kenya, Tanzania, and Uganda maintain, with considerable outside support, the East African Agriculture and Forestry Research Organization (EAAFRO) and the adjacent East African Veterinary Research Organization (EAVRO). Neither organization now has complete interdisciplinary teams for either crop or animal work. With some reorientation of program, a few major scientists on long-term assignment, and some additional financial support, these institutes (possibly merged) could become a much greater force for accelerating development in East Africa. If it were politically feasible, they could, with additional support, also serve other nations of the region. Another regional center is the College of Agriculture of the University of the Philippines, which is to serve the nations of Southeast Asia. A tropical vegetable research institute in Taiwan also has been under consideration for several years.

A problem that commonly arises in joint support by several nations of such institutes or programs is the uncertainty or irregularity of financial support given by cooperating nations. Greater success could perhaps be assured if nations were to agree to borrow for such purposes from international lending agencies, then allow the international agency to supply funds directly to the institution serving the several nations and to participate with the cooperating nations and others in its guidance.

Opportunities for strengthening existing regional research centers, and for establishing additional ones, should be explored.

**International Programs and Projects**

At relatively little expense, cooperative attacks on some problems of international importance can be initiated and maintained. The Rockefeller Foundation has assisted with some: the Central American Food Crop Improvement Program (via CIMMYT), the Inter-Asian Corn Improvement Program, the Inter-American Potato Improvement Project, the East African Maize (Corn) Improvement Program (via CIMMYT), the Inter-American Swine Improvement Project (via CIAT), and the Middle East Wheat and Barley Improvement Project (via FAO and CIMMYT).

The Foundation is considering assistance for coordinated work on the downy mildew disease of corn and on the shootfly that attacks sorghum.

There are many other diseases and insect pests and other problems on which dynamic programs—with continuing, highly competent scientific leadership—are needed. Among them are the major rust diseases of wheat, the gall midge of rice, and the rice blast disease (on which activity has already been launched by FAO).

In such cooperative programs, scientists in each nation are primarily supported by their own governments or institutions. Assistance is generally required to support a coordinating group and to finance travel by cooperators to periodic planning and review conferences, publication of results, and some operating costs. Such cooperative projects permit the concentration of expertise on problems of high priority, the welding of otherwise fragmentary efforts into a more complete attack, and the elimination of duplication.

It is recommended that further opportunities for international cooperative attack on major problems be immediately reviewed, hopefully under the auspices of the Food and Agriculture Organization of the United Nations.
National Research, Training, and Production Systems

There is an urgent need for establishment or further development of coordinated systems in many agrarian nations. Such efforts should have the following characteristics:

1. Ambitious but technically feasible goals for both production (by commodity) and farmer involvement.

2. Functioning interdisciplinary teams at major experiment stations capable of handling all problems of each important commodity, with smaller teams at regional stations, and with production specialists, trained in testing and demonstration, at the farm level.

3. Continuous, competent scientific leadership.

4. Integrated involvement of colleges of agriculture and the ministry of agriculture.

5. Serious efforts to reach the small farmer.

6. In-service training of substantial numbers of production specialists.

7. Research (and training) focused on high-priority problems—"directed" research, carefully guided by well-informed leaders who must insist that national interest not be neglected.

8. Close association with appropriate international centers and international projects.

Since investments in such research and production systems produce capital and should provide high returns, it is hoped that international lending agencies will assist nations with loans for such purposes.

Colleges of Agriculture

It is recommended that assistance agencies consider carefully the full mission of the college of agriculture in a developing nation, and require that institutions receiving loans orient their efforts, as indicated. Investments in such institutions and programs are vital, not only for meeting educational needs but also for accelerating economic development. Especially needed in Latin America, Africa, and Asia is postgraduate training leading to advanced degrees. Costs of training should thereby be minimized, and research and training should become more relevant to local needs.

Centers of Specialization in Developed Nations

Among the world's great scientific assets are the centers of excellence—at universities and in ministries or departments of agriculture—in the technically advanced nations. But only a beginning has been made in harnessing these capabilities for worldwide development. For almost every problem to be faced in the decades ahead, there are individuals or groups of scientists in developed nations who could and would contribute importantly to work in other countries if given the opportunity.

In the United States, for example, plant pathologists at the University of Wisconsin are collaborating in the solution of potato disease problems in Latin America with modest Rockefeller Foundation assistance. Texas A & M University, with U.S. AID and Rockefeller Foundation support, is building expertise in tropical veterinary medicine, in part in cooperation with CIAT in Colombia. The Foundation has provided funds primarily to allow such groups to strengthen home programs and to permit staff to travel abroad to further cooperative work.

The opportunities for developing linkages between specialists in the developed nations and at appropriate international centers, and those attached to regional and national programs and projects are so great as to tax the imagination. Costs, however, need not be great.

It is recommended that national assistance agencies consider increased support for centers of excellence at universities and in departments of agriculture in their own nations, with necessary funds included to permit their involvement in significant international activities.

On a worldwide basis, it might be most helpful if an inventory were made of such centers of specialization, by commodity or problem area, with indications of cooperation now in effect. Perhaps such centers or groups should be recognized, possibly by FAO, as cooperators in the world effort.

Corps of Career Scientists

Too few highly competent career scientists are available for assignments in leadership roles (not merely as advisors) in developing nations. The developed nations could contribute greatly by supporting their own scientists while they are on extended assignments abroad wherever needed. Such personnel, in greater numbers, would allow decreased dependence on short-term (one- to two-year) personnel, who usually are of minimum effectiveness. This is an urgently needed change.

Toward Greater Complementarity of Effort

Speed and uniformity of progress in the intensification of agriculture will be determined, to a substantial degree, by the complementarity of activities of assistance agencies and of nations assisted.
Arrangements should be made for continuing dialogue among appropriate staff members of interested organizations—a dialogue that would permit plans, ideas, and specific needs to be aired.

Such conversations, first at the international level (as in the present conference), might result in the scheduling of other discussions by specialists, either of narrower scientific problems or of needs of specific regions or nations.

Particular attention should be given to intensification of joint discussion by economists and agricultural scientists actively involved in agricultural development. Neither group yet appears to be promoting such exchange on the scale needed. Consequently, planning for the future—both at national and international levels—too often reveals ignorance of the advanced state of man’s knowledge and capability in science and economics.

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"Through the new technology, production of food grains is increasing in a number of developing countries. This calls for a global strategy for channelizing the use of growing production for increased human welfare. This may represent one of the greatest challenges for the social scientists and politicians in this century."

"The Green Revolution offers an unparalleled opportunity to break the chains of rural poverty in important parts of the world. . . . Overnight, the image of agriculture in the developing countries has changed from that of an economic backwater to that of a major potential contributor to overall development." 

The above statements are from discussions of problems generated by successful production acceleration efforts. Both speak to second-generation problems. Second- or later-generation problems center about those public and private decisions and actions necessary to promote continued economic growth— to achieve or maintain rates of output increase that appear to be within reach once major food deficits are reduced. Resource allocation, marketing, international trade, diversification, distribution, and institutional matters assume new importance.

First- and succeeding-generation problems are not easily separable one from another. First-generation problems draw heavily upon science and technology for their resolution. A stated goal is to increase output in order to narrow or close the population-food gap. Science and technology define and demonstrate the new physical production possibilities. At this stage it is apparently assumed that if output increases are achieved, accompanying social changes will be positive.

As the population-food gap is narrowed, more comprehensive social goals than nutritional sufficiency rise in priority. This requires that solutions to later-generation problems take total developmental objectives into account. If development is defined not as simply increasing the national product but as effectively widening the range of choice available to larger and larger numbers of people, public policies and institutions have a decisive role to play. Policies and institutions having to do with prices, taxation, education, land tenure, migration, minimum diets, health, and the political process itself shape the economic and social environment in which production and distribution take place. While policies and institutions are important in launching first-generation changes, choices with respect to later-generation problems may be even more difficult. Growth in per capita production, most would agree, is a necessary condition for development. Rising output, be it industrial or agricultural, is but one of the changes essential to an enlargement of human choice.

Successful use of science and the application of output-increasing technology, therefore, are both problem-solving and problem-generating. Let us examine some of the kinds of problems that are generated by successful efforts to increase agricultural production.

TECHNICAL AND ECONOMIC ASPECTS OF MARKETING

Once a nation’s production exceeds that quantity which can be marketed domestically at prevailing prices, producers and policy makers are confronted with new technical and economic problems in marketing. (Drawing upon the West Pakistan case, Dean Norman Efferson observed that "without improvements in the processing and marketing systems equal to those being achieved in production, the potential export markets for rice, and, more importantly, the much higher incomes and standards of living for farmers, are not likely to be realized." Technics for physically handling assembly, grading, storage, processing, and distribution functions can be transferred in and adapted to local conditions. More fundamental questions require local analysis, however. What financial priority should be given to moderniza-

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tion of marketing systems? Is the nation’s comparative advantage such that, given minimal trade barriers, it can break into the export markets? Domestically, do means exist for expanding per capita consumption?

Trade policies need to be examined, as do means of obtaining more reliable, locally available, outlook information and forecasts concerning important inputs and products. These analyses should include both domestic and international considerations that treat supply, demand, price, and price policy. Price theory is being extended to planned economies. As noted by Schultz, “the theory of competitive capitalism is also the relevant theory for a planned or socialist economy.”

Reliable market information is a requisite for the functioning of efficiency prices. As food-deficit nations approach self-sufficiency in grains, price relationships and established trade patterns change, economic dislocations occur, and progress in regional integration is threatened.

Production advances permit one to think of production and marketing systems that integrate the provision of purchased inputs with the handling of products after they leave the farm. Diversification in crop and animal production may be considered. One-crop farming may give way to a sequence of crops or to more specialization and internal trade—in part because supplies of traditional food crops are more nearly adequate. Such production possibilities should be guided by both advanced production technology and market intelligence. This opportunity further underlines the research and informational needs in the areas of market demand, outlook, comparative advantage, and international trade—an endeavor in which the industrialized and developing nations should jointly participate. As Wharton asks: “Will such developments [the Green Revolution in the tropical and subtropical world] lead to an improved reallocation of productive specialization among the developed and developing world, or will nationalistic trade barriers continue to flout natural comparative advantages?”

LIVESTOCK INDUSTRY

As the population-food gap is narrowed, opportunities to diversify agricultural production may develop. Scavenger production of swine and poultry may increase. Some by-products and cereals may be diverted to commercial production of meat and eggs. Also, expanded cattle production may complement rather than compete with food crop production—so long as cattle continue to feed from land resources unadapted to food crops. Over 60 percent of the world’s agricultural land is nonarable and suited only to grazing.

Livestock products are not the food of the poor. Ever-increasing numbers of people do not, by their presence, guarantee an expanding market for meat, milk, eggs, and animal fiber. Even though millions consume protein-deficit diets, nutritional need does not equate with effective demand. Nevertheless, in the developed world, beef among the livestock products enjoys a high income elasticity of demand. Several developing nations, therefore, seek to increase their beef production and exports. Even if nutritionally needful local consumers are bypassed in order to reach an export market, this, because of the multiplier factor, may be a helpful development strategy. In this context, beef may be a commodity that is pushed in part for export purposes. Imported industrial inputs acquired with foreign exchange (as from beef exports) have an internal multiplier of as high as 4 to 1 (according to private estimates by Albert Berry, based upon current research at the National University, Bogotá, Colombia, March 1969). Net foreign exchange is often the key factor. The agricultural strategy of pushing export products, even at fairly high development cost, is thus viable—if reliable, hard currency markets can be penetrated and local production sustained at world prices.

The livestock industry, therefore, becomes a realistic source of derived demand for by-product or surplus feedstuffs and for the use of labor, capital, and otherwise nonproductive land. While relatively capital intensive, the livestock industry is labor consuming and can be built largely with domestic savings and inputs. Foreign-exchange requirements to sustain the industry are modest. Livestock farmers have a built-in predisposition to save and accumulate capital in that they tend to grow their herds rather than purchase them.

Technical research and educational requirements for a successful livestock industry, however, are of major proportions. Such an infrastructure requires public inputs for its creation. While animals in large numbers exist in developing nations, production levels are extremely low. (“Over 60 percent [of the world’s livestock] are in the developing countries, but these countries produce only 20 to 30 percent of the world’s meat, milk and eggs.”) Hence a decision to diversify an agricultural economy by expanding livestock production is a serious one. To mount a program without having (a) tested adapted production technology and (b) obtained some assurance of reliable markets and a system of reaching them, is to court failure.
UNEQUAL SHARING IN THE FRUITS OF TECHNICAL ADVANCE

There is rising social and political concern that the fruits of production advances are not uniformly shared. Too little is known with respect to the multiplier effect of the use of improved production technology. Who does benefit—in the short run and in the longer run? Are public investments in agricultural production research regressive in their income effects, as is charged by some? Are the principal beneficiaries the operators of the larger commercial units? Is the effect of modernization one of making the rich richer? To what extent can or should a nation be primarily concerned with distributive effects while simultaneously straining to increase the product available for distribution?

Technical production advances, by their very nature, do have differential impacts. Some ecological areas benefit more than others. Chances for success are enhanced where climatic conditions are predictable or partially under man’s control (as with irrigated vs. natural-rainfall areas). Those who are in an ecologically favorable situation capitalize on the new production packages. Land values rise. A capital base is created; farmers can borrow for further investment; the unit costs of production decline; efficient producers can profitably sell at prices that would be disastrously low for the farmer who is unable to participate in the agricultural breakthrough. Hence a by-product of success in one geographic area may be the worsening of economic welfare of rural people in another region, the creation of bypassed areas not unlike Appalachia in the United States.

Further, individual farmers and farm units within an area differ in their capacity to respond to the new technology. (Aresvik estimates that in West Pakistan the production breakthroughs to date are concentrated among about 10 percent of the bigger farmers operating about 40 percent of the land area. At least one-third of the farming population is as yet untouched by the agricultural revolution.) This is partly associated with size of unit—the capacity of the unit to substitute capital (machines or animal power) for human labor. Advanced production technology has had its most rapid development in nations where capital was inexpensive relative to labor. In most developing nations, the reverse situation obtains: Capital is dear, but labor is cheap—largely because its productivity is low. Hence the question:

To what tests, with respect to size of production unit, should recommended packages of practices be subjected? In some situations, the manner by which increased output is achieved may be just as important to overall development as the increased production itself. Are researchers consciously examining labor-intensive vs. capital-intensive systems of farming? Is there a potential payoff in the development, testing, and dissemination of packages of production practices that are (a) labor intensive and/or (b) specifically tailored to the realities of the small farm? One can raise similar questions about the organization of urban industries and agribusiness firms.

Theory and practice tell us that scale-efficiency relationships cannot be ignored. In the longer run, man will certainly find means increasingly to substitute mechanical for human energy in producing goods and services. Until human fertility is brought more nearly under control, however, rural population in many developing nations will continue to rise absolutely. Urban centers simply cannot accommodate the flood of migrants that would otherwise descend upon the cities. Thus man-land ratios are worsening in some instances, even though purchased inputs and improved technology are partial substitutes for land. Social pressure is for subdivision of the production units—often in sharp juxtaposition to the economic pressure for farm consolidation in the interests of efficiency. Agriculturists (those concerned primarily with the generation of production technology that increases total output per hectare per year) often find it difficult to work in harmony with their agrarian reform colleagues. For the agrarian reformists see as their mission the social and political integration of rural people. They stress wider distribution of income and enhanced buying power in the hands of the poor, that all may share in the increased output. In several situations the agriculturists serve the commercial units, while the agrarianists are concerned with the subsistence or laboring groups that coexist in the dual rural economy.

The understandable aspirations of the people left behind may be expressed in such a way as to threaten political stability. Even if such were not a concern, success in development involves the spread in benefits that is in fact achieved. Means of closing the gap between nutritional needs on the one hand and the ability to buy on the other, as is now being demonstrated in the United States, involve political power as well as purchasing power.

SOME GENERALIZATIONS

To nations that have already scored significant production breakthroughs in food crops—Kenya with corn, West Pakistan with wheat and rice, the Philippines with rice, and Mexico with wheat and corn—
the problem is one of how to keep moving. How can they sustain growth rates in production and move on to higher levels of productivity and output in these and other crops? Reviewing their experiences, one observes the following points:

1. Efficiency pricing and economic incentives play a key role in the production and distribution process, whether the economic system is a competitive-capitalistic or a planned socialist one. Reduction of price uncertainty is an essential component of the incentive package. Care is necessary, however. In efforts to make price relationships attractive, flexibility is enhanced by subsidizing the inputs rather than by supporting the price of products substantially above world levels. Nations can quickly become the unwilling owners of large quantities of food products marketable only at disposal prices well below acquisition costs—if forward prices are guaranteed with little reference to prospective world markets and prices.

2. Small incremental changes (as in the use of purchased inputs such as fertilizer, even when accompanied by responsive varieties and associated practices) are seldom adequate to disrupt the established low-level equilibrium. Significant jumps are required. The evidence on this score is striking. (Commenting on wheat improvement and production in India, Dr. R. G. Anderson observes: “In the beginning a paper war was waged between agronomists and economists as to the level of fertilizer to be applied. The economists and statisticians stated and rightly so, that because of the law of diminishing returns when fertilizer was in short supply, it was better to spread this amount over a large acreage at a small dose. The research people [agronomists] maintained that this would not sell the idea of fertilizer since the farmer could put down his small increases to favorable weather or some other factor. However, at high doses where yields could be doubled or tripled, there would be no question that fertilizer was responsible and this would give the impetus for rapid change.”) At the individual farm level, progress often comes by jumps rather than by gradual increases. Lumpiness and unevenness in production and in income may well be a characteristic of successful efforts.

3. Sustained local, adaptive research inputs are necessary when biological processes are involved, because many problem solutions are location specific. Yesterday’s varieties and practices that account for today’s production gains may not meet tomorrow’s attacks from diseases or insects or counter-advances from competitors in international markets.

4. Techniques of grading, storage, loss prevention, packaging, and handling are more readily transferrable and less location specific than are locally adapted production practices.

5. A public and private mentality forcibly conditioned to low-level sufficiency is ill prepared to think ahead, plan for, and develop safe storage, systems of grades and standards, and more flexible trade policies. Responsible leaders perceive that these are functions which in many nations are performed largely by the private sector; they would like to know more about the consequences of moving in this direction.

The developing nation that is serious about increasing its agricultural output can now obtain assistance that makes a difference. The international community has the capability to help a nation bring about crop production changes that do matter. Within fairly broad limits, the production consequences of tested output acceleration programs can be predicted.

What the nations emerging from a food-deficit status are less likely to find is assistance to help anticipate, identify, and resolve second-generation problems. At this stage they face issues not unlike those of less-advanced nations whose rates of increase in agricultural production have generally kept pace with population and income growth—as in Brazil or Nigeria. If they consciously accelerate the application of modern science and technology to their agricultural sector, do they risk disastrous low product prices? (“Nigeria [because of food self-sufficiency and low per capita incomes], unlike India and Pakistan, does not raise its real national income greatly when domestic food crop supplies are expanded beyond population growth rates. This expansion results in sharply declining food prices, as experienced in 1968 in the northern states.”) To ignore one’s own adaptive production research and training may be to concede to other nations the first chance to lower unit costs and win export markets. Equally important, in such modernization rests the opportunity to increase supply reliability and achieve lower costs of foodstuffs to domestic consumers.

IMPLICATIONS

The thrust of the foregoing discussion is not that the exciting potential for output-increasing, unit-cost-reducing technology should be minimized. Rising productivity remains a necessary condition for general improvement in living standards and human welfare. (“Increasing productivity is the best way to attack the poverty problem in agriculture. Redis-
tributing current income may be highly desirable on equity grounds but will fall far short of providing decent living standards for the large number of small farmers and landless laborers.\(^{4}\) To sustain annual agricultural output increases equal to population growth rates of 3 percent per year is a demanding task. To increase per capita output requires that total production rise not 3 but 4 to 5 percent annually. While heartening success has been achieved on those relatively few farms where physical and economic conditions are favorable, significant advances have yet to be scored on the larger number of farms where the production environment is difficult.

This discussion goes beyond production, however, to stress the importance of:

1. Transferring, adapting, and placing in use the technology of modern systems of marketing both for factors and for products. This reaches all the way back to the genetic architecture of the product. It requires that transportability, storability, and consumer tastes and preferences be engineered into new varieties and seed-stocks. It suggests expanded responsibility to the private sector in the performance of off-farm functions of providing inputs and handling products.

2. Generating technical and economic answers to critical unresolved problems of animal agricultural systems in the tropics and subtropics. Concurrently, diversification potentials of industries that draw upon agriculture for their raw materials should not be overlooked.

3. Giving more substance, continuity, and stature to policy research, planning, and management as related to public policy and to institutions. The economics of production, marketing, and trade are involved, as are means of spreading the fruits of technical progress. Advances in the physical and biological sciences are relatively noncontroversial; with adaptation, they can be moved across international boundaries. Continuity in such programs is less influenced by ideologies and political uncertainties than is that in programs involving application of the social sciences.

Sources of technical information and institutional arrangements are available or are being developed to deal at least partially with points 1 and 2 above. (The International Center of Tropical Agriculture in Colombia, for example, will work with forage-beef cattle systems; technical systems of grain milling, preservation, storage, and processing can be partially transferred from Japan, Australia, Canada, the United States, and Europe, if appropriate linkages are established.)

The more difficult economic analysis, policy conceptualization, and planning and evaluation functions (point 3) also deserve systematic attention. What is sought to help resolve later-generation problems is improved capability to predict the effect of technological change on social change—within a particular culture and society. What impact may be predicted for alternative price, taxation, education, land tenure, migration, minimum dict, and health policies? What structural and institutional changes are needed to lead, support, and capitalize on technical potentials?

Since national policies and institutions are domestic matters, what assistance role, if any, is there in this area for international agencies? Should development assistance be limited essentially to the scientific-technological problems?

Perhaps the success of the international agricultural research and training institutes gives us one lead. Development assistance agencies could offer to append a social-science component to the international centers. Or perhaps an international agricultural policy institute could be created. Envisioned is a relatively small nucleus of first-class minds, a small “think tank” perhaps, devoted to comparative research that probes actual experience. It would conceptualize and evaluate the consequences of alternative national policies bearing on agriculture and rural people as related to total development. (I am indebted to F. F. Hill for drawing to my attention the possible similarity of such an institute to the London-based Institute for Strategic Studies, directed by Alastair Buchan; and to Dr. Hill and Kalman H. Silvert for critical help in developing this paper.)

Continuity could be provided. Research would be centered in the nations where the problems are, but continuity would not be dependent upon local resources. The sovereignty of the individual nation in delineating its own policies and means of implementation would not be at issue. The policy institute would simply be a resource base upon which nations could draw. Its effectiveness, in turn, would rest upon the quality and relevance of its own work, and on its dialogue with national institutions responsible for policy formulation and implementation in their own countries.

Such a policy institute would not be a substitute for national research, training, and evaluative programs, any more than the international agricultural centers are substitutes for national scientific and educational efforts in agricultural production. Conceivably, the policy institute would also perform a valuable training function.
In itself, the policy institute idea is an inadequate response to the later-generation agricultural development problems. In concert with parallel efforts in the several nations, however, the work of such an institute might make a difference.

REFERENCES


CAPITAL FLOWS AND INCOME TRANSFERS WITHIN AND BETWEEN NATIONS TO SUSTAIN THE AGRICULTURAL REVOLUTION

Stanley Please

In a celebrated but controversial statement in its "Perspective of Development," published in 1964, the Indian Planning Commission asserted that "it is not appropriate to look at the problem of resource mobilization mainly in financial terms"; that policy objectives which are both desirable and technically, administratively, and managerially feasible should also be financially feasible. When one surveys the technical breakthrough that has been achieved in agriculture in recent years and places it against the starvation and near-starvation of much of the world's population, this cri de coeur can certainly not be ignored. Poverty is bad enough, but the existence of extremes of poverty in the midst of potential plenty is abhorrent morally as well as being socially and politically dangerous.

Nevertheless, the Indian statement is a "cri de coeur." It is, furthermore, one that has been widely taken up in national slogans such as "Priority to Agriculture," "Self-Sufficiency in Food," and similar expressions of national objectives. These are certain objectives to which the World Bank subscribes, though not unreservedly—particularly when, in implementing them, no account is taken of the costs involved. However, it is of little, if any, value to accept these slogans unless their implications are understood and acted upon. If agriculture is to be developed more rapidly, more real resources must be devoted to this purpose.

No estimates of the size of the additional resource requirements are immediately available. Our own analysis, however, suggests that the orders of magnitude are significantly large if the agricultural revolution is to meet the projected growth of demand for agricultural output. The FAO has estimated the combined effect of rising population levels and rising per capita incomes on the rate of growth of food demand in particular, and of agricultural output in general, up to 1975. These estimates indicate that, at a minimum, demand will rise by 3.2 percent annually and, at a maximum, by 3.9 percent. The lower figure is a reasonable estimate only if growth of production and of incomes is curtailed even below the levels attained in recent years. It would indeed be sad if we could not plan more optimistically than this.

These demand projections can be compared with rates of growth of food and agricultural output in recent years of about 2.8 percent. If, therefore, the rate of growth of agricultural output is to keep pace with the higher of the two rates of growth of food demand, it is apparent that the annual addition to output must be stepped up by almost 40 percent.

Our analysis suggests that, on the basis of certain assumptions, the investment required to generate this increased rate of growth of output will require the mobilization of additional resources equivalent to between 3 and 8 percent of the existing level of investment funds available to developing countries as a whole. However, the magnitude of the problem varies from country to country. In the case of India, for instance, the additional investment funds required to attain the 4.1 percent rate of growth of agricultural output projected by the FAO would probably imply an increase in the total investible funds available in the economy of around 20 percent. Furthermore, if the whole increase had to be borne out of India's internal savings, these would need to go up by around 25 percent.

These numbers cannot do more than illustrate the fact that the resource problem to be faced is quantitatively significant in terms of the policy changes that are needed if these resources are to be mobilized. These additional resources will have to be found either from within the agricultural sector itself, from other sources within each developing country, or from the developed countries. What I have to say in this paper will, in fact, be primarily concerned with certain problems relating to the first two of these alternatives. It will focus on problems relating to the self-financing by cultivators of their investment.

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expenditures, on problems of government expenditure and taxation policy in relation to the agricultural sector, and, finally, on the role of financial institutions in mobilizing savings more effectively for financing agricultural investment.

Experience has shown that external aid can assist in development only if governments themselves are actively pursuing developmentally oriented policies. World Bank or foreign assistance for, say, livestock production, irrigation, agricultural credit, etc., will be effective in achieving its objectives only if it is being injected into an economic environment which ensures that it will not be wasted and that complementary domestic resources are available. This is not to deny the crucial nature of external assistance in breaking the balance of payments constraint on development and supplementing domestic savings. Moreover, it is not to deny the inadequacy of such assistance at the moment and the urgent need that the World Bank and other international and national aid-giving agencies have for mobilizing more budget funds in order to supplement this flow of assistance to agriculture. For while foreign assistance may be of little use without complementary domestic measures being taken, the converse is almost equally true for most developing countries.

I should also point out in advance that most of my discussion of the internal financial problem will be in terms of, or illustrated by reference to, the experience and problems as they arise in India and Pakistan. This is for a variety of reasons. Most important, of course, is the fact that the food problem of the Indian subcontinent is dominant in all our thinking on this matter. Here live over 40 percent of the population of the developing member countries of the World Bank, and it is a part of that population which continuously hovers on the brink of actual physical starvation. It is an area, furthermore, where 16 million extra mouths have to be fed annually. Secondly, however, although the institutional setting varies enormously from country to country, the major problems and policy questions that arise in India and Pakistan have, I believe, their parallels in most other countries. Finally, and more prosaically, has been the need to present a paper that has both substance and digestibility. The latter could not be achieved by comprehensiveness in country coverage, while the former could not be achieved without systematically looking at the problem in country contexts.

PRICING POLICY

The subject assigned to me was “Capital flows and income transfers within and between nations to sustain the agricultural revolution.” Strictly, therefore, I should not concern myself with the self-financing by cultivators of their capital needs and the related question of agricultural pricing policy. The structure of prices, however, affects the distribution of income and hence the extent and character of income transfers. We would, then, be in danger of losing perspective on the problem of financing agricultural development if we failed to consider these wider issues. In this connection, it has to be noted in particular that the levels of agricultural prices and of agricultural inputs have been used very widely in developing countries as extra-fiscal devices. Overvalued currencies have depressed import-competing and export-oriented agriculture, food-grain procurement has typically been at artificially low prices, and the prices of many inputs have been set with the object of using them for taxing or subsidizing agriculture.

The term “priority” is one that repeatedly occurs in writings on economic development—including those produced in the World Bank—without always any clear indication of how such priority should be manifest. We presumably mean that more economic votes should be given to the priority activity than previously—in this case, to food production—and, therefore, fewer economic votes to other activities either within agriculture or outside. In effect, this means that the priority should be reflected in the price paid (i.e., the financial vote) to those who directly or indirectly produce food. One does not have to be a 19th-century believer in the efficacy of the price system for solving all economic problems to argue that attempts to solve resource allocation problems through nonprice measures, in a situation in which prices are fighting against these other measures rather than with them, are unlikely to be successful. This is particularly true where the decision makers whose actions must be influenced are operating in an atomistic sector such as agriculture, as opposed to a highly centralized sector such as, say, the production of steel.

As a question of empirical observations, there is a growing body of evidence which confirms that, within the agricultural sector itself, cultivators are very sensitive to changes in the relative prices of different agricultural products—rice as against jute in East Pakistan, cotton as against karakul in Afghanistan, rice as against cotton in the United Arab Republic, etc. Nevertheless, the belief that cultivators in developing countries are less prone than their colleagues in developed economies to note and to act upon the “come-ons” and “put-offs” of the relative
market prices for their output, is one that dies hard.

Evidence regarding the sensitivity of total agricultural output to changes in the terms of trade of agriculture to nonagriculture is not so conclusive. This sensitivity is a longer-term phenomenon, so that observations of the price effects are clouded by the effects of other secular changes and, thus, efforts to quantify them are extremely difficult. What little evidence is available, however, confirms that total output does respond positively to an improvement in agriculture's terms of trade.

The probability that prices will have a positive impact on productivity and on total production in a situation in which new technical possibilities have arisen for achieving such increases, can, of course, be readily explained on a priori grounds. Higher prices provide not only the incentives but also the wherewithal to increase output. It is the latter that is more important from the point of view of the subject of this paper. High prices enable farmers to invest more heavily in land clearance, tractors, fertilizers, wells, pump sets, and all the other inputs that constitute the agricultural revolution. However, not only are they enabled to invest more heavily, but the evidence is that they are also willing to do so, providing profitable investment opportunities exist and the physical inputs for such investment are available. It is unfortunate that the evidence on this question is fragmentary rather than systematic. Savings rates are, of course, unreliable both conceptually and empirically, and this is doubly true for the developing countries and again, even more so, for the rural sector. We would, however, be foolish to ignore the fragments of evidence we have on the subject. In both Pakistan and India, for instance, it has been apparent over the past five years that farmers have been investing heavily in private tubewell construction, largely, it would appear, out of their own funds. The Bank's study of the water and power resources of West Pakistan (Pieter Lieftinck and others, Water and Power Resources of West Pakistan: A Study in Sector Planning, 3 vols. [Baltimore: Johns Hopkins Press, 1968-69]) emphasizes the crucial importance of profitable investment opportunities in generating these funds. The study argues: "The availability of tubewell equipment in itself represented an opportunity for investment which would not otherwise have been there; this opportunity in turn encouraged interested farmers to save." Likewise, there frequently appear to be adequate funds in private hands for the purchase of available supplies of tractors, fertilizers, new seeds, etc. A similar situation has existed in India in recent years.

Savings data do not permit us to judge whether these funds have merely been diverted from other investment outlets or whether they reflect a reduction in what would otherwise be expenditures on consumption—more elaborate weddings, etc. It is of interest to note, however, that the analysis of capital flows within Pakistan shows a large, unexplained, residual net outflow of private savings from the agricultural sector. To quote again from the Bank's West Pakistan study: "Very little is known about the extent of private saving, but it has been thought for some time that substantial transfers of private savings were being made out of the agricultural sector."

This assertion has been confirmed by more recent work that the World Bank has undertaken on this subject. It seems probable that this outflow has been curtailed in the circumstances of increased profitability of investment in agriculture, with cultivators showing increased preference for investing in their farms. In addition, private savings in the nonagricultural sector have probably been flowing into agriculture. This latter possibility is certainly borne out by the reports of investment in farming by industrialists, civil servants, army officers, professional men, etc., both in Pakistan and in India.

It must be emphasized that the impact of these developments is, at the moment, limited to a small part of the agricultural sector and that it is unevenly spread geographically. Nevertheless, the existence of both a capacity to save and a willingness to save on the part of the agriculturist is an extremely important qualification to the customary assertions that policy makers must assume these households to have an extremely low marginal propensity to save. The evidence also suggests considerable sensitivity in the use of savings according to changes in the pattern of profitability of these different uses.

Nevertheless, it could be argued that the financing of agricultural development does not require a rise in food prices. If financial resources are mobilized through the budget or the financial institutions, these can then be dispered to the cultivators for meeting their need for funds. It might also be argued that in this way the funds will be more productively used by being combined with the technical-assistance, project-appraisal, etc., capacity available to financial institutions. This is a valid line of argument up to a point, and certainly the development of the flow of funds through the institutions is, as will be indicated later, extremely important. It does not, however, negate the previous analysis. To begin with, borrowers are expected to supplement borrowed funds through their own contribution to the financing of
a tubewell, a tractor, etc. Secondly, however, the argument assumes a degree of efficiency in the structure of institutions responsible for mobilizing and channeling investment funds that does not exist in any country or for any sector, and least of all for the agricultural sectors of the developing countries.

This emphasis on the financing function of food prices should not distract attention from their incentive function, which is probably still more important. It is quite apparent that the higher are food prices and the lower are the prices of inputs into food production, the greater will be the incentives to employ the most advanced technology and to produce for the market. The level of output prices received by the farmers should be kept under constant review to assure that domestic farmers are not subjected to unnecessary and uneconomic disadvantages. Too often, domestic farmers have been offered prices much lower than the value of their output, as measured by domestic scarcity value or by the prices that the economy would have to pay for a secure supply of food imports. On occasion, the disincentive effect of these low prices has been at least partly offset by subsidized inputs, tax relief, subsidized credit, and so forth, but these small favors have, by and large, been applied haphazardly. Furthermore, they entail inefficiencies of their own in the input markets, the tax system, and the money markets.

The Bank has been pleased to note that the importance of the food price problem has apparently been recognized in developing countries, and that the trend in India and Pakistan, as well as in many of its other member countries, has been toward more realistic output prices. A good deal of the subsequent discussion builds on this improvement in the price structure.

GOVERNMENT FINANCING OF AGRICULTURAL INVESTMENT

The magnitude of the required additional investment in agriculture has already been indicated. It comprises both investment in agricultural infrastructure by governments and on-farm investment by cultivators themselves. Both will require the mobilization of additional resources by the government. This is obvious for the first category, but on-farm investment will also have to be financed to a considerable extent out of budgetary funds channeled through the agricultural credit institutions.

The possibility of meeting it by expansionary financing through the banking system is probably limited in most countries, if the general level of prices is not to rise. What needs to be emphasized is that the replacement of food aid (e.g., PL 480 supplies) by domestically produced food supplies, as contemplated in many countries under policies of food self-sufficiency, will itself generate financially expansionary forces. Consumer expenditure on food supplies under food-aid programs that have been going into budget revenues will be generating increased incomes for domestic suppliers of food. Thus, if government expenditure is unaffected, there will in any case be a need to ensure that the financial expansion does not develop undesirable increases in the general level of prices. This will depend upon the willingness of the agricultural sector to save (which might, in fact, be higher than we usually assume) and upon the extent to which the fuller utilization of productive capacity in other sectors of the economy has been held back as a result of the food shortage. The easing of this shortage, then, makes possible the easing of the restraints on the monetary demand on these other sectors.

The authorities must therefore necessarily look to the generation and/or diversion of public savings if the internal financial needs of the agricultural investment program are to be met. In principle, it is possible to envisage funds being derived by governments from a combination of an increase in the tax burden on the nonagricultural sector, a reduction in current development and nondevelopment expenditure, and a curtailment of investment outlays in the nonagricultural sector. Experience in recent years and general considerations suggest that the likelihood of action along any of these lines is either not very great or, in some cases, not even desirable, and that therefore the increased burden must fall largely on the agricultural sector itself.

Some curtailment of nonagricultural investment is possible, but it must be emphasized that much of this is complementary to investment in the agricultural sector—maintenance of feeder roads, electrification schemes beneficial to agriculture, fertilizer investment, etc. In part, of course, this is a time-dimension problem in that the choice has to be made between projects with quick-yielding returns in the form of increased food output and projects that pay off in the much more distant future. If adequate emphasis is given to the latter, then it becomes dangerous to reduce, say, investment in steel production, to produce machine tools for producing agricultural equipment that ultimately will have a beneficial impact on food output. What this is saying, in effect, is that increased investment in agriculture should as far as possible be additional investment in the economy and not simply take the place of other invest-
ment. But this means that domestic savings must be increased, even if part of the increase can be met by increased inflow of external capital.

The chances of achieving this through the budget are slight unless governments show far more willingness and ability to reduce the level, or at least the rate of growth, of their nondevelopment expenditure than has typically been the case. Certainly any relaxation of discipline in this regard that might result from the availability of increased tax revenues would be self-defeating. With this very strong reservation in mind, the solution of the public savings question then becomes one of determining the sectors upon which an increased weight of government revenue generation should fall.

The combined effect of increased productivity resulting from the employment of the new technology and of improved terms of trade for agricultural producers has been, of course, to increase the incomes of these farmers. While this phenomenon of increased agricultural incomes is widely recognized in countries like India and Pakistan, it is difficult to quantify. Furthermore, it is impossible to generalize upon the distribution of the increased incomes between one region of a country and another, one socio-economic group and another (e.g., traders as opposed to hired laborers), and between one income- or land-holding-group and another. It is apparent, nevertheless, that income disparities have been widened rather than reduced.

Against this impact of agricultural change upon incomes must be seen the relative failure of governments to ensure that some significant part of the incremental incomes is mobilized for financing the further development of the economy. This failure takes different forms in different countries, but its general nature is widespread. It comprises a failure, on the one hand, to tax the agricultural sector to the extent of other sectors of the economy and to the extent that is economically possible, and, on the other hand, a tendency to provide fiscal subsidies to the sector through the underpricing of irrigation water, electricity, credit, fertilizers, seeds, pesticides, etc.

For instance, in the case of India and Pakistan, the rates of land revenue taxation have remained virtually unchanged for decades, so that revenue from this tax now represents only about 1 percent of the net output of agriculture. At the same time, the state and provincial governments have failed almost completely to utilize their constitutional prerogative to tax agricultural incomes over a period when the national governments in New Delhi and Islamabad have markedly increased the income tax rates on nonagricultural incomes. While there has been this lack of buoyancy in revenue generation from the conventional direct taxes on agriculture, revenues from irrigation rates, rural electricity charges, fertilizer sales, etc., have also failed to rise in relation to the costs of the provision of these goods and services. As a consequence, the fiscal subsidy to agriculture has grown. In 1966-67, for instance, in India the subsidy through irrigation rates alone represented more than 40 percent of direct tax revenue derived from agriculture.

In a situation in which food prices are being kept below their optimum, the undertaxation of the agricultural sector through the conventional direct tax measures can be justified. In effect, the higher real incomes of the nonagricultural sector, which this policy implies, can then be taxed by government in lieu of taxing the farmers directly. Once it is accepted, however, that prices should be used to give correct market signals rather than as tax devices, this argument no longer holds. Agricultural incomes must be taxed directly by the government if the aggregate tax base is not to be eroded and if the equity of the tax structure is to be maintained.

Undoubtedly, then, the strongest attack on the problem of raising increased resources for financing agricultural development must be to increase the taxation of the agricultural sector itself. There appears to be widespread agreement that an increase in the mobilization of agricultural incomes by governments is possible without undermining the incentives to increased production. Furthermore, it is possible to devise such measures while at the same time keeping within the constraints imposed by the obvious problems of tax assessment and collection in the agricultural sector and by the need to ensure an equitable burden on different farm-income groups. What must be borne particularly in mind in this regard is that the part of the agricultural community that is benefiting from the agricultural revolution is not made up of the subsistence farmers, each with 2 or 3 acres of land; it is the medium and larger farmers, representing, for instance, perhaps no more than 5 percent of the 60 million farm families in India, who are the beneficiaries. These are not, therefore, farmers who represent a social problem. They are, on the contrary, farmers who are equally as commercially motivated as their counterparts in industry. Of course, the tax system must not dull the incentives to this dynamic part of the farming community; but neither, on the other hand, must the government feel the sense of social responsibility to these larger farmers that it might justifiably show to smaller ones.
Given the obvious political difficulties that countries like India and Pakistan have experienced in increasing land taxes and income tax on agricultural incomes to more meaningful levels, it is natural that a less direct frontal assault on the problem should be considered. The first and most obvious way to do this would be to weight the structure of indirect taxes on consumer goods so that they fell more heavily on those consumed by the agricultural community and less heavily than might otherwise be desirable on those consumed by the nonagricultural community. Care would have to be taken to ensure that these changes did not reduce the progressivity of the tax system. While there may be some scope for such a policy, the differences in the patterns of consumer expenditure at any given income level are probably not large and, even where they exist, the competition of substitutes is always a danger. Our studies of Pakistani household budget data have not suggested much scope for action along these lines, though it must be emphasized that the data deal only with broad aggregates of expenditure, such as “cloth and accessories,” “kitchen accessories,” “furniture,” etc.

The second possibility that should be considered by governments is reduction in the subsidy on agricultural inputs. Increments to agricultural output largely result from the use of more inputs of water, fertilizer, insecticides, etc. As a consequence, the consumption of these inputs can be used as a proxy for increased output. Furthermore, the administrative problems of assessment and of collection do not arise if this means of “taxation” or of government-expenditure reduction is used, since the existing commercial and institutional machinery can be employed. This is an area of discussion upon which it is difficult to generalize. Both the cost and the demand aspects of input pricing raise problems requiring detailed analysis and judgment. One particular aspect of this analysis, which is of very great importance, is to know for each commodity to what extent the expansion of the demand for an input must be dependent upon the breaking down of traditional attitudes of farmers by, perhaps, temporary reductions in price below cost. This appears to be an irrelevant argument in the case of irrigation, and it is the subsidy on this input that dominates the transfer of income from government into the agricultural sectors of many developing countries. In India, it has already been noted that it represents over 40 percent of direct tax payments by farmers. Yet, according to the Bank’s West Pakistan study, “water is an accustomed input, the critical importance of which is already widely understood by the farmers, so that increased water charges should have no disincentive effect.” In the case of fertilizer, plant protection, and improved farm machinery, the situation is less clear, though the existence of black-market prices for these inputs from time to time and from country to country suggests that availability rather than effective demand is the constraint on an expansion in utilization. Furthermore, the general tendency for subsidies introduced for a temporary period to remain on the statute books far beyond this period, is a danger that should make governments think twice before subsidizing agricultural inputs.

To summarize this section of the paper, what requires to be emphasized is the need for changes in tax and subsidy policy, which at present unduly favors the agricultural sectors of many countries. Such changes would reflect the new circumstance that has arisen in which a commercially oriented and growing section of the agricultural community is the beneficiary, not only of rising incomes resulting from improved prices and of technological change, but also of a favorable tax-subsidy situation. This situation is neither just nor economically defensible. From the point of view of the subject of this paper, it is difficult to see how a stepped-up investment program in agriculture, and specifically in food production, can be financed unless the contribution of farmers to government-generated investible funds is increased.

It should be emphasized that this conclusion is not simply a repetition of the argument that the mobilization of savings from the agricultural sector is essential for the development of the nonagricultural sector. My conclusion is that increased mobilization of incomes is required for the development of the agricultural sector itself.

This conclusion is important from a tactical-political point of view. Farmers the world over are conscious of the danger that their tax payments might be used by city-based governments for purposes other than the development of the agricultural sector. It may be necessary to break through this suspicion by linking any increased tax imposition upon them to expenditure proposals beneficial to the agricultural sector. The shortcomings of earmarking arrangements of this nature, from the standpoint of budget flexibility, are widely recognized. There might, nevertheless, be a need to trade off reduced budget flexibility against a larger flow of mobilized funds. Earmarking is a device that is used widely in some countries (e.g., Latin American countries, the Philippines, French-speaking West African countries, etc.)
but not in others (notably India, Pakistan, and other ex-British colonial countries). The developing political situation in these latter countries might make resort to this device essential if increased domestic resources are to be made available for financing priority sectors such as agriculture.

MOBILIZING PRIVATE SAVINGS FOR FINANCING AGRICULTURAL INVESTMENT

Even if action in regard to the taxation of agricultural incomes is taken, savings mobilization through the development of savings institutions and media is still important. Of course, the more pessimistic the assumptions made regarding the possibilities of increased resource mobilization through fiscal action, the more important does it become to develop the market channels for mobilizing and channeling private-sector rural savings. This immediately raises the whole question of the role of financial institutions in developing countries.

In principle, they should be concerned with mobilizing private savings and allocating them in the most efficient manner between sectors, firms, etc., within the economy. In fact, the emphasis in most developing countries has been to ensure that these institutions make available a supply of cheap funds to favored borrowers—particularly to the public sector itself and to agriculture. The government has been concerned to keep down the cost of debt servicing to itself and to public utilities, and has also taken the view that, in some sense, farmers are “entitled” to low rates of interest and other concessionary terms on their borrowing from the financial institutions. The desire for concessionary terms to borrowers from the organized financial institutions extends, in fact, beyond the government and agriculture. For instance, ceilings on interest rates on bank advances are almost universal and, in some countries at least (including India and Pakistan), are effective, with no hidden charges through commissions, compulsory redeposits, etc.

It is difficult to determine the motive behind this attitude toward the cost of investible funds. The most obvious rationalization is, firstly, that the attitude reflects the adoption of Keynesian cheap-money policy prescriptions in economic circumstances completely different from those of widespread unemployment in developed economies in the 1930's. Secondly, in the case of agriculture in particular, the attitude could be ascribed to an overreaction to “usurious” interest rates charged by lenders in the unorganized market.

The desire to keep interest rates to borrowers from institutions low has been exaggerated by the rise in the “general level” of prices that has taken place in most developing countries. A rise in prices, of course, reflects a fall in the real interest rate. Generalization on this matter is difficult. In the case of Brazil, for instance, the effective real rate of interest on commercial bank loans (i.e., including hidden commissions, etc.) has been negative almost continuously since at least the early 1950’s, and at times has been as low as minus 30 percent. However, even for a country like India, with a record of price stability that is unlikely to be bettered if development is not to be sacrificed to price stability, the annual average rate of increase in prices over the past decade has been between 6 and 11 percent (depending on the index of prices used). Thus, with borrowing rates over this period of around 5 percent for the public sector, 8.5 percent for agricultural borrowers from land mortgage banks, and 9.5 percent for commercial bank advances, real rates of interest have been around zero in most instances, and definitely negative for the public sector.

It can be questioned, in the first place, whether in a country that is short of investible funds in relation to investment demand, a real interest rate around zero will result in the most efficient utilization of such funds. This paper, however, is particularly concerned with the implications for the mobilization of rural savings through the financial institutions of this policy of low formal rates of interest in the face both of rising prices and of capital scarcity. If the lending rates of the financial institutions are kept low, then, in the absence of subsidization on any adequate scale (as, for instance, in Korea), borrowing rates must also be kept low. This might not raise problems while the borrowings are from government and captive near-government agencies such as, in some countries, the insurance companies and the commercial banks. Once, however, it becomes apparent that these sources are inadequate and that additional free-market savings must be mobilized by the organized institutional sector, the gap becomes critical between what this sector can offer its depositors and the alternative combinations of return, security, and liquidity that are available from, for instance, the unorganized market, from foreign investment, or from investment in precious metals, etc. These differentials, when translated into real interest rates, imply a difference, not between two sets of positive rates, but between, in effect, close to zero, if not negative, real rates to savers who invest in the paper of the financial institutions in the organized sector and high positive real rates to those using their funds in alternative ways.
The level and structure of interest rates is not, of course, the only determinant of the mobilization of funds by the financial institutions. Undoubtedly, the creation of an appropriate network of financial institutions in the rural areas is also important. Empirical evidence for India and Pakistan, for instance, certainly suggests that the growth of commercial bank branches is linked to the growth of deposits, and that this holds not only for unbanked areas but also for those already banked. The creation of new branches and the process of generation of new deposits are, however, costly. These costs cannot be met if the bank net revenues are squeezed below an uneconomic ceiling on their lending rates. While in some countries there is danger that an inefficient banking structure has arisen, or can arise, because of the inflation of socially unnecessary costs in a situation in which the margin between lending and borrowing rates is too wide (e.g., Brazil), in many other countries (e.g., India and Pakistan) the danger is exactly the reverse, namely, that the growth of an efficient banking system to serve rural areas may be frustrated because of the inadequate margin between borrowing and lending rates.

The above analysis is in terms of the resource mobilization problem of the commercial banks, but the same basic issues arise in the case of the other financial institutions. For instance, the mobilization of rural savings by insurance companies raises particular problems stemming from the variability of agricultural incomes, the lack of insurance-mindedness of the rural community, etc. The costs that would be involved in facing up to these obstacles (creation of contingency reserves, the incurring of additional selling costs, etc.) can be met only if the insurance companies are operating on an adequate return on their investments. Such a return cannot be generated if the companies are forced to hold a portfolio of assets bearing low rates of interest. In India, for example, the gross rate of return by the Life Insurance Corporation on its portfolio has been less than 6 percent (5.88 percent in 1967-68 and 5.76 percent in 1966-67)—a negative rate in real terms. This low rate results from the fact that over 80 percent of its funds are in securities of the public and the cooperative sectors combined (72.6 percent in the public sector and 7.8 percent in the cooperative sector). The one attribute of this portfolio is, of course, that it gives assurance of security of the monetary value of policies. In a situation of rising prices in which, rightly or wrongly, expectations are of future rises in prices, security of the monetary value has little "salability" as compared with alternative investment opportunities. Insurance, par excellence, must provide a guarantee of a maintenance of value in real terms if it is to be salable in competition with alternative storage places of wealth. This, in the circumstances of many developing countries, might even justify consideration being given to the issue of value-linked government bonds to provide security of real value to the portfolios of financial institutions.

While the emphasis of this paper so far has been on the problem of the level of real interest rates, other concessions to agricultural borrowers are also important in certain countries from the point of view of ensuring adequate financial resource availability. Unduly low contributions by borrowers out of their own resources, together with long repayment periods, are commonplace in agricultural lending. The latter, of course, affect the resource position in the future rather than in the current period, but are not for that reason less important. A further widespread feature of agricultural credit operations is the levels of overdues, large proportions of which are probably irrecoverable.

All these concessionary elements reflect a "soft-hearted" attitude toward agricultural borrowers and an attitude toward the resource mobilization problem on the part of the lending institutions that does not reflect the seriousness which the situation demands. This attitude is likely to prevail as long as the institutions are deriving their funds at concessionary terms from the government or, as is frequently the case, from the central bank. The serious resource position can be made to register only if the real cost of the resources they receive is made clear to them. This is most likely to be achieved if the institutions are forced to be responsible for the mobilization of some large part of their financial needs, rather than being permitted to drift into the belief that this is not their responsibility, but the responsibility of government, the central bank, etc.

The important point to be emphasized is that national authorities must pay more attention than heretofore to the employment of the financial institutions as mobilizers of financial resources in the agricultural sector. In some countries, these institutions are still at an early stage of development and require to be established and expanded; in others, a sophisticated structure already exists. In India and Pakistan, for example, there are elaborate structures of rural banking facilities that have been developed through the cooperative system. Their functions as mobilizers of resources, however, are subordinated to their use as a source of low-cost funds to favored borrowers.
and as a channel for budgetary and other captive funds. As a consequence, voluntary private savings are bypassing the organized financial institutions in order to seek higher private financial returns elsewhere or, of course, are being consumed. Whatever the alternatives, the implication is that they are being used for lower-priority purposes and less efficiently than if they were mobilized by the organized sector of the financial market and thus more effectively channeled into financing the new developments in agriculture.

Central to the whole of this approach must be a revision of the level and structure of real interest rates to savers and, in the absence of subsidies, as a consequence to borrowers. This, however, presupposes in its turn a revision in the way in which the government regards agricultural borrowers. In the circumstances of a static agricultural environment it is perhaps justified to treat this as a social problem, and there are and will remain parts of the agricultural sector that must be treated in this way. The technological breakthrough that has now occurred in agriculture has brought into existence a dynamic sector. This nontraditional sector is rapidly growing, and policy must be adapted to ensure that the decisions it makes about inputs and outputs are economically desirable. In a situation in which the financial returns to investment in tubewells, tractors, fertilizer, new seeds, etc., are recognized to be high, there is no justification for encouraging the uneconomic use of borrowed funds by making them available at very low, if not negative, rates of interest. Financial policy toward agriculture must be revolutionized to match the revolution in agricultural technology.

EXTERNAL ASSISTANCE TO SUPPORT THE AGRICULTURAL REVOLUTION

The topic of foreign assistance to support the agricultural revolution has been left until last because the ability or inability of countries to sustain the agricultural revolution will primarily depend upon their own exertions and upon their own willingness and ability to take crucial policy decisions in relation to the mobilization of the resources required. These will not be easy decisions. This makes it all the more important for the aid-givers to be in a position to support those countries that are taking their responsibilities seriously in this regard. For while the weight of responsibility falls on the governments of the less-developed countries, their efforts will be less successful if the catalytic effect of foreign assistance is either not available at all or is not available in adequate amounts and at appropriate times.

No up-to-date estimate of the level of aid to support investment in the agricultural sector is available. The most recent survey undertaken by the Organization for Economic Cooperation and Development covers only the period up to 1965. In that year such aid amounted to almost $1 billion, of which about 70 percent was bilateral assistance. This represented approximately 12 percent of bilateral and 20 percent of the total assistance given by multilateral lending institutions. It should be emphasized that 20 percent of this aid was for the purchase of production inputs, particularly fertilizer, and another large proportion was for technical assistance, training, education, agro-industrial investment, etc. The agricultural revolution in developing countries has gained momentum since 1965, so that these estimates do not cover the changes that have occurred in the level and composition of aid over the most relevant and interesting period.

As regards future requirements for foreign aid, it is apparent that these are likely to be large. Although many agricultural projects require predominantly local resources, for many others the foreign-exchange input is large. For instance, in a sample of World Bank projects examined, the foreign-exchange component represents, on average, 40 percent of total project expenditure. Although the World Bank attempts to select projects with a high foreign-exchange component in total project costs, it would probably be unwise to assume that, for the additional agricultural investment taken as a whole, the proportion would be less than 20 percent; and it might be much larger.

In any case, of course, the need for foreign assistance does not always derive from the direct foreign-exchange component of agricultural investment, but sometimes from an internal savings constraint. This necessitates making additional resources available more generally to meet the aggregate level of demand within a country. This need, and the desirability of meeting the need, can be determined only within the context of a wider evaluation of a country's savings effort and of its general economic policies. Such an evaluation could suggest a level of external assistance to support an increased agricultural investment program higher—or lower—than that suggested by a direct estimate of the foreign-exchange component of the program. This approach gets us back to the earlier point: Where governments are taking their responsibilities seriously in regard to the formulation and execution of their agricultural programs, aid-givers should support them to the fullest extent possible.
It is, of course, possible to argue that governments could make additional foreign exchange available to support their agricultural programs through an improvement in their balance of payments positions on current account, from a redirection of their capital inflows toward projects in the agricultural sector, etc. The scope for achieving the required additional foreign exchange in these ways is, however, limited. This would be particularly true if the easing of the food bottleneck permitted a higher rate of growth of other sectors of some of these economies than has been possible in recent years. In these circumstances, the demand for imports in general would increase and there might also be an adverse effect upon exports (e.g., in the case of India, upon the export of railway wagons, electrical generation and transmission supplies, etc.).

Undoubtedly, the way in which to make certain that the agricultural revolution is not held back, either through a shortage of foreign exchange in particular or of resources in general, is for the volume of foreign assistance assigned specifically to this purpose to be increased by an increase in the total volume of foreign assistance. This is certainly the conclusion which we, in the World Bank, have drawn in terms of our own lending strategy. The evidence is strong that, when the supply of fertilizers, seeds, tractors, etc., is increased, the willingness of the agricultural sector to save or to divert existing savings into agricultural investment is likewise increased. In other words, the common assumption of all economic plans that domestic savings are determined independently of investment opportunities must be seriously questioned. In doing so, we must then recognize that the extent of these investment opportunities in agriculture will be determined in its turn in no small measure by the availability of increased foreign assistance, for it is only in this way that some of the essential ingredients of the new agricultural technology can be obtained.

Thus, in conclusion, what needs to be emphasized is the complementary nature of the actions of aid-givers and of the recipient countries themselves. An increased savings effort by the latter is of little, if any, use unless the internal real resources that it frees for agricultural investment—digging wells, building irrigation ditches, leveling land, producing new seeds, etc.—can be matched by inputs that are often obtainable only from other countries—e.g., fertilizer, pump sets, tractors, etc. In the absence of these complementary inputs, either the investment projects cannot be undertaken at all or, alternatively, their full productive potential must remain unexploited.
Although at this conference we are concerned primarily with agricultural production, let me begin by expressing a personal judgment concerning two other high-priority areas.

The one objective that all countries agree upon, whether large or small, rich or poor, developed or underdeveloped, socialist or nonsocialist, is that of improving material levels of living for their people. In the modern world, this requires the development of economies based on the application of science and technology. This process, in turn, requires educated people in large numbers and institutional arrangements that make it possible for these educated people to combine effectively their knowledge, skills, and efforts in producing ever-increasing quantities of goods and services, ranging in kind from food to transistor radios.

It is said that the Congo, at independence, had fewer than 20 college graduates among its total of some 15 million people. Whatever else the Congo may accomplish between now and the year 2000, it clearly is not going to develop a fully modernized agricultural and industrial economy managed and operated by Congolese. The job simply cannot be done with the manpower the Congolese can hope to train in the course of the next 30 years.

In contrast, developed countries have large numbers of trained people in many fields. In the United States, for example, more than 300,000 men and women were graduated from colleges of agriculture between 1920 and 1960. Some of these graduates became farmers. Others went into teaching, research, and the administration of programs directly or indirectly affecting agriculture. Still others entered private businesses serving agriculture—lending agencies, feed companies, farm machinery companies, fertilizer companies, and, more recently, organizations applying computer techniques to problems of modern farm management. Although many elements have combined to increase the productivity of the country's agriculture during the past 50 years, the thousands of men and women trained in U.S. agricultural colleges and universities are a key element, without which the national progress made in industrial as well as agricultural development could not possibly have been achieved.

The conclusion I draw from the experience of developed countries is that, regardless of immediate and pressing concerns in other fields, high priority must continue to be given to education, including agricultural education, in developing countries if they are to succeed in building modern economies based on the application of science and technology. As a matter of fact, I would go so far as to suggest that, if this were the year 1850 instead of 1969, assistance to developing countries might be largely limited to assistance in education, with each country left to work out its own salvation in other fields, including agriculture.

But this is 1969, not 1850, and the population explosion forces us to give top priority to the problem of human fertility control—or so it seems to me. And to gain time in which to achieve greater control over human numbers, food production also must be given high priority, on grounds of humanitarianism and, perhaps, of social and political stability as well. I am not at all sure, however, that better diets are a guarantee of social and political stability; they could, in some circumstances and for a time, exert a contrary influence. But this is not a reason for putting a brake on efforts to increase food production.

I end up, then, with three high-priority items on my development agenda, items that developing countries and assistance agencies can ignore or skimp only at their peril: human fertility control, food production, and education. I am not suggesting that other aspects of development are unimportant or can be ignored. But I am suggesting that, when the inevitable trimming of development budgets takes place, it is important that as many resources are put into these three fields as can be used effectively, given the facts that time as well as facilities and money is required to produce trained people and that, in many situations, lack of trained people and of effective

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infrastructures limits the amount of resources that can be utilized efficiently in the short run.

Now let me turn to the question of priorities in agricultural development, recognizing the interdependence and necessary interrelationship between agricultural development and the expansion of general economic activity. (For further elaboration of this point, see Hopper and Bell et al.) I should like to begin by listing three fields to which I would assign high priorities because of their prospective influence on food production and agricultural development generally in the years ahead:

1. Development of modern, science-based, production technology suitable for use in the tropics and subtropics, particularly for food crops.
2. Water management, exploration, and development.
3. Price policies affecting agriculture.

After pointing out why I think these are fields meriting priority attention, I should like to comment briefly on two of the second-generation problems discussed in the resource paper prepared for this conference by Dr. Hardin: the problem of providing adequate diets for persons on the lower rungs of the economic ladder, even after domestic food production has reached levels where this is possible; and the problem of preventing further deterioration of the economic position of small farmers and other disadvantaged producers as new, high-yield, production technology is introduced.

DEVELOPMENT OF IMPROVED PRODUCTION TECHNOLOGY

There are three principal ways by which a country can increase its food production: by increasing the area planted to food crops; by increasing unit yields of crops and livestock products; and by increasing the number of crops grown on the land each year.

Increasing the Area in Food Crops

Many developing countries still have some land that can be brought under cultivation. Much of it is poor, however, and large investments in roads, irrigation, drainage, housing, schools, and marketing facilities are often necessary to bring new areas under the plow. Although economically sound opportunities for increasing the area of land in crops should not be overlooked, it is often quicker and cheaper to increase food production in other ways.

Increasing Yields of Crops and Livestock Products

Most of the huge increases in food production achieved in developed areas of the world during the past 50 years—in Europe, North America, Japan, Australia, New Zealand, South Africa, Taiwan—have come from increased yields on land already under cultivation (Figs. 1, 2). Higher yields in these areas have been largely the result of widespread use of modern production technology based on scientific principles developed over the past 100 years or more. As Dr. Wortman emphasizes in his resource paper prepared for this conference, it is essential that technology be tailored to fit the wide range of physical environments that usually exist even within a single country, if agricultural production is to be maximized. This the developed countries have done.

Increases in crop yields corresponding to those in developed countries have occurred in only a few of the developing nations, such as Mexico and Taiwan. For the most part, yields of food crops in developing countries are low (Figs. 3, 4). If they are to be increased to levels approximating those in developed countries, modern, science-based, production technology must be introduced.

Unfortunately, the possibilities of direct transfer of production technology from developed to developing countries are limited. Most of the developed regions of the world are in the temperate zones, whereas most of the developing countries are in the tropics and subtropics. Climates are different, soils are different, and insect pests and plant diseases are different. Rice varieties and production practices developed for use in Japan are not suitable for use in India; corn varieties and production methods developed for use in Iowa are not suitable for use in Nigeria. What is needed in the developing countries are high-yielding varieties and production practices specifically developed for use over a wide range of environments in the tropics and subtropics.

This is a research and development task that few developing countries are equipped to perform at present. Many of them will not be able to take full responsibility for it for decades to come. This is not because their agricultural scientists lack competence but because, in most cases, there are still too few of them and all too often research organization is poor, leadership is weak, facilities are poor or unsuitable, and budgets are inadequate.

If time were not important, the task of creating effective agricultural research services in less-developed countries could be left to those countries themselves. But creation of such a service is slow business in a country where there are few well-trained and experienced agricultural scientists, where there is little or no history of good research, and where those who till the soil are frequently at the bottom of
CURRENT RICE YIELDS IN SELECTED COUNTRIES RELATED TO JAPAN'S HISTORICAL TREND

CURRENT CORN YIELDS IN SELECTED COUNTRIES RELATED TO UNITED STATES' HISTORICAL TREND

FIGURE 1.

FIGURE 2.
RICE YIELDS IN MAJOR PRODUCING COUNTRIES, 1963

<table>
<thead>
<tr>
<th>Country</th>
<th>Pounds per Acre</th>
</tr>
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<tbody>
<tr>
<td>Japan</td>
<td>5000</td>
</tr>
<tr>
<td>United States</td>
<td>4000</td>
</tr>
<tr>
<td>Taiwan</td>
<td>3000</td>
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<tr>
<td>S. Korea</td>
<td>2000</td>
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<tr>
<td>Ceylon</td>
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<td>India</td>
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<tr>
<td>Philippines</td>
<td></td>
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<tr>
<td>Cambodia</td>
<td></td>
</tr>
</tbody>
</table>

* ROUGH RICE

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FIGURE 3.

GRAIN YIELDS IN JAPAN AND INDIA

KILOGRAMS PER ACRE

JAPAN

India*

NOTE: DATA FOR ALL GRAINS COMBINED, PLOTTED AS 3-YEAR SLIDING AVERAGE.
* PAKISTAN INCLUDED PRIOR TO 1925.

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FIGURE 4.
the economic and social ladder. It was to help fill the production technology gap as quickly as possible in developing countries, particularly in respect to food crops and beef cattle, that the four international institutes and centers were established: the International Rice Research Institute (IRRI), Republic of the Philippines; the International Maize and Wheat Improvement Center (CIMMYT), Mexico; the International Institute of Tropical Agriculture (IITA), Nigeria; and the International Center of Tropical Agriculture (CIAT), Colombia. Another important function of these institutes and centers is to help strengthen agricultural research and extension services in developing countries by training scientists and production specialists.

In addition to cropland, there are vast areas in the tropical and subtropical regions of the world used for grazing (principally beef cattle) in which production of livestock products per unit of land area is extremely low. (It is estimated that beef production in the tropical areas of Latin America can be increased approximately three times.) Only a small percentage of this land is likely to be used for arable farming in the foreseeable future. If it is to make a significantly greater contribution to the world’s food supply and to economic development in the years ahead than it has in the past, ways must be found to increase the production per acre of livestock products.

There are three principal reasons why beef cattle production per unit of land area in the tropics is now low: (a) soil fertility is low, which limits both the quantity and quality of forage produced; (b) rainfall is often highly seasonal, with wet periods followed by long dry periods in which cattle lose rather than gain weight; and (c) high temperatures, poor nutrition, and diseases and parasites all contribute to low reproduction, high mortality, and retarded results.

In addition to research for the purpose of developing improved production technology for food crops in the tropics (primarily Central and South America), CIAT will undertake research on the production of forage crops and beef cattle in the tropics. Work already done in Australia, Latin America, and Africa suggests there is an excellent possibility that a long-term, systematic attack on problems of producing pastures and beef cattle in tropical areas will yield a high return. (The Commonwealth Scientific and Industrial Research Organization of Australia, in particular, has used a systems approach in its tropical pastures research program, with excellent results.)

**Increasing the Number of Crops Grown Each Year**

Rather than taking time to discuss intensive multiple-cropping as a means of increasing food production in the tropics and subtropics, let me briefly indicate its possibilities and refer you to a recent paper by Richard Bradfield, professor emeritus of soil science, Cornell University, who, since his retirement in 1961, has been carrying on research in multiple-cropping at IRRI.

Professor Bradfield points out that the greater part of the newly developing world lies in the tropics and subtropics where temperatures are such that crops can be grown 12 months of the year. In those areas where water is available and water control is good throughout the year, two, three, and even four crops can be grown every 12 or 13 months. (Intensive multiple-cropping is not new; it is now used in parts of Taiwan and other Asian countries, including Indonesia and mainland China.) For example, Professor Bradfield recently produced at IRRI 22.5 metric tons of food grains per hectare in 12 months (one crop of rice of 5.5 metric tons and three crops of grain sorghum totaling 17.0 metric tons). The average yield of rice (one crop) in South and Southeast Asia is approximately 1.7 metric tons per hectare. In good, well-watered, rice-growing areas, such as the Tanjore district of South India, as many as three crops are grown each year; for South and Southeast Asia as a whole, however, two crops is more common and most farmers grow only one crop. In many cases, of course, this is because of lack of water or poor water control. The average yearly production from three crops of rice in the Tanjore district for the crop years 1962-63 was 7.6 metric tons per hectare. The 10 percent of all farmers obtaining the highest yields during this three-year period averaged 11.5 metric tons of rice per hectare per year from three crops. (This statement is based on unpublished calculations of average yields for each of the crop years 1961/62-1963/64, inclusive, by W. David Hopper, The Rockefeller Foundation, New Delhi. Dr. Hopper’s averages are based on crop cuttings data for districts in India’s Intensive Agricultural Districts Program.) This is still only half Professor Bradfield’s production of 22.5 metric tons of rice and grain sorghum in a 12-month period. However, in comparing the two figures, one should keep in mind that Professor Bradfield is not only an excellent scientist but also an excellent farmer, and that his yields were obtained under experimental conditions (good water control, timeliness of operation, etc.) whereas the figures for Tanjore are estimates of yields from farmers’ fields.
Nevertheless, the possibilities of increasing food production by intensive multiple-cropping in adapted areas of the tropics and subtropics are indeed substantial—Professor Bradfield estimates by a factor of 3 or 4. As he points out, however, "this will call for large investments in education, scientific research, technology, water resource development and fertilizers..." But he goes on to say that "if they are wisely made, [these investments] will yield a large return."  

In addition to the possibility of introducing intensive systems of multiple-cropping in those parts of the tropics and subtropics where the necessary water is available, there is a further possibility of increasing agricultural production in tropical regions. In Africa and other parts of the tropical world, there has evolved over the centuries a system of shifting cultivation or bush-fallow that has enabled cultivators to produce their food requirements from tropical soils without destroying them. (In the preface to The Soil under Shifting Cultivation, Nye and Greenwood state: "Over 200 million people, thinly scattered over 14 million square miles of the tropics, obtain the bulk of their food by the system of shifting cultivation. They form a little under 10 per cent of the world's population and are spread over more than 30 per cent of its exploitable soils." This area is over four times that of the United States and over 40 times the area in crops in the United States.) Under this system most of the trees are cut down, allowed to dry out, and then burned. The ashes enrich the soil for a short period. ("Despite the lush growth of trees, shrubs and grasses in the humid tropics, the soils of these vast areas are characteristically low in fertility, with most of the available plant nutrients located in a relatively thin layer of surface soil.") Food crops such as cassava, yams, bananas, maize, sorghum, and millet are planted soon after burning. Competition from annual weeds is usually not serious the first year after clearing, and fair yields are obtained for two or three years. These gradually decline, however, as weed competition increases and the limited supplies of plant nutrients in the surface soil are used by crops and weeds, lost by leaching, or eroded away by heavy rains. After three to five years of cropping, the area is usually abandoned and allowed to reforest naturally. After 10 to 20 years of regrowth, the trees are cut again and the cycle repeated. Given a sufficiently short period of cultivation and a sufficiently long period for regeneration of soil fertility by natural processes, a viable balance between man and his environment is maintained. But in recent decades there have been marked changes that threaten to upset the equilibrium of the age-old, bush-fallow system in Africa. The most serious and far-reaching has been the rapid increase in population and the resulting increase in the amount of land required for the production of food crops. At the same time the area of land available for food crops has been reduced by the planting of cocoa, rubber, palm oil, and other export crops and restricted by social and political disturbances that limit interregional movements of people in search of land.

The effect of these developments has been to put cultivators in many areas under pressure to shorten the length of time the land is in bush-fallow. In the past the fallow period usually ranged from 10 to 20 years. More recently it has dropped to seven to ten years and in places, to three to four years. In some densely populated areas, continuous cultivation is now common, not by choice but by necessity. Even seven to ten years is too short a time in most areas in which to restore soil fertility.

What is needed are economically viable soil management and cropping systems for use in the humid tropics that will (a) maintain soil productivity and (b) permit continuous instead of intermittent use of land for the production of food, feed, fiber, and oilseed crops. There are good reasons for thinking that such systems can be developed if a team of competent scientists is assigned to the task on a long-term basis. (This statement appears in a private memorandu to the writer from Professor Richard Bradfield. See also Herrmann, "Soil fertility in the tropics, a research proposal.").  This proposal is based on recommendations by an international panel of 12 distinguished soil and crop scientists who met in London January 15-19, 1968, "to consider the content and ways and means of implementing a comprehensive research program designed to meet the soil fertility needs of the tropics.") To help develop such systems is a major objective of IITA, recently established in Nigeria.

Substitution of continuous for intermittent use of land for crop production would make two major contributions to world agriculture. First, it would provide an alternative to the prospective denuding and possible ruin of millions of areas of land in the humid tropics as pressure of population increases. Second, it would greatly increase the human carrying capacity of such land. It is estimated, for example, that under the bush-fallow system upwards of 30 acres of land is required to produce the food needed by one person; this in regions where crops can be grown 12 months of the year if the necessary water and water
control are available. Assuming that viable systems of continuous use of land for agriculture are developed, less than an acre of land will be needed to produce the food required by one person.

WATER MANAGEMENT, EXPLORATION, AND DEVELOPMENT

In 1967-68 the Asian Development Bank sponsored a comprehensive survey of Asian agriculture. In his recent paper, "Promise of Abundance," W. David Hopper, a member of the Bank's survey team, has the following to say about water and water control in Asia:

"The component singled out by the Survey Team as being perhaps the most critical element for the future of Asian agriculture was the degree to which cultivators can control the water available to their crops on their own individual fields. This conclusion does not reflect the Team's view alone. Asian farmers know it and wherever possible have invested personal capital in water lifting and spreading devices to provide better moisture control on their fields. But farmer action alone or with neighbors cannot effect the construction of a system of ditches to remove excess water from river drainage areas, nor can it result in the building of a network of channels to bring water from canals and large reservoirs to individual fields. These are tasks that must be undertaken by government.

"In much of the Region, irrigation is in the early stages of development. And of the older water systems many are poorly maintained or managed. Again, the needs are obvious: the development of irrigation and drainage facilities where this can be done; the repair and better maintenance of works that are dilapidated; improved programs of water management where these are needed. Not so obvious, however, is the need to alter the predominant pattern throughout Asia of flowing irrigation water from inlet channel to drainage outlet, field to field, down and across a terraced slope. Under this system of water delivery the farmer has little or no control over the moisture that comes to or leaves his field, a condition that may have been marginally satisfactory for traditional agriculture but which is far from satisfactory for the sophisticated crop management required in modern intensive farming. Control at each field commanded by a major water system depends on the construction of a terminal network of interlocking supply channels and drains serving fields that have been leveled and shaped to permit a uniform water distribution to all their parts. Such networks are not cheap to build. But water control is the major barrier that Asian agriculture must hurdle if it is to fulfill its promise of abundance."  

In addition to the need for better water control and management at the field level, as emphasized by Dr. Hopper, and for the development of additional irrigation and drainage facilities, there is urgent need for reliable surveys of surface and subsurface water resources in areas such as the Indian subcontinent and for better control of excess water in areas subject to extensive flooding, such as East Pakistan.

A great deal is known about soil and water management in irrigated arid areas and in areas of limited rainfall where so-called dry farming is practiced. A great deal also is known about drainage. Nevertheless, it has long been the view of the writer that there is need for one or more international or regional research and training centers organized and financed on a long-term basis to assist developing countries in finding effective and feasible solutions to their soil and water management problems. The functions of such a center(s) would include:

1. Making studies of water and soil management problems at the field level in both irrigated and non-irrigated areas for the purpose of developing improved water and soil management practices.

2. Conducting demonstrations of water distribution and control systems from canals to farmers' fields, including layout of irrigation and drainage ditches, land leveling, etc.

3. Advising on operating and maintenance problems of major irrigation works, such as siting, seepage, and salting.

4. Upon request, helping plan and arrange for surveys of surface and subsurface water resources and of major drainage problems.

5. Making studies of water rights and related problems with a view to assisting in the development of policies and practices that will make for better use of available water resources.

PRICE POLICIES AFFECTING AGRICULTURE

There are three principal requirements for converting traditional, low-yield agriculture in developing countries to modern, high-yield, high-output agriculture: (a) improved, science-based, production technology tailored to fit the variety of physical environments that exist in developing countries; (b) farmer access to the fertilizers, pesticides, tools, machines, fuel, repairs, credit, and other services required by modern agriculture; and (c) prices for farm products that are high enough in relation to prices paid for purchased inputs and services to provide an incentive for farmers to increase production.
Although only a small percentage of farmers in poor countries can read and write, all of them can think and all of them can figure. As a group, they are shrewd, hardheaded, and calculating in their economic decisions. If a developing country wishes to increase agricultural production, farmers must be provided with both means and incentives—a point many governments have been slow to realize. (For an excellent discussion of the role of prices in increasing agricultural production, see Schultz.)

The attention so far given by governments in developing countries to price and other incentives for increasing agricultural production varies greatly, as do the number and quality of the studies made by economists in these countries in this important field. Moreover, experience in one country is not always available to other countries, even when they are in the same region.

The writer believes that a team of competent economists and agricultural economists serving a region such as Latin America, Africa, or South and Southeast Asia could perform an important service for developing countries in respect to price policy and other incentives for increasing agricultural production. It could, for example:

1. Keep abreast of economic and technological developments affecting unit costs of production of agricultural products important in the region, and appraise the probable effect of such developments on the competitive position of different countries in the region, farming areas within countries, and farms of different types and sizes.

2. Cooperate in making or sponsoring studies of agricultural prices and price policies in individual countries within the region and their effect on the production and distribution of farm products.

3. Sponsor professional and other meetings and conferences for discussion of economic problems relating to agriculture.

4. Help train predoctoral and postdoctoral fellows from developing countries through participation in studies of price and other economic problems relating to agriculture.

If such a team is to be of maximum effectiveness, it is important that it (a) be composed of competent senior economists, some of whom are from the region, who expect to serve as members of the team for at least five years and preferably for indefinite periods; (b) be located in the region it is to serve; (c) be established in such a way as to assure appropriate freedom of action and publication; and (d) have a budget adequate to finance appropriate travel, conferences, and meetings and to help finance studies in developing countries in which economists in the countries concerned participate.

DISTRIBUTION OF BENEFITS FROM IMPROVED PRODUCTION TECHNOLOGY

Seldom do all the citizens of a country benefit from the development and adoption of improved production technology in agriculture. Two groups in particular are frequently no better off than before, and one of them is often worse off. These two groups are composed of (a) persons at the bottom of the economic ladder, who do not have money to buy additional food at prevailing prices even if it is available, and (b) farmers on small farms of poor land, who cannot reduce unit costs by the adoption of improved production technology to the same extent as can farmers on good agricultural land with farms of economic size.

The United States is an example of a country that still has large numbers of people with inadequate diets despite high agricultural production and large exports of foodstuffs. We have not yet adopted a national policy of providing an adequate diet for everyone, nor does our economy work in such a fashion that everyone has the income with which to buy an adequate diet. (It is true, of course, that many people have the necessary income to buy adequate diets for themselves and their families but spend it in other ways.)

As production in food-deficit countries increases, additional developing countries will reach the point that Pakistan, the Philippines, and Kenya have already reached, where all the food produced is not consumed domestically at prevailing prices even though large numbers of people are still inadequately fed or even hungry.

This raises important policy and operational questions. Under such circumstances, shall government pursue a policy of seeking export markets for food not sold domestically at prevailing prices, or shall it undertake to improve the diets of low-income groups? If the decision is to improve diets, how shall this be done? If farm prices are kept at low levels so that food prices to consumers will be low, production may be reduced and consumption increased to a point where food shortages again occur. Moreover, purchasing power in the agricultural sector may be reduced to a point where producers and distributors of consumer goods, farm equipment, and supplies are adversely affected, with a consequent braking effect on the economy generally.

On the other hand, if prices paid farmers for food products are kept at levels sufficiently high to main-
tain or increase production, low-income groups are not likely to have access to the amounts and kinds of food required for adequate diets. In such case, some form of food subsidy will be required if the objective of good diets for all is to be reached. This raises questions of where the necessary funds are to come from, the form or forms the subsidy should take, how the program can best be administered, etc. This conference is not the time or place to discuss alternative ways of providing better diets for disadvantaged groups; however, the subject is one that needs urgent attention in both developed and developing countries.

In his resource paper prepared for the present meeting, Dr. Hardin discusses at some length the stresses to which small holders and farmers on land with serious production limitations are certain to be subjected as the "green revolution" progresses. I merely wish to register agreement with Dr. Hardin that this is an extremely important problem, with social, political, and economic overtones. Having struggled with it for more than 15 years in the relatively favorable circumstances of New York State, where the number of farms decreased by nearly 40 percent between 1880 and 1940 (with further decreases thereafter), I am not optimistic about quick or easy answers. But this in no way decreases the importance of the problem.

CONCLUDING NOTES

1. Most of the less-developed countries in the world are located in the tropics and subtropics. Science-based, high-yield, production technology designed for use in these regions is basic to substantial and sustained increases in agricultural production in the less-developed countries and, therefore, to their development generally. At present, few such countries have research organizations capable of producing and improving the kinds of agricultural production technology that they need. Most of them will not reach this point for many years. The establishment of international or regional agricultural research centers such as IRRI, CIMMYT, IITA, and CIAT is one way of helping fill the technological gap during the period required for developing countries to bring their agricultural research competence to international standards.

A top priority of aid agencies concerned with agricultural development should be to see to it that international and regional agricultural research and training centers now in existence, and such others as may be established, are adequately financed on a long-term basis.

2. If, in the decades ahead, newly developing countries in the tropics and subtropics are to achieve and maintain parity with developed countries in the temperate zones in respect to the quality of the agricultural production technology available to their farmers, they must develop high-quality research and training institutions of their own.

A major objective of newly developing countries in which agriculture is important should be to strengthen their agricultural education, research, and extension organizations until these reach international standards. A major long-term objective of aid agencies should be to assist them in this effort.

3. Modern, high-yield agriculture is necessarily commercial agriculture in the sense that farmers, both large and small, must buy some of their production inputs in the marketplace and sell farm products to pay for them. Unless prospective returns exceed prospective costs by a margin sufficient to justify the venture in view of the risks and uncertainties involved, farmers will not shift in large numbers from old production methods to ones new and untried. Prices of farm products, production inputs, and consumer goods all influence farmers' production decisions, a fact that should never be overlooked by government policy makers interested in increasing the production of food and other agricultural products. The prices that consumers pay for food are not only a proper but also an inescapable concern of government policy makers. But food must be produced before it can be consumed, and it may not be produced in adequate amounts if incentives for increased production are not such as to render it worthwhile for farmers to make the necessary investments, do the work, and take the risks involved in production. This is not to argue that the interests of low-income consumers should or can be overlooked, but only to say that ways to protect their interest must be found that are consistent with ensuring the production of the food which they and their fellow countrymen require.

Cost-price relationships at the farm level and other factors influencing farmers' production decisions should be a matter of continuing concern to governments of developing countries and aid agencies engaged in assisting them. The writer would like to see a competent team of economists tackle this problem on a regional basis. The initial effort might well be on an experimental basis, covering a period of five to ten years. Such a project could be set up independently or assigned to the agricultural policy "think tank" suggested by Dr. Hardin in his resource paper.
4. Assuming that modern, science-based, production technology is developed suitable for use in the tropics and subtropics, shortage of water and lack of good water control are the two factors that will next place a ceiling on agricultural production in many newly developing areas of the world.

High priority should be given to the establishment of an international research and training center (or to regional centers) focusing on problems of soil and water management, including not only irrigation and drainage but also the exploration and development of water resources.

5. Improved production technology does not of itself produce more food. Farmers must be instructed in its use; the necessary production supplies, equipment, and services must be made accessible to them; and prices must be such as to provide incentives for increased production. Moreover, the increased output must be transported, processed if necessary, stored, and marketed at home or abroad.

While the importance of these services in sustaining the green revolution should not be underestimated, it is the writer's view that, except for price policy, they can be much more easily and quickly provided than can, say, improved production technology or better water control. There is a great deal of knowledge in the private sector in developed countries concerning the production and distribution of farm supplies and equipment and the marketing of farm products. Private, cooperative, and government-financed credit agencies, national and international, know a great deal about how to set up and operate credit systems to serve agriculture. And a great deal has been learned in recent years about how to train and organize an effective extension service to help introduce science-based, high-yield agriculture in developing countries.

For the most part, what is needed in developing countries in connection with the marketing of farm products and the production and distribution of farm supplies, equipment, and services are government policies and administrative machinery that put existing knowledge to work. The Government of the Philippines, U.S. AID, the Esso Research and Engineering Company, and IRRI have shown in the case of rice in the Philippines how the job can be done.

6. Two second-generation issues certain to produce controversy and conflict in newly developing countries as the agricultural revolution progresses are those relating to adequate diets for persons with low incomes and the distribution among farmers and farm laborers of increased agricultural income generated by improved production technology. These are problems with social and political implications that make it difficult for aid agencies to deal with them.

As a first step, it is suggested that systematic studies be made of the experience of a number of newly developing countries in dealing with these and other problems of major social significance growing out of the agricultural revolution. Such studies, after distribution to interested individuals and organizations, including governments, might provide the basis for regional seminars. As Dr. Hardin suggests in his paper, this might be an assignment for the staff of a new kind of public-policy think tank.

REFERENCES
SUMMARY

I. The importance of vastly superior technologies of production was a thread running through the entire meeting.

A. Such vastly superior technologies are a pervasive force in disrupting traditional agriculture and paving the way to its modernization and to great increases in agricultural production.

B. So long as technologies are deficient or inadequate, other efforts to stimulate agricultural development and productivity increases will have disappointingly little impact. Much more frequently than is commonly recognized, the technologies of production available in the less-developed countries are inadequate to permit any substantial increase in productivity.

C. The adequacies of the presently available technologies and the values of improved technologies are measurable in terms of impact on yields per acre or per hectare.

D. In the past two or three years, a major impact of vastly improved technologies on yields of the cereal grains — rice, wheat, maize, and sorghum — has been seen in a number of countries. Because even these presently available superior technologies have important limitations, however, there must be a continuing infusion of new and better technologies if the revolution in cereal production is to be sustained and if the agricultural revolution is to be extended to other sectors of agriculture in the less-developed countries.

E. The need for superior technologies may be more limiting and a more difficult limitation to fill in agricultural development than are the financial requirements.

II. Assistance with obtaining the necessary superior technologies and with training the required numbers of people can be provided by the multilateral and bilateral assistance agencies through support to a hierarchy of institutions, including the following:

A. International agricultural research institutes like the four that have been established, i.e., the International Rice Research Institute (IRRI), the International Maize and Wheat Improvement Center (CIMMYT), the International Institute of Tropical Agriculture (IITA), and the International Center of Tropical Agriculture (CIAT).

1. These international institutes provide a major shortcut in developing improved technologies and training people that will fill the gap while national institutions and programs are being established and strengthened. Meanwhile, by their activities they will assist with and expedite the establishment and strengthening of national institutions and programs. Outstanding scientists from the several disciplines important in agricultural science are assembled at the institutes. These multidisciplinary teams can concentrate on the major bottlenecks restricting productivity increase in specific sectors of agriculture — rice, wheat, maize, the humid tropics. These teams of scientists also provide a resource for relevant training of scientists and extension workers to staff national institutions and programs. They are available for advisory and technical assistance to national institutions and programs. They engage in cooperative research activities with scientists in national institutions which assist with the development of national research and extension programs. Through maintaining library and documentation services, and by means of workshops, conferences, and similar devices, the institutes facilitate communication among scientists of the less-developed countries, who otherwise tend to work in isolation.

2. The capital costs of the four institutes will reach or probably exceed $30 million, including the costs of the land — which in each case has been provided by the host nation. Recurring annual costs are now at about $6 million for the four institutes, and it is projected that over the ensuing five years the total will rise to at least $12-14 million if adequate sources of support are available.

3. Half a dozen additional institutes were mentioned as needed if funds were avail-
able for development and support of them. These include institutes dealing with:

a. Water development and utilization.
b. Economic, social, and agricultural policy problems.
c. Arid lands.
d. Protein-rich crops.
e. Animal health and production.
f. Rodent and pest control.

It was emphasized that the decision to establish a new institute in a particular field requires very careful study; and without such study, one could do hardly more than speculate on the needs. It is possible that more institutes would be indicated as needed if the matter were carefully studied.

4. The existing institutes have been a major engine in powering the revolution in cereal production that is occurring today in various parts of the world.

5. There was consensus about the desirability of additional support for the existing institutes up to the levels suggested and of establishment and support of some of the additional ones mentioned. Some agencies will encounter difficulties in making direct grants to the institutes, and various mechanisms and arrangements for overcoming these difficulties were discussed.

B. Regional institutes. Several were suggested, but these were not discussed in detail. It was pointed out that current plans are for IITA and CIAT to serve as outposts or regional institutions for IRRI and CIMMYT in regard to improvement of rice and maize, respectively. Furthermore, the programs of IITA and CIAT are being planned in such a way that each will serve as the regional institution for certain activities for which the other has primary worldwide responsibility.

C. National institutions and programs.

1. Institutions are needed for research, teaching, special training, extension, development, and other activities related to agricultural programs. Discussed in this regard were universities, colleges of agriculture, research institutes, extension programs, and production programs.

2. The development or strengthening of such national institutions and programs to the point where they are capable of meeting the needs of the countries they serve must be the ultimate organizational objective; but such development takes a great deal of time, both for the provision of adequate numbers of trained people and for the elaboration of adequate and relevant programs.

3. There was much emphasis on the necessity of ensuring that the national institutions and programs be relevant to agricultural improvement and development. It was suggested that improvement may better come from sharply focused programs on specific sectors of the agricultural economy such as maize, wheat, or rice production, rather than from broad programs that attempt to cope with problems of improvement across the entire agricultural sector of the country. It was further suggested that these separate and sharply focused programs, whether they be research, extension, or developmental activities, might ultimately grow and coalesce to form a dynamic institution. The alternative would be to start with a well-planned institutional structure, whether it be for a university, a research institute, or an extension service, and then to develop individual programs and activities consistent with the broad design. There seemed to be some sentiment for the principle of growing from the bottom up rather than from the top down.

4. It is important to maintain a linkage between the national institutions and programs and the international institutes in order to take advantage of the personnel and other resources of the institutes in training people, expediting the research programs, and guiding research, extension, and action programs.

III. Acceleration of production requires, in addition to adequate technologies, supplies of the necessary inputs—fertilizers, seeds, equipment, water, credit—and economic incentives or absence of disincentives.

A. Arrangements must be made and institutions must be developed to supply the necessary in-
puts. Many of these may be provided by institutions of the private sector, but government has the responsibility for developing and following policies for encouragement of the development of the private-sector institutions. Furthermore, in the initial stages at least, substantial government assistance may be required to ensure foreign exchange for importation of fertilizers and machinery. Development of water resources may, in most cases, be a public-supported activity, and public support of the development of fertilizer factories, credit institutions, etc., may also be required. External, technical, and financial assistance may be critical to provision of adequate supplies of inputs. Before providing such external assistance, however, a multilateral or bilateral agency should assure itself that the technologies of production are not a limiting factor, since disappointingly little advantage will be gained from the production inputs if that is the case.

B. Farmers respond to economic incentives, and arrangements must be made by the national government, if necessary, to ensure a suitable relationship between price of inputs and price received by the farmer for his products.

IV. For the technologies to be effective in increasing agricultural production, they must be used by the farmers, and this requires extension of them to the farmers. The matter of extension of the results of research was not discussed at great length, but was referred to frequently during the conference. Basic requirements seem to be:

A. Adequate technologies must be available. Nothing is gained from an extension program that has little, if anything, to extend to the farmers.

B. There must be a close linkage of research and extension. The research scientists must have the mandate to provide suitable combinations or packages of practices and a feeling of responsibility to ensure that these are used by the farmers. It was pointed out that single practices usually will not be effective in bringing about production increases, and that most farmers in the less-developed countries will not have the managerial capabilities and experience to select from a smorgasbord of individual improvement practices a combination that will be effective. This must be done by the scientists and the extension specialists working with them. Such relationships also facilitate the flow of information about problems from the farmers, through the extension workers, to the scientists.

C. Relevant training of extension personnel is extremely important. The extension worker must know more than the farmers whom he is advising. Most university graduates will not have this knowledge unless they have received special training or had special experience. The training program at IRRI, in which extension specialists are required to go through all the steps in producing a crop of rice, was suggested as a kind of relevant training required by extension specialists.

D. Extension programs should be focused on clearly definable objectives, and results should be measurable in such terms as kilograms per hectare and economic benefits gained by the farmers.

V. There was considerable discussion of priorities with respect to various sectors of agricultural production, assuming continuing needs to provide food for hungry people in an expanding population.

A. The major cereal crops—rice, wheat, maize, sorghum, and millets—continue to have the highest priority because of the enormously important role they play in feeding people and because of the large numbers of farmers who depend on them for a livelihood.

1. Despite the great advances that have been made in these crops, as indicated by the impact on cereal production in several countries, there are major problems remaining which can be solved only with vigorous research programs. More emphasis is needed on the extension of the presently available superior technologies to new areas and new nations in which they are adapted and on the development of new technologies. The FAO High-Yielding Varieties Program, which was discussed at the conference, is designed to provide major emphasis on extension of the presently available technologies. In part, the recent spectacular successes were obtained on the “easy” areas. Such increases in other areas may be more difficult to accomplish. Therefore, new and even better technologies will be required.

2. It is clear that the time is not ripe to
withdraw support from the cereals. Therefore, increased emphasis in other priority areas should be in addition to, rather than at the expense of, the cereals programs.

3. There is need for more research on protein quantity and quality of the cereal crops as a means of improving the protein content of the diets of the vast majority of people who depend primarily on the cereals for their food. Potentialities of using the opaque-2 gene in maize and of breeding rice varieties with a higher average protein content are encouraging developments in this respect.

B. The protein-rich crops, including the oilseed crops and the grain legumes, deserve much more attention than they have received to date. These crops have not had the benefits of improved technologies of production such as been so important in improving production in the cereal crops. The amount of research conducted to date on these crops is infinitesimally small compared with that which has been carried out with the cereals. A major effort will therefore be required—a much greater effort than with the cereals—to obtain comparable advances in technology for such crops.

C. There was considerable discussion of the relative importance of animal production and health research compared with research on the cereals and protein-rich crops. It was suggested that animal products tend to be luxury food and are therefore less likely to be a major factor in feeding masses of people in the less-developed countries. There was a strong opinion, however, that animal production and health research have substantial importance for the following reasons:

1. Animal products are the prized food as incomes rise, and in many of the less-developed countries there is already a substantial demand for them in the urban areas and among the more affluent sectors of the society. This has resulted in political pressures for improvement in animal production.

2. Animals are a major source of protein of high quality.

3. Animal products can, under proper circumstances, be an important source of export earnings.

4. Animals provide a means for utilizing large land areas that are unsuitable for crop production.

VI. Later-generation problems.

A. As soon as production increases are generated through availability of adequate technologies, supplies of inputs, and production incentives, there immediately arises need for marketing, storage, transportation, and processing organizations and facilities to deal with the production that is in excess of local needs. This may involve distribution to other areas within the nation, development of international markets as a means for earning foreign exchange, or storage of strategic reserves for use during periods of deficient production. There was much discussion of problems created by pockets of surplus that may provide disincentives in particular areas for further production. Concern was expressed, however, that overemphasis on the importance of excess production in local areas as a disincentive might cause us to overlook the vast deficiency in available food supplies that occurs in many areas. Some participants questioned whether the word “surplus” should be used in this connection.

B. There is need, when production increases are generated, to become concerned about distribution of the benefits from increased incomes resulting from the improved production. Social strains are created because of the increasing disparity among farmers in different parts of the country and even among individuals in the same village. There is also need to find ways to get some of the extra food into the stomachs of people who need it.

C. Means must be found for draining off some of the benefits of increased production to finance other aspects of development.

D. In the discussion of the later-generation problems, it was suggested that the complex might be broken down another way, into:

1. Problems related to continuing agricultural production increases, and

2. Problems and potentials resulting from the increased production itself.

E. There was considerable discussion of how external agencies could become engaged in assisting with the later-generation problems. Several suggestions came out of this discussion, as follows:
1. Assistance agencies, while helping with activities conducive to increasing production, should seek to ensure that local officials are aware of the second-generation problems that will arise if the production-increase efforts are successful, and should encourage local officials to develop plans for coping with them. At this time, however, it is probably unrealistic to expect serious efforts to prepare for the second-generation problems until the local officials have seen that large production increases are indeed possible. It was suggested that technologies create the crises that move governments to act.

2. It is important to define manageable aspects of the problems and to attack these separate aspects in order of priority. There is real danger that assistance agencies will disperse their help over the whole range of later-generation problems instead of concentrating resources on the solution of them seriatim in order of importance.

3. There is a problem of engagement and relevant training of social scientists, particularly economists and people in the managerial aspects of institutions and programs required to cope with the later-generation problems. It was suggested by some that social scientists in many developing countries are more concerned with studies than with generating action programs. The role of the universities in training social scientists and in developing relevant activities to deal with the later-generation problems was discussed, but without very formal conclusions.

4. There was discussion of the desirability of new institutional arrangements, including an international institute on agricultural policy that was suggested in the resource paper on later-generation problems. An alternative suggestion was an international institute dealing with rural development, which would presumably have a somewhat broader mission than the proposed international agricultural policy institute. There was also some discussion of the idea that these activities might be included in the present international agricultural institutes, to effect a close relationship between the scientists concerned with agricultural production problems and those concerned with policy, marketing, pricing, etc. The consensus seemed to be, however, that while there is need for a strong economic and social-science component at the four international research institutes, provision of such would not reduce the need for an international institute concerned particularly with economic policy and related considerations. There was also some discussion regarding whether new machinery was needed or only better use of existing machinery.

VII. Financing of agricultural development through capital flows and income transfers was discussed.

A. If an annual growth rate in agricultural production of 4 percent is maintained, production will double in 18 years and quadruple in 36 years. It was suggested that the technologies required to provide such large increases in production would be a greater limiting factor than the money required for that purpose. The estimate is that capital accumulation at the rate of $4 billion annually will be necessary to obtain a 4 percent annual growth rate.

B. Approximately 20 percent of the additional capital accumulation may be expected from external sources, i.e., $800 million annually. It was suggested that obtaining this amount would not be an insurmountable problem.

C. Approximately 80 percent, or $3.2 billion, of the required capital accumulation will need to come from internal sources, including internal savings and taxation. There is need for substantially improved institutions for internal savings and also for improved policies, programs, and administration of taxation. In response to the question of who worries about these problems, it was suggested that the banks are concerned in relation to security of proposed loans. It was also suggested, however, that the banks’ concern may not go far enough; that other agencies should also be concerned; and that the banks or other agencies might wish to develop special expertise and offer advisory services to less-developed countries in the establishment and management of such institutions and policies.
D. One of the greatest problems in relation to providing the external sources of funds from the banks or the United Nations Development Program, for example, is the lack of capability in many less-developed countries to generate and prepare suitable projects. This is the result of too few suitably trained people in these countries. Accordingly, more preinvestment work is required on the part of the donor agency.

E. There is need to place high priority on financing projects that utilize high orders of technology and therefore have the possibilities of high rates of payoff. It was suggested that financing of some components of high technology—water supply, for example—should be at the subsidy level until farmers get in the habit of using these technologies. At present, one of the major problems in using a high level of technology as a criterion for determining projects to be financed is the general lack of availability of such high levels of technology. We must therefore continue vigorous efforts to develop more and more technology.

VIII. Several other problems were mentioned frequently during the meeting and were obviously of major concern to the participants, even though relatively little time was devoted to discussion of them. Among these were:

A. The population explosion and the need for population stabilization.
B. The excessive supplies of labor in the less-developed countries, generated by the population explosion and by the almost inevitable reduction in requirements for farm labor as capacities of production per acre and per individual increase.

IX. Future meetings.
A. It was suggested that there be a meeting in the near future of the principal technical or agricultural officers of the various agencies involved in this conference. The purpose would be to provide an opportunity for more detailed assessment of research, training, and development opportunities and for mutual consideration of program plans of the different agencies. The willingness of The Rockefeller Foundation to provide the initiative, and possibly the facilities of the Villa, for such a meeting was expressed.
B. There was general agreement as to the usefulness of another meeting, about one year hence, of those involved in the present conference and of representatives of other appropriate agencies. The Rockefeller Foundation will determine dates during which the Villa would be available and will correspond further with participants in regard to such a meeting.

W. M. M.