cal experience in similar countries that make reasoning by analogy reliable. This lack of consensus is an important contributor to differences in projections that venture 80 to 100 years into the future.

6) Nor is there consensus as to what the size of the world's population will be when it ceases to grow. A few optimistic analysts set the figure around 8 billion, but a population of 10 billion to 12 billion seems more realistic. For example, if replacement fertility were reached in every country of the world by the year 2000 the population would grow to 8.5 billion. But such a rapid decline in fertility seems very unlikely. If replacement fertility were achieved by the period 2020 to 2025, the population of the world would grow to 10.7 billion. If the achievement of replacement fertility were further delayed, say to the period 2040 to 2045, the population of the world would grow to 13.5 billion (see Fig. 4). There seems to be an emerging consensus that if the leaders of the major developing countries view rapid population growth as an impediment to economic development and act accordingly, and if the donor community (*21*) also continues and perhaps increases assistance to such countries, the population of the world might plateau around 10 billion. But larger numbers are all too possible.

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World Food and Nutrition: The Scientific and Technological Base

Sterling Wortman

In the mid-1960's, the ominous nature of the world food problem began to be recognized widely in academic and governmental circles. Brown (*1*) presented disquieting food supply projections to the year 2000. Africa, Asia, and Latin America, which as regions had been net exporters of food grains (their major staple foods) prior to World War II, were becoming increasingly dependent on imports, and alarmingly so. Many developing countries were viewed as losing the capacity to feed themselves (*2*).

In the United States, a major "official" study of the world food problem was first undertaken in 1967 under the auspices of the President's Science Advisory Committee (PSAC) (*3*). This landmark review, the result of the combined efforts of 125 of the nation's most knowledgeable authorities, remains as one of the major balanced and readable analyses of a complex phenomenon. Its conclusions, in the first volume, still are generally valid, even if still ignored.

Total world food output has continued to rise, but so have numbers of people to be fed. The increase of food output, varying among countries and from year to year because of weather, has not been great enough to permit desired improvements in food availability per person, and today the actual number of undernourished and malnourished people is believed by some observers to be greater than at any time in history. Most of these people are in the poorer countries, particularly in the tropics and subtropics. Rates of increase of food output in the developing regions except for Africa have in recent years been as high or higher than in developed countries, but gains in the low-income countries largely have been offset by higher rates of population growth. Consequently, food production per person in most developing countries has been rising very slowly.

Recent projections by the International Food Policy Research Institute indicate that if there is no improvement in staple food production, primarily cereal grain, in countries with developing market economies and if income growth continues at the present low rate, the developing countries will have a food deficit of 120 million tons and the net world food deficit could reach 84 million tons by 1990 (*4*). Clearly, greatly stepped-up production of food, especially in the developing countries, is essential to the alle-

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viation of hunger and malnutrition, but other actions also are required. It is important to understand these diverse requirements to appreciate the roles of science and technology.

Hunger and Poverty

Individuals may obtain food in one or a combination of four ways. First, those with land (farmers) may produce some or all of their requirements, bartering or selling any surpluses if there are markets. Second, people may purchase food and other necessities, creating markets. Most of the people in the world depend on this method of obtaining food; but this presupposes that they have money and therefore a livelihood. Third, some people may from time to time receive food as a gift, but food is costly to produce and donations on the increasing scale required in the decades ahead are not feasible for governments either of low-income or more affluent nations. Finally, people who are hungry and poor may resort to theft or violence if no other options are available.

While food donations buy precious living time for the destitute, they do little to solve the hunger problem, and we can only hope that violence will not be the only option. For governments of poorer countries, whose responsibility it is to meet the food and other needs of their own people on a continuing basis, two complementary approaches are required: they must increase output of basic food commodities (or purchase them to assure that supplies are locally available) and they must increase the purchasing power of the masses of the poor. Such advances in real incomes of people—a critical element in the alleviation of hunger and improvement in nutrition—may be fostered by any form of economic activity that generates wealth and contributes to increased employment, such as agriculture, extractive industry, manufacturing, tourism, or others, plus services.

The Solution

The importance of overcoming hunger and malnutrition, country by country, is now becoming more widely recognized (*5–8*). Clearly, food production must be increased wherever and however it is feasible and appropriate, particularly in low-income, agrarian countries which cannot afford to purchase externally or which must generate employment and increased incomes for their rural people, whether farmers or the landless. Simultaneously, improvement of all sectors of the economy, rural or urban, must be sought. Increased production and incomes of the rural people will create domestic markets for urban-based industry (and jobs for urban people), while industry will supply the goods and services required for intensification of agriculture and related activity; both should contribute to the growth of each nation's economy, allowing increased trade with others.

Summary. Alleviation of world hunger and poverty will require the accelerated development and application in each low-income country of a broad spectrum of technologies based on advances in the biological, social, and physical sciences. They will range from improved cropping systems for farmers or small labor-intensive enterprises (small and beautiful) to nationwide transportation and communications systems, power grids, and other distribution and marketing capabilities (big and beautiful). Concerted action through a combination of commodity production campaigns, area development efforts, and overhaul of outdated national agencies offers the best prospect for overcoming both hunger and poverty.

If crop and animal yields are to go up, and if agricultural output over and above the requirements of each farming district is to be achieved, there must be suppliers of necessary inputs (such as seed, fertilizers, and equipment, and vaccines and feed supplements for animals), of water for irrigation, of credit. There must be means to collect, process, and transport products to other areas in the country or to external markets. An increasingly wide variety of consumer items desired by the people must be supplied through wholesale and retail marketing systems. Provision of these and other services requires the establishment or improvement of systems of transport, storage, communications, power supply, banking, processing and marketing, and others.

Other advances are important, particularly in education, in health services, in reducing rates of population growth, and in provision of safe water supplies and other means of improving sanitation.

The PSAC report of 1967 (*3*) presented the following findings.

1) The world food and nutrition problem is so large and complex that it is difficult for most people to comprehend.

2) The problem "seems deceptively straightforward and unusually susceptible to oversimplification."

3) "The details of the task involved in increasing food production to meet world needs have never been charted with the clarity and exactness that the available information will permit."

4) "Food shortage and rapid population growth are separate, but interrelated problems. The solutions, likewise, are separate, but related. The choice is not to solve one or the other; to solve both is an absolute necessity."

5) For both the food and population imbalances, there is the common feature that "eventual solution is crucially dependent upon success in convincing millions of citizens in the developing nations to take individual action."

6) "The eventual alleviation of world hunger will take many years. It is dependent on far-reaching social reforms and long-range programs of hard work which offer no promises of quick and dramatic results of the type so helpful in maintaining enthusiasm for a concerted, difficult undertaking."

7) "The problem of food production is but one part, albeit a very important part, of the enormous problem of economic development in the poor nations."

Science and technology have contributed enormously to improvements in communications, transport, power supply, data handling, and other sectors, as well as the intensification (improving output per unit area per unit time or per unit of labor) of agriculture and the preservation, storage, and marketing of improved food products. Most such advances can be demonstrated to be important to all countries attempting to alleviate hunger and malnutrition. Some have resulted from publicly supported research and development efforts, others have been generated by the private sector, especially business and industry. The increases in productivity in virtually all sectors have thus been science-based and industry supported. Advances in most disciplines—wherever they occur and whether in the physical, social, or biological sciences, or in the diverse technological fields, or in education and other areas—can be demonstrated to be important to the future economic or social progress of any country.

Attention in the remainder of this article is given to the more direct relationships of science and technology to improving food production and distribution, and to creating purchasing power among poor and hungry people. This is not intended to minimize the critical importance of corollary advances in most other sectors of each nation's economy.

Importance of Agricultural Development

Central both to food production and to rural income generation is the intensification of agriculture. Although in some countries there remain significant opportunities to extend land areas under crop cultivation or in managed animal production, most increases in the future must come from higher crop and animal yields. This requires (i) improvement of nutrition of both cultivated crops and pasture or forage for animals; (ii) provision of supplementary water, on time and where needed; (iii) control of plant diseases and animal pests; (iv) improved crop and animal management practices; (v) arrangements for marketing, storage, and processing of fragile or perishable products; (vi) the development of more efficient crop varieties (Fig. 1) or animal strains through genetic means; and (vii) the tailoring of crop or animal production systems involving all these and other components to the specific conditions of soil, rainfall, day length, biological milieu, and social conditions of each locality of each and every country.

The task of developing the particular combinations of technology, the training of farm people, the arrangements for supply of necessary inputs, and the establishment or strengthening of mechanisms for collection, storage, processing, and marketing of products can only be the responsibility of government and business of each country. Particularly, it is the responsibility of each government to set the policies, strengthen the research and educational institutions, and foster the orientation of governmental services to meet the requirements of the many farmers still in remote areas and other rural people. External agencies can assist, principally through the supply of technology, training opportunities, and financial support.

Fig. 1. Science has contributed significantly to the development for the tropics of short, stiff-straw, highly productive varieties of rice. [Photo by courtesy of the Rockefeller Foundation]

Transferability of Science and Technology

In recent decades there has been a growing realization that while the principles of science are widely applicable, many forms of technology are not. This particularly is true for technological systems involving biological and social variables—as agricultural and rural development activities do. Utilization in the tropics and subtropics of those scientific principles employed in the revolution of agriculture in the temperate climate countries is appropriate, even essential. Many technologies based on advances in the physical sciences (as in communication, transport, manufacturing, and extractive industry systems) can be utilized directly in the lower latitudes. But, this is not true for much of the technology based on biological and social sciences; technological components must be developed in the regions where they are to be used, then in the same regions incorporated into agricultural systems tailored to the requirements of localities—a vast and complex task.

Meeting Needs of Small Farmers

In most of the poorer countries the number of hectares of productive land per person is low. There are numerous small farms, tiny by American standards. Productivity is extremely low. In many cases farm families are eking a livelihood from long impoverished soils and do not have access to the technology and services that would allow them to increase their productivity. With the extension of roads and radio and television systems into the rural areas, these rural people are aware of advances in standards of living elsewhere in their own countries and are becoming restless. Theodore Schultz in the 1960's demonstrated clearly that these farmers, while having little education, are profit-maximizers and are intelligent (*9*). They will change to more productive activities if it is feasible for them to do so and if they and their families will benefit in the process. There must be incentives to produce.

Another consideration, often overlooked by scientists, is that small farms intensively cultivated through "gardening" techniques can be much more productive per unit area than highly mechanized agricultural systems as known in the United States, Canada, or Australia. For example, beans, peas, and tomatoes grown on poles or trellises can produce much more per square meter than bush-types grown without such support. Use of systems of intercropping, relay planting, and other "multiple cropping" systems can result in much more produce and income per hectare per year than monocultures. Moreover, they allow the farm family to spread labor requirements over the year. Such intensive cropping has been developed to a high degree in the People's Republic of China, Japan, Taiwan, and a number of other countries, including parts of Europe.

For countries where land resources are limited and populations are high, there are clear-cut political, social, and economic reasons for promoting the increased productivity of small farm units. Productivity can be higher. Employment in rural areas, including trade centers, is stimulated. Increases in productivity and incomes of rural people contribute to the tranquility necessary for general economic development. Large numbers of producers become large numbers of consumers of products of urban industry.

A major problem now and for the future is that few individuals trained in the temperate climate countries have experience in development or improvement of such intensive agricultural systems—a weakness that must be overcome.

Accent on Speed

A number of the temperate climate countries of Europe and North America have experienced intermittent crop and animal production surpluses since World War II. The rate of growth of agricultural output in many high-income countries has been relatively slow, perhaps in the neighborhood of 2 percent per year. For developing countries to meet the future needs of populations whose growth rates are 2 to 3.5 percent and if there are to be gains in output per person to allow for higher standards of nutrition, agricultural output must go up at rates of 3 to 4.5 percent per year. Therefore, in the developing countries there is a need to move agricultural and rural development far faster than has been experienced in North America or Europe. And such gains must be achieved at relatively low cost, for most of the countries are poor.

Few individuals and institutions in the temperate climate countries have experience in organizing fast-moving, effective, and relatively low-cost agricultural or rural development efforts—or in orienting research efforts to support such fast-moving development efforts. Fortunately, since World War II a substantial number of individuals from the tropical and subtropical countries have received advanced education in Western institutions and have since acquired considerable experience in their own national efforts to utilize science and technology to speed national development.

The Spectrum of Research Requirements

To assess the research requirements for the future as they relate to world food and nutrition, it may be instructive to consider the spectrum of research involved. In an earlier publication (5) five categories of research were described as essential to progress in dealing with hunger and poverty. Because it was believed that agricultural development "campaigns" are necessary to achieve the rates of advance required in the low-income countries, some of the terms were borrowed from the military. Examples that follow are primarily biological, but there are parallel requirements in the social sciences, where efforts must be made to learn the aspirations of the people, how to organize services they will require, and what policy changes would be beneficial.

The first category of research, termed "operational," is that involved in determining on each farm, usually by the farmer with some outside help, the particular combinations of crop and animal systems that will be most productive and profitable. However, individual farmers in a farming district or region cannot individually test all of the varieties, animal strains, fertilizer combinations, disease and pest control agents, and other technology and practices to identify those most promising for their own farms. Such trials, which can be called "tactical" research, are best conducted on a regional basis and are aimed at meeting the requirements for a particular region; some of these trials should be undertaken on regional experiment stations and in associated regional laboratories with some outlying tests on farmers' fields. Involved will be trials of crop varieties developed elsewhere and of kinds, amounts, and timing of fertilizers alone and in combinations; experiments on dates of planting and on disease and pest control measures; work on crop and animal production systems considered promising for the localities served; and determination of desires of of the people and constraints on their participation in development.

In a third category is "strategic" research, which is intended to provide technology and knowledge to support development over a wide area and over time. Such strategic research is necessary to backstop all tactical and operational activity. The international agricultural research institutes and some national and provincial research centers in the larger countries (as in India, China, Japan, Brazil, Mexico) are engaged in strategic research for the most part. Likewise, the state agricultural experiment stations in the United States as well as the regional stations of the U.S. Department of Agriculture conduct strategic research, and this research supports the tactical efforts at regional substations within each state, which in turn support the efforts of farmers and those assisting them. Strategic research is focused directly and intentionally on the creation of the technology required to support development efforts.

The fourth category, termed "supporting," is fundamental research which, it is believed, will lead to new advances likely to be useful in the near future. Supporting research will also expand frontiers of knowledge, but the ways in which it will be useful will be at least dimly perceived. Development of an understanding of the genetics of an economic plant or animal could lead to improvement of crop or animal breeding techniques. An improved understanding of the physiology of economic organisms, or a knowledge of the factors affecting distributions of diseases or insect pests, or work on systems of biological nitrogen fixation would be in the "supporting" category.

Finally there is true "basic" research which is undertaken primarily to expand the frontiers of knowledge with no requirements that relevance be demonstrable.

Such categories of research are not discrete; rather they represent bands on a spectrum of research from the laboratories of the scientists engaged in basic research to the farmer who is testing new combinations of technologies for his own use. All are important and are interdependent.

Country Research Requirements

Many of the world's nations are small, as well as poor. For example, in 1975 there were 61 countries with per capita gross national products (GNP's) of less than $500; in the same year, the per capita GNP for the United States was $7060. Of the 161 nations or geopolitical entities in 1976, 105 had populations less than 10 million, 78 had 5 million or less, and 34 had fewer than 1 million people. These and related factors have significant implications for the organization of science and technology to support the world efforts in food and nutrition.

Each and every country, if its own rural areas are to be advanced, must have capabilities at the operational and tactical levels, even if it can afford no other work. Establishment or strengthening of tactical research efforts will allow any country, even though small, to draw in technologies from elsewhere and to adapt them to regional and local needs.

Some larger countries also will be able to support and, in fact, will need, such strategic research efforts as, for example, are being developed through the Indian Council of Agricultural Research, the Instituto Nacional de Investigaciones Agricolas in Mexico, the Philippines Council on Agricultural Resources and Research, and the National Agricultural Research Agency of Brazil (EMBRAPA, from the Portuguese). Because there are so many small countries that cannot afford strategic research efforts in all fields related to national development, their local efforts at adaptation and testing must be backstopped by centers of strategic research elsewhere in their regions. It was for this reason that the Ford and the Rockefeller foundations in the early 1960's—and more recently the Consultative Group on International Agricultural Research (CGIAR)—established in cooperation with host governments a network of international agricultural research institutes to backstop national research efforts and to train personnel for national programs. There are now 13 activities supported by the CGIAR system, including ten research institutes. Other centers outside the CGIAR system also are engaged in strategic research; among them are the International Fertilizer Development Center, the International Centre for Insect Physiology and Ecology in Nairobi, and the Asian Vegetable Research and Development Center in Taiwan.

Research of the supporting type will be found to some extent in the major research centers of the larger developing countries and in the international agricultural research institutes, but most is conducted at universities or in industrial laboratories in the more affluent countries; only a relatively small number of countries can afford to support vigorous work covering the entire spectrum.

Fig. 2. The International Rice Research Institute in the Philippines was the first of ten centers now supported by the Consultative Group for International Agricultural Research. [Photo by courtesy of the Rockefeller Foundation]

The Three-Tiered Research System

In the last three decades there has begun to emerge what some call a "three-tiered" system of agricultural research with all elements interlocking. One tier consists of the national programs, large or small, in each country. A second consists of the international or regional research installations in the tropics or subtropics which backstop the national efforts and provide some linkages to centers of specialization elsewhere. The third tier consists of the centers of specialization in the developed countries for the most part, where advances through basic and supporting categories of research (and in some cases strategic) are generated.

Those participating in the creation of this international network of research activities hope that through it scientific and technological advances, wherever they occur, can be brought to bear on improvement of human conditions wherever that is feasible and without undue delay. Conversely, it is hoped that problems wherever they arise can receive the attention of individuals or institutions able to contribute to their solutions wherever those individuals or organizations may be, again without undue delay. To a substantial degree that interlocking network is being brought into being in the agricultural sector.

The CGIAR Network

In 1960 the International Rice Research Institute was established in the Philippines to develop the necessary technology and to train the people required to achieve increases in rice output in the tropics (Fig. 2). The early success of this institute led to the establishment of the International Center for Improvement of Corn and Wheat (CIMMYT, from the Spanish) in Mexico to serve as a world center for work in developing regions on those two important and neglected food crops.

In 1967, the International Institute of Tropical Agriculture was established in Nigeria to work on the agricultural commodities and systems important in sub-Sahara Africa. At about the same time the Centro Internacional de Agricultura Tropical (CIAT) was established near Cali, Colombia, and has concentrated on work on cassava, beans, and pasture-beef systems. The CIAT also is concerned with other crop and animal systems for the tropics, particularly in Latin America and the Caribbean. Each of these four institutes was established through the cooperative efforts of the Ford and Rockefeller foundations and the government of the country concerned.

In 1969, the leaders of a number of international and bilateral agencies, meeting in Italy, recognized that such international agricultural research centers, located in the tropics or subtropics, are vital to national agricultural and rural development efforts throughout Africa. Asia, and Latin America. Subsequently, an international consortium, the CGIAR, was formed to finance the existing institutes and to establish and support new ones. CGIAR operates under the auspices of the World Bank, the United Nations Development Programme, and the Food and Agriculture Organization (FAO). Members include the three sponsors; the Asian, African, and Inter-American development banks; the European Economic Community; the International Fund for Agricultural Development; most of the bilateral assistance agencies, including those of Europe, North America, Australia, New Zealand, and Japan; the Ford, Kellogg, and Rockefeller foundations; the International Development Research Centre of Canada; the Leverhume Trust; plus governments of a growing number of oil-exporting and developing countries. In 1971, this club of donors marshalled some $15 million for then four institutes. In 1980, CGIAR is supporting work at 13 centers with a combined budget of about $120 million.

The more recently established crop research institutes are as follows. In India, the International Crops Research

Fig. 3. In the fertile river delta areas of China crop management is excellent. [Photo by courtesy of the Rockefeller Foundation]

Institute for the Semi-Arid Tropics (ICRISAT) serves as the developing world center for work on sorghum and millets, the fourth and fifth food crops in world importance. In addition, ICRISAT conducts research on groundnuts (peanuts), pigeon pea, and chick-pea, three of the more important pulses or food legumes in the cooler arid tropics, as well as on cropping systems. The International Potato Center, located in Lima, Peru, is concerned with the improvement of the white potato and the technical support of national potato improvement programs around the world. The International Center for Agricultural Research in Dry Areas (ICARDA), located in Lebanon and Syria, primarily works on improvement of durum wheat and barley; on pulses, including lentils, broad beans, and chick-peas; and on improvement of cropping systems for rain-fed areas in North Africa and the Middle East.

Livestock research is conducted at the International Laboratory for Research on Animal Diseases (ILRAD), located in Kenya, which is actively seeking effective means, including vaccines, to control two serious animal diseases in Africa—trypanosomiasis and theileriosis (East Coast fever); and at the International Livestock Center for Africa (ILCA), headquartered in Ethiopia, which is engaged in improvement of ruminant animal production systems on that continent.

In 1979, the International Food Policy Research Institute, based in Washington, D.C., became a member of the CGIAR system. Its efforts are devoted, as its name implies, to research on policies important to the alleviation of hunger and malnutrition in individual countries, and to the tracking of the food problem on a global basis.

In the mid-1970's the International Board for Plant Genetic Resources, based at FAO in Rome, was established to coordinate and support efforts to collect, preserve, and make available to plant breeders throughout the world the germplasm of important plant species.

Technical Advisory Committee

The Technical Advisory Committee of CGIAR includes 13 authorities in agricultural research—with representation from both the biological and social sciences—from developing and developed countries. The committee is concerned with the establishment of global priorities for future research, for monitoring the progress of each international center in the system, and for recommending to the CGIAR the principles that should be considered in determining amounts of financial support that should be provided.

In 1979 the committee established a framework for consideration of the priorities for support of international agricultural research. This framework includes (i) commodities, including food and nonfood crops or animals, and both preharvest and postharvest aspects; (ii) production systems; (iii) production factors and inputs, such as seeds, fertilizers, agrochemicals, soil and water, mechanization, and energy; and (iv) the process of accelerating the development and application of improved knowledge and technologies.

The committee considers that among the cereals, rice, wheat, maize, sorghum, and millet should continue to be given first priority for international support, with barley and triticale (a new man-made species derived by crossing wheat and rye) in a second category. Among the roots, tubers, and other starchy crops, cassava and the potato are considered to be of first importance, with work on sweet potatoes, plantains, and yams being given second priority. Research on dry beans is given first priority among the pulses or food legumes, with cowpeas, chick-peas, pigeon peas, broad beans, beans, and lentils being of second priority.

Research on vegetables in the tropics and subtropics remains weak. The committee has concluded that first priority should be given to the amaranths and other leafy crops, beans, peppers, and okra, with a number of other vegetables being of secondary importance. Of the oil seeds, groundnuts (peanuts) and soybeans are given first priority, with coconut, cotton, sesame, sunflower, safflower, mustard, and rapeseed being of second importance.

In the field of animal production, the committee accords first priority to the improvement of production of ruminant animals, with particular reference to their improved nutrition, reproductive efficiency, production systems management, and control of major diseases, including trypanosomiasis and theileriosis. Aquaculture, particularly low-cost systems involving plankton feeders, is now accorded first priority along with work on ruminant animals. Research on poultry and swine and on other systems of aquaculture is considered to be of secondary importance.

With regard to production systems, the committee accords first priority to work on rain-fed and irrigated croplands of the arid and semiarid tropics (Fig. 3), to arid rangelands, and to the infertile lands of the subhumid and humid tropics; it also accords first priority to food policy research because this is related to first priority commodities and production systems. The second priority under production systems is given to the high-rainfall, tropical lowlands, the tropical and subtropical highlands, to agroforestry, and to the broader aspects of food policy research.

Among the production factors, first

priority is accorded to research on the first priority commodities in the areas of (i) development of improved crop varieties and animal strains, (ii) plant nutrition, (iii) plant pest and disease management and control, (iv) soil and water management, (v) postharvest technologies, and (vi) mechanization.

Future of the International System

In 1980, the international agricultural research centers budgeted for 573 senior staff. By the end of the year it is expected that about 7000 persons will be employed in the network. By 1984, it is anticipated that expenditures on an expanded system could reach $250 million, or $184 million in 1980 dollars. While these amounts may seem large, the Technical Advisory Committee of CGIAR points out that about $150 billion is spent globally each year on research and development. Of this, 25 percent is spent on defense, 15 percent on basic research, 8 percent each on nonmilitary space activities and energy, and only 3 percent on agriculture worldwide. Moreover, much of this expenditure is in the developed countries, with only about 5 percent of all research and development expenditures in all sectors being in the developing countries.

More support to developing countries. While the CGIAR system has been growing, many members believe that they should increase the flow of support to the developing countries to strengthen national agricultural research systems. There are many commodities and problems that are not being addressed by the international agricultural research institutes but that nevertheless are important to the developing nations. And, unless there are strong national agencies, the materials and methods flowing from the international system cannot be put into use in each country in need. Consequently, in 1979, CGIAR agreed to the establishment of a new component to be called the International Service for National Agricultural Research (ISNAR). This small unit, which includes professionals in various aspects of agricultural research, will work with agencies of each interested government in designing national research efforts and in arranging bilateral or international support for those efforts. It is believed that through this mechanism additional resources can be channeled to the low-income countries to complement the assistance made available to them through the FAO and other agencies of the United Nations. ISNAR should be established, with headquarters in the Netherlands, by the end of 1980.

Other important activities. While the international agricultural research institutes, which account for part of the second tier of international research activities, are becoming firmly established, other actions are being undertaken or considered to strengthen the other tiers and to form linkages among them. As indicated earlier, both FAO and ISNAR support the strengthening of national systems, as do the International Agricultural Development Service in New York, the Ford, the Rockefeller, and the Kellogg foundations, the International Development Research Centre of Canada, and several regional research organizations, including the Instituto Interamericano de Ciencias Agricolas operating in Latin America from a base in Costa Rica.

In the United States, increased linkages between U.S. universities and institutions in developing countries are being fostered by the Board for International Food and Agricultural Development (BIFAD); these linkages may also be enhanced by the creation of the Institute for Scientific and Technological Cooperation (ISTC), now under consideration by Congress. Most of the other high-income countries have established or are establishing mechanisms for strengthening cooperation between their own universities and agencies and those in developing countries. Among the older and more established ones are the Ministry of Overseas Development of the United Kingdom and the several international agencies of France and the Netherlands.

The United Nations University, in recognition of the substantial effort going into production of food, is concentrating its own efforts on the postharvest aspects of food, its distribution, and on nutrition.

Prospects for the Future

Since the world food and nutrition problem began to be defined with some clarity in the mid-1960's there have been diverse new efforts to strengthen capabilities to generate and apply necessary technology. With the recognition that the food problem requires advances in all sectors of each nation's economy, it is becoming clear that a wide variety of technologies are needed. They range from small and beautiful to big and beautiful. They will require cooperation among institutions in all of the three tiers of research effort. Such linkages increasingly are being supported by governments and international agencies because they generally are found to be more effective than other approaches tried in the past.

If progress in the future is to be as rapid as desired, means must be found to involve the cooperation of business and industry. There now exists a world network of financial institutions, ranging from the World Bank to the regional banks, the national development banks, and rural credit institutions. A diverse array of technical assistance organizations is in place, including the multilateral agencies, the bilateral agencies, and a number of private efforts, including those of foundations. The agricultural research network is taking shape. A principal weakness in the system seems to be the absence of acceptable and effective means of involving business and industry, but new mechanisms are being explored in the United States to facilitate public-private cooperation.

A key to success in meeting world food and nutrition needs is the action of the government of each and every low-income country. Where governments have demonstrated the will to invest their own personnel and financial resources in concerted efforts to develop their rural areas, progress has been rapid. Many leaders of such nations find it difficult to comprehend the complex development task before them. Scientists can do much to help by articulating the strategies for successful approaches to the hunger and poverty problem.

The organization of commodity production programs, based on sound scientific principles and improved technology, has been shown to be effective. Stimulation of agricultural output and increases in incomes of large numbers of people clearly can be fostered through concerted efforts to develop farming districts or other defined regions within nations. The overhaul of government services to support accelerated agricultural and rural development will be necessary; most agencies were established at an earlier time when the urgency of action was not so apparent. These strategies have been described in a recent publication (*5*). The importance of resolving the world food and hunger problem must be understood by the people of the developed nations including the United States, which must supply much of the scientific, technical, and financial help. Much is at stake. Not only is there a humanitarian concern for the welfare of hundreds of millions of destitute people in low-income countries, but also the future price of food worldwide, the stimulation of the world economy, the levels of employment in both developed and developing countries, and the prospects for peace could well be involved.

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Energy Dilemmas in Asia: The Needs for Research and Development

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Summary. Outside of China, the countries of southern and eastern Asia contain 30 percent of the world's population but only 2 percent of the known fossil fuel resources. Economic growth has resulted in increasing imports of petroleum and petroleum products. Because of the tenfold rise in oil prices since 1972, several of these countries are faced with two dilemmas—one short range and one long range. Unless they can discover more fossil fuel resources within their own borders, they must either incur dangerously growing foreign exchange deficits or drastically slow their economic growth. Research and development in energy production, conversion, and conservation should eventually allow local energy sources, of which the most promising is biomass energy, to be substituted for imported fuels. But diverting scarce land and water to plantations of fast-growing trees or other kinds of biomass may seriously limit food production in these crowded countries.

The 15 largest countries of southern and eastern Asia contain half the earth's population, but only 14 percent of its inhabited land area and about a fourth of the cultivated land (Table 1). Although these countries were originally heavily forested, the need for agricultural land to feed growing populations has resulted in a reduction of the forest area to only 11 percent of the world's total (*1*).

Energy Resources of the Asian Countries

Known or estimated energy resources for each country are shown in Table 2 in a common unit—millions of metric tons of coal equivalent (1 million metric tons of coal equivalent contains 27.8 trillion British thermal units or 7 trillion kilocalories, close to 1000 megawatt-years, or 10^{-3} terawatt years). In general, the location and extent of the nonrenewable fossil fuel resources (coal, lignite, petroleum, natural gas liquids, and natural gas), have been inadequately explored, and no more than guesses can be made concerning the fraction that could be recovered or the costs of recovery. For the potential "renewable" resources (hydropower and thermal energy in forest biomass), estimated maximum annual yields have been multiplied by 100 to give some measure of comparability with the total fossil fuels (*2*).

The People's Republic of China (China) has by far the most energy resources, both in total and per capita (*3*). Its fossil fuels and potential hydropower correspond to 868 tons of coal equivalent per person and make up about 13 percent of the estimated world total. Outside of China, the Asian countries, with 30 percent of the world's population, are endowed with only a little more than 2 percent of the world's fossil fuel and hydroelectric power resources. Even this small fraction is unevenly distributed. India, Japan, Malaysia, and the Republic of China (Taiwan) possess more than 100 tons of coal equivalent per person. So far as is known, the remaining ten countries have much less than 100 coal equivalent tons per person, ranging from 58 for Korea to 3 for Sri Lanka. On a per capita basis, Burma, Indonesia, Malaysia, Nepal, the Philippines, and Thailand have fairly extensive forest resources, with potential sustainable yields of between 0.5 and 3 tons of coal equivalent per person per year. Potential sustainable forest yields in the other countries are smaller, varying from 0.48 ton per person per year in Vietnam, to 0.06 ton in Pakistan and 0.03 ton in Bangladesh.

Present and Future Uses of Energy in Asia

Most available statistics on energy use refer only to so-called commercial energy, that is, energy from fossil fuels and hydroelectric installations. But for the poor countries of Asia, the figures on commercial energy are misleading. On the average, total energy use is about twice the amount of commercial energy. The major part of the difference is made up of biomass fuels—wood, charcoal, agricultural residues, and cattle dung—and a significant fraction is accounted for by energy expended in human and animal labor. Estimated use of biomass fuels, plus human and animal labor, corresponds to around 200 to 400 kilograms of coal equivalent per capita per year (Table 3). Most of this noncommercial energy is devoted to cooking and other household uses, and most of the remainder to agriculture.

In the past, the proportion of commercial energy has increased with time and economic growth. This increase re-

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