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CONSORTIUM FOR INTERNATIONAL DEVELOPMENT

S&T/AGR RESEARCH STRATEGY FOR THE 1990s

PREPARED FOR

BUREAU OF SCIENCE AND TECHNOLOGY
OFFICE OF AGRICULTURE

IQC Contract No. PDC 1406-I-00-7008-00
Delivery Order No. 6

PREPARED BY:

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FOREWARD

The Office of Agriculture in AID's Bureau of Science and Technology (S&T/Agr) is currently involved in a consideration of its research agenda for the decade of the 1990s. To assist in this effort, S&T/Agr entered into a contract with the Consortium for International Development (CID) to make an assessment of a number of factors that might affect such an agenda, including an evaluation of the state of world agriculture, a projection of present trends into the decade of the 1990s and an identification of physical, biological and socio-economic/institutional constraints to world food and agricultural development. With such an assessment, CID was requested to develop recommendations for a research agenda and a strategic plan which might guide the S&T/Agr efforts during the next decade.

In response to this request, CID organized a team made up of the following people to conduct the requested study and to develop a report which would address the issues of concern. The study team was composed of:

Dr. E.T. York, Distinguished Service Professor, University of Florida, who served as Chairman;

Dr. Roger Fox, Professor of Agricultural Economics, University of Arizona;

Dr. Nigel Smith, Professor of Geography, University of Florida.

Dr. Don Plucknett of the World Bank had hoped to participate in the study but illness limited his involvement.

Drafts of the report were reviewed by a number of people including Drs. Earl D. Kellogg and Jean R. Kearns of the CID staff along with three external reviewers, experienced and knowledgeable in the field. The external reviewers were Dr. James B. Henson, International Program Development Office, Washington State University; Dr. Merle H. Niehaus, Dean of the College of Agricultural Sciences, Colorado State University; and Dr. Peter Oram, International Food Policy Research Institute, Washington, D.C.

The study team expresses its appreciation to all involved in the review process and to the many people in AID who provided valuable information for the report.

EXECUTIVE SUMMARY

The research strategies for the S&T Office of Agriculture should relate directly to the Agency's overall goals for addressing developing country needs. The goals of AID's food and agricultural program are stated as follows:

- to increase the income of the poor majority;
- to expand the availability and consumption of food; and
- to maintain and enhance the natural resource base.

In considering these specific goals, it should be recognized that AID's efforts to make the agricultural sector of developing countries more productive and efficient is basic to overall economic growth in these countries. Indeed, agricultural development is the primary engine that drives overall economic growth in developing countries. Moreover, cost-reducing, improved technology must provide the primary fuel for this engine.

Declining Support for Agriculture

Given the vital role which agriculture must play in the development of poor countries, it is most disturbing to see the declining support given to agricultural development efforts by AID in recent years. Moreover, given the vital role which research must play in agricultural development efforts, it is equally disturbing to see that the portion of AID's agriculturally-related budget devoted to research has also declined significantly.

These circumstances lead to the strong recommendation that AID take steps to address the declining support for agriculture--and especially for agricultural research --and seek the means to substantially expand the resources for these efforts which are vital to the achievement of development goals in poor countries.

Growing Need for Agricultural Products

Future research needs will be influenced greatly by changing global circumstances that impact the demand for agricultural products. Following are some of the expected changes and their consequences during the next decade:

- Global population will increase at a rate of about 2% annually, with 90% of the growth occurring in developing countries.
- The incomes of people in developing countries should also increase at an average per capita growth rate of some 3% annually.
- With this projected growth in population and income, the demand for food in developing countries should increase at a rate of about 3.5% annually.
- The trend towards higher income should result in a growing demand for livestock products as well as for fruit and vegetables in many parts of the developing world.

- There will be a continued trend towards urbanization, with such growth resulting in an increase in demand for different types of food commodities, especially those that can be easily processed, transported and stored.

Despite global increases in agricultural production in recent years, per capita production of food has actually declined in several areas of the developing world. In recent years, some countries have experienced not only per capita reductions--but also absolute reductions--in levels of food production.

The rapidly growing demand for agricultural products must be met, primarily, by more intensive use of existing arable land. This will require that much greater emphasis be given to research to generate the improved technology required to increase agricultural productivity.

While there must be significant increases in production of agricultural commodities to meet growing needs, this alone is not sufficient. The incomes and purchasing power of poor people must also be improved so that needed food and other products of agriculture can be purchased. Effective programs of agricultural research are vital to the achievement of this objective as well.

Agricultural Research Within AID

AID has made significant contributions to the development of research-related institutions in developing countries as well as the human resources needed to staff them. These institutions, in turn, have had a significant impact in developing country agriculture through the generation and introduction of improved agricultural technology. The Agency has also made wise investments in supporting specific research projects and programs, such as those of the international agricultural research centers.

Despite significant advances made through AID-sponsored efforts, there are growing indications that what is being done is inadequate. Current circumstances suggest the need for major, well-focused research efforts within AID to assist developing countries to meet growing needs for agricultural products and achieve overall development objectives.

In addition to the reductions in support for agricultural research within AID, the Agency's research efforts seem to lack an overall strategy or sense of direction or coordination. These circumstances lead to the recommendation that AID develop an appropriate mechanism and/or structure to achieve a more sharply focused, coherent and better coordinated overall research effort in agriculture--an effort that would be directly supportive of the goals of the Agency.

The Mission of S&T/Agr

The Science and Technology Bureau of AID has two primary responsibilities: (1) providing technical assistance to country missions; and (2) supporting research activities to benefit developing country agriculture. This report deals primarily with the research mission of the S&T Office of Agriculture.

The research efforts administered by S&T/Agr have made significant contributions to the improvement of developing country agriculture. It should be noted, as well, that U.S. agriculture has also reaped substantial benefits from AID-supported research efforts. Of major significance has been the work of the international centers, both in and outside the CGIAR. The CRSPs, also, are proving to be a very productive channel for AID research funding.

The S&T Office of Agriculture is currently engaged in an effort to develop a better defined strategy or direction for its research program. Indeed, this report is a part of such an effort.

Strategies for S&T/Agr

In the absence of other Agency-wide mechanisms, S&T/Agr should take the initiative in helping to establish an overall agricultural research agenda for the Agency. This is obviously not something that the Office can do alone but must involve other parts of the Agency concerned with research.

The Office should formulate a carefully planned strategy for its total research portfolio--a strategy that will result in a total effort which is more sharply focused on the high priority needs of the Agency.

In formulating such a strategic research plan, the Office should have as an objective that of helping developing countries achieve food self-reliance rather than food self-sufficiency. In this regard, consideration should be given to increasing the incomes and improving the nutritional status of people as well as to meeting the changing patters of demand for food which are related to increasing incomes and greater urbanization.

The rapidly growing demand for agricultural products, along with the serious degradation of many of the natural resources on which agriculture depends, emphasizes the absolute necessity for giving major research attention to issues of agricultural sustainability.

There is a need to give greater emphasis to research directed towards addressing the problems of less-endowed areas--areas which frequently involve more fragile ecosystems. At the same time, the better-endowed regions must not be neglected because they provide opportunities for more significant gains in food production.

In formulating a research agenda for S&T/Agriculture, adequate attention must be given to the need for "maintenance" research to protect the productivity gains already realized with many commodities. Similar recognition must be given to the need for research addressing post-harvest losses of food.

A strategic research plan for the S&T Bureau should take fully into account the programs supported by the Regional Bureaus/Country Missions and the Science Advisor's Office in AID as well as that of other donors.

Given the major commitments by AID to the international centers--commitments which we believe should be continuing--there is an opportunity, if not a need, for AID to play a more active role in helping to influence the research agendas of the IARCs.

Some have considered the emergence of the newer techniques in modern biology as a panacea that will provide the basis to solve future global food problems. While these techniques may offer opportunities for accelerating progress, they will not revolutionize developing country agriculture. It is not recommended that AID mount a major biotechnology research thrust, per se. Instead research institutions supported by AID should assess, on a continuing basis, the potentials for incorporating such techniques into their research programs. Institutions involved in productivity research should have the capability to monitor advances in biotechnology and, when appropriate, develop the capacity to use such techniques that will assist their research programs in a cost-effective manner.

It is recognized that many of the problems which limit agricultural development relate to economic, social, political and institutional considerations. Although these problems do not have technological solutions, they lend themselves to social science research aimed at identifying those options most likely to create the circumstances favorable for development.

There are needs and opportunities to forge linkages or networks among research institutions, both public and private, in industrialized as well as developing countries. There is a special need for AID to help facilitate the involvement of the U.S. scientific community in helping to accelerate Third World agricultural development. There are also potentials for AID to enlist the participation of other donors, both multilateral and bilateral, in supporting high priority research programs of relevance to developing countries.

Recognizing the dual research and technical assistance roles of S&T/Agr, consideration should be given to the appropriate balance between the two and to the potential for having a major part of the cost of the technical support functions borne by the country missions making use of such functions.

Many have questioned the current organizational structure within S&T--especially the manner in which forestry, natural resources and rural development are separated from agricultural production and policy work. Consideration needs to be given to a structure and/or to working relations that could facilitate a more closely integrated approach to meeting agricultural research needs.

A matter of serious concern is the extent to which Congress continues to earmark research funds in the Bureau for projects of relatively low priority. This has prevented AID from using its resources in the most productive manner.

Priority Research Agenda for S&T/Agr

The significant breakthroughs in food production in developing countries during the past two decades have resulted from concerted interdisciplinary efforts aimed at improving targeted crops through plant breeding and related crop management research--perhaps best exemplified by the work of the international agricultural research centers (IARCs). This type of commodity-oriented research emphasis continues to offer great potential with a wide array of commodities and agricultural enterprises. This should enable S&T/Agr to address, in a meaningful way, Agency goals of increasing the incomes of the poor and expanding the availability and consumption of food.

Research with the staple food crops should continue to receive major emphasis. However, other commodities or enterprises which offer promise of making significant contributions should not be excluded and should receive research attention where appropriate. This would include vegetables, perennial tree crops (for food and feed), animal-based enterprises including aquaculture, and non-food commodities such as ornamentals, feedstuffs, and crops for fiber, energy, oil, pharmaceuticals and other specialty purposes--as well as for fuelwood.

It should be noted that the improvement of commodities or enterprises such as the above is often seriously limited not only by biological and physical constraints but also by major institutional, economic, and policy constraints. Accordingly, the S&T/Agr research agenda should give priority attention to efforts aimed at identifying those economic and policy options that are most favorable to agricultural development or to improving a given part of the agricultural sector.

Consideration might be given, as well, to research in soil and water management and to pest management. Such research is not only important in commodity improvement efforts, it can also make significant contributions to the achievement of sustainability objectives.

The third major goal of the Agency--that of maintaining and enhancing the natural resource base--should be addressed by making sustainable agriculture a primary, overarching priority and goal of the Agency's research efforts.

Addressing Research Priorities

In addressing proposed research priorities set forth in the foregoing section, the S&T Bureau might be guided by the following considerations:

- High priority should be given to supporting the work of the international centers and CRSPs that can contribute to research priorities of AID. These are programs of proven effectiveness and they also provide an opportunity to leverage AID resources or generate other sources of funding to help achieve Agency objectives. It should be noted that consideration is now being given to the inclusion of other international centers into the CGIAR System.

- AID should use its own portfolio of research projects to complement the programs of the IARCs and CRSPs and to address needs not covered by these other programs.

- Most of the basic or staple food crops are receiving significant research attention through the CRSPs and the CGIAR System of international centers. The S&T Bureau should carefully review these efforts to determine if there are significant gaps (from an AID perspective).

- AID is also allocating resources to animal-based research programs, including fisheries aquaculture. As in the case of staple food crops, the Agency should carefully review the programs currently being supported to determine if there is need for additional effort or if some of the current efforts need to be determined or reoriented.

- Several vegetables are included in the mandates of the CGIAR centers and are, thus, receiving research attention through this source. However, many of the common vegetables are not included in the work of the CG centers. If the CGIAR adds a vegetable research center to its system, such a center could provide an excellent vehicle for AID to support developing country research on vegetables.

- The international research system is currently devoting little attention to perennial tree crops for food and non-food uses. Given the nature of the crops involved and the fact that many of these crops vary greatly in importance from one country to another, USAID missions may find it desirable to give increased attention, on a selective basis, to such crops. The role of S&T/Agr should be one, primarily, of stimulating interest in such research--perhaps supporting networks of research programs dealing with these commodities and in encouraging the participation of other donors and the regional bureaus in such networks. Special mention might be made of agroforestry research such as that carried out by ICRAF and IITA. Sustainability considerations as well as a growing fuelwood crisis in much of the developing world suggest an urgent need for greater research attention to agroforestry.

- We question whether the current emphasis by S&T/Agr on policy work is commensurate with the importance of the problems which such research needs to address. The Office of Agriculture should be giving higher priority to the allocation of available resources to research in this important area.

- While recognizing its importance, research on post-harvest losses of food have not singled out as an area of priority research concern. We suggest that research on post-harvest losses should be made an integral part of other research with the various commodities recommended for priority consideration. To the extent that this is not done and significant problems are not being addressed, S&T/Agr should consider specific research projects to deal with such needs.

Allocating Resources to Address Priority Concerns

There should be a careful assessment of the manner in which S&T/Agr resources are currently being used in support of research, and available resources should be allocated to address priority concerns of the Agency. This means that the Office should examine the programs and potentials of the international centers and the CRSPs to determine the extent to which they address priority concerns. Similarly, a careful review should be made of the projects now included in the S&T portfolio.

The key issue is not whether some of the current prospects are doing useful work or not. The concern is one of priority and whether there may be other research activities that could be more relevant in terms of addressing critical developing country research needs.

Charting a Future Course

We believe that the types of efforts proposed herein can contribute to a more meaningful research program for S&T/Agr and the Agency. A part of what is being proposed can be accommodated by taking fully into account the existing or

redirected programs of the IARCs and CSRPs. Other objectives can be achieved by closing out lower priority research programs in the current portfolio and reallocating these resources. Greater leverage of AID resources can be achieved through the development of appropriate linkages with other donor agencies as well as with public and private research organizations to support high-priority research needs.

We further believe that the recommended courses of action will be desirable, irrespective of the level of resources available. However, we must emphasize the inadequacy of current financial resources to support these activities. With current budgets and levels of funding for the IARCs and CRSPs, there is only $13.2 million to support the S&T Office of Agriculture project portfolio. This is a woefully inadequate amount to meet the priority research needs which are not being addressed by the IARCs and the CRSPs. Moreover, reductions already made in the financial support accorded to CRSPs and IARCs limit the effectiveness with which these programs can carry out needed levels of activity.

All of these circumstances make a compelling case for substantially increasing the budgetary support for research in S&T/Agr (including the CGIAR centers which are funded through the PPC Bureau).

In the event, however, that such funding increases are not forthcoming, serious consideration should be given to how the $13.2 million currently allocated to the S&T/Agriculture project portfolio could be most effectively used.

Should these resources continue to be used to support an array of projects as currently is the case? Or could some of the resources currently allocated to projects be more effectively used in one or more of the following ways:

- Supporting additional CRSPs which are oriented towards addressing some of the priority research concerns of the Agency;

- Providing more support to some of the non-CGIAR centers which are concerned with issues of high priority to AID;

- Expanding the concepts embodied in the Special Constraints Research project to support linkages between the IARCs and the U.S. scientific community, both public and private; or

- The development of additional linkages or networks which could focus attention on some of the priority research needs of the Agency--including vegetables, perennial tree crops for food and fuel, and non-food crops.

The time constraints associated with the current study do not permit a thorough exploration of these alternative courses of action. However, we believe these are issues the S&T Office of Agriculture needs to address further as it develops its agenda for the 1990s.

Several criteria might be used in determining how resources might be most effectively used by S&T/Agr to support research activities. These might include the following:

- The degree to which a given research activity might contribute to the food and agriculture goals of the Agency;

- The potential for achieving useful results including a consideration of risks and pay-offs;

- The type of research (adaptive, applied, strategic, or basic) and how it fits in with the other research activities supported by AID and the donor community;

- The degree to which the problem area is being addressed by other institutions;

- The extent to which the research might have broad global application;

- The extent to which the U.S. (or AID as a donor) might have a comparative advantage in supporting a given research activity;

- The extent to which S&T/Agr funds might be leveraged through support by others; and

- The extent to which there may be mutual benefits--to developing countries and to the U.S. While developing country needs must be the primary concern of AID-supported research, it is recognized that such research often makes significant contributions to U.S. agriculture as well.

Chapter 1

WORLD AGRICULTURE--TODAY AND TOMORROW

The post-World War II period has seen an unprecedented growth of food and agricultural production. On a global basis, food and agricultural output has grown at about 2.5 percent per year (Figures 1.1 and 1.2). Much of this growth resulted from productivity increases that represent the application of agricultural research. The increase in global food production has generally exceeded the growth of population, resulting in an overall increase in per capita food production of about 0.6 percent per year between 1950 and 1986 (Figure 1.2). On a global basis, there is enough food produced to provide adequate calorie and protein levels for today's population (World Bank, 1986).

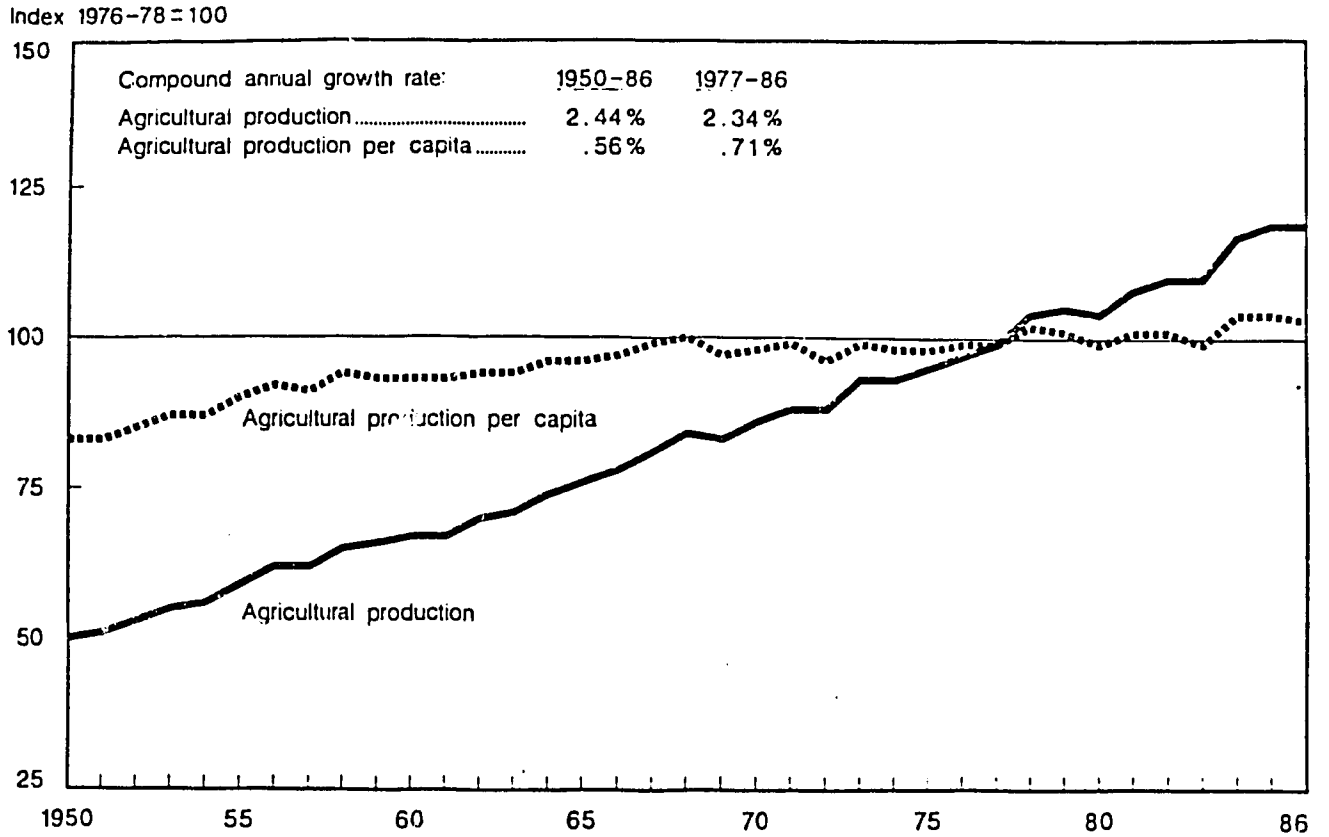
The apparent adequacy of the global food supply is misleading because poverty and poor distribution of food leave a significant portion of the world's population hungry and malnourished (Table 1.1). A high proportion of the poor and undernourished live in the rural areas of the developing countries. The primary cause of hunger is the lack of purchasing power on the part of nations and households, not inadequate food production. Increased food production, however, is needed to meet the expected increases in demand resulting from population growth and economic development. Natural disasters and political upheaval, such as the current situations in Bangladesh and Sudan, can lead to famine conditions that require emergency relief efforts as well as long-term solutions.

The rate of growth of agricultural production has not been uniform, and some parts of the world, notably Sub-Saharan Africa, have experienced declines in per capita production. Increases in world trade in food, originating primarily in the U.S., Canada, and Western Europe, have alleviated the food deficit in many countries. There is evidence in other parts of the world, especially in Asia, that the rate of growth of food output is slowing as the easily obtained benefits of the Green Revolution have been already exploited (Herdt, 1988; Barker and Chapman, no date). Furthermore, recent downturns in cereal production and continued degradation of the agricultural resource base are creating widespread concern about the sustainability of both high-input modern agricultural systems and low-input traditional systems.

Expected population and income growth will continue to increase the demand for agricultural products and put enormous pressure on the world's agricultural production systems. Although population growth rates are declining, population in the developing countries is expected to increase by about 2.0 percent per year between 1986 and 2000 (Table 1.2). This growth rate translates into an increase of about 1.1 billion people in the developing countries by the year 2000. Per capita income growth of 3.0 percent per year in the developing world, a rate slightly less than what was obtained between 1973 and 1980, raises the potential growth of demand for food in these countries to about 3.5 percent per year (assuming an income elasticity of demand for food of 0.5). This continued pressure for increased food production is the most certain element in the world food equation.

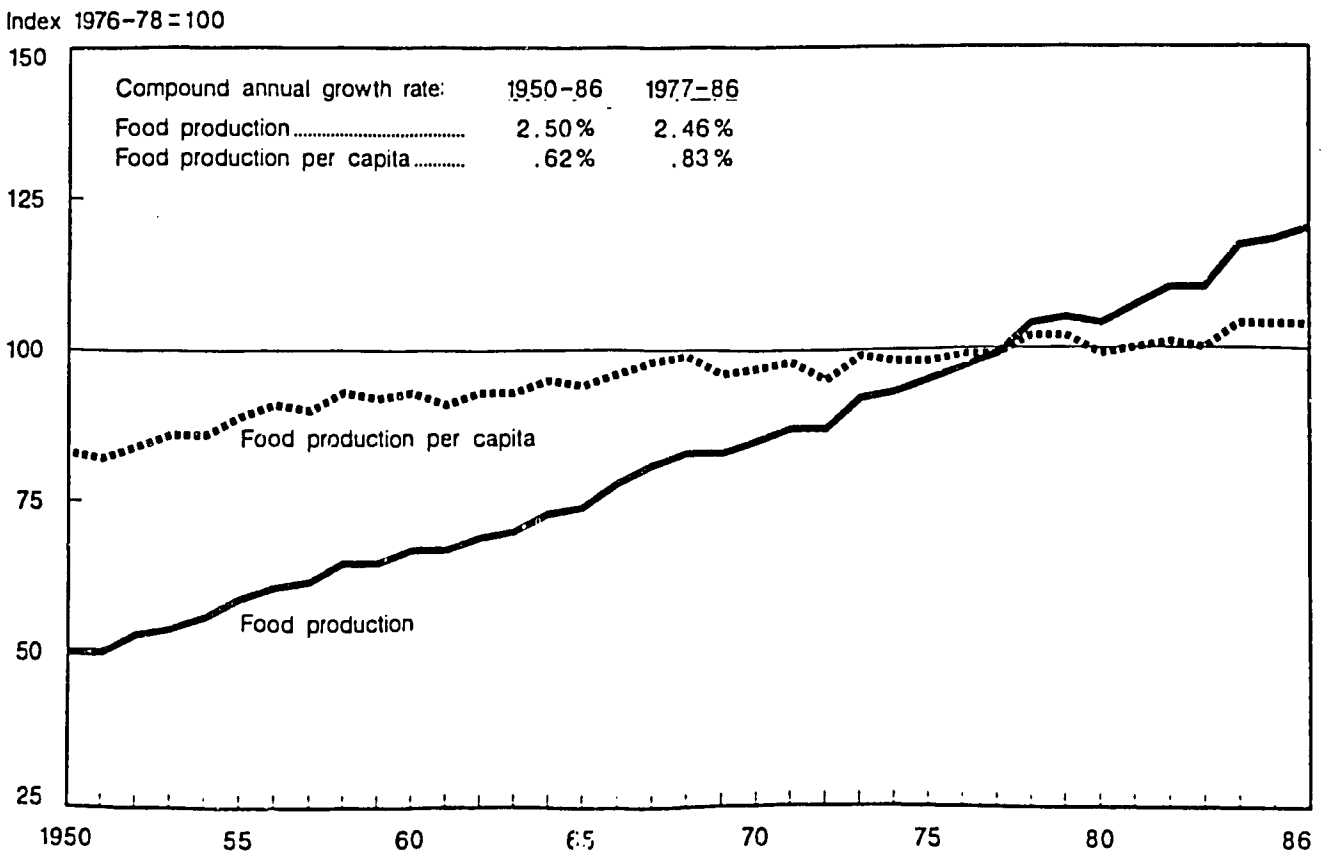
Much of the future growth of the world's population will occur in the urban areas of the developing countries. The United Nations projects that in

Figure 1.1--World: Index of Agricultural Production



Source: USDA, World Indices of Agricultural and Food Production, 1977-86, p. 6.

Figure 1.2--World: Index of Food Production



Source: USDA, World Indices of Agricultural and Food Production, 1977-86, p. 6.

Table 1.1--Prevelance of Enery Deficient Diets in Eighty-seven Developing Countries, 1980

Country group or region[a]	Not enough calories for an active working life (below 90 percent of FAO/WHO requirement)[b]		Not enough calories to prevent stunted growth and serious health risks (below 80 percent of FAO/WHO requirement)[c]	
	Share in population (percent)	Population (millions)	Share in population (percent)	Population (millions)
Developing countries (87)	34	730	16	340
Low-income (30)[d]	51	590	23	270
Middle-income (57)	14	140	7	70
Sub-Saharan Africa (37)	44	150	25	90
East Asia and Pacific (8)	14	40	7	20
South Asia (7)	50	470	21	200
Middle East and North Africa (11)	10	20	4	10
Latin America and the Caribbean (24)	13	50	6	20

a. The eighty-seven countries had 92 percent of the population in developing countries in 1980, excluding China. See Appendix Table 1 for regional classification of countries. Numbers in parentheses are the number of countries in the sample.
b. Intake at this standard is sufficient for a person to function at full capacity in all daily activities.
c. Intake at this standard is sufficient to prevent high health risks and growth retardation in children.
d. The low-income countries had a per capita income below $400 in 1983; the middle-income countries had a per capita income about $400 in 1983.

Source: World Bank, Poverty and Hunger, p. 17.

Table 1.2--Population growth, 1965 to 1986, and projected to 2000

Country group	1986 population (millions)	Average annual growth (percent)				
		1965-73	1973-80	1980-86	1986-90	1990-2000
Developing countries	3,528	2.5	2.1	2.0	2.1	1.9
Low-income countries	2,374	2.6	2.0	1.9	2.0	1.8
Middle-income countries	1,154	2.5	2.4	2.3	2.2	2.0
Oil exporters	475	2.6	2.6	2.6	2.5	2.3
Exporters of manufactures	2,081	2.5	1.8	1.6	1.7	1.5
Highly indebted countries	570	2.6	2.4	2.4	2.3	2.2
Sub-Saharan Africa[a]	399	2.7	2.8	3.1	3.3	3.2
High-income oil exporters	20	4.8	5.5	4.2	4.0	3.4
Industrial countries	742	1.0	0.7	0.6	0.5	0.4
World[a]	4,290	2.2	1.9	1.8	1.8	1.7

a. Excludes nonmarket industrial economies.

Source: World Bank, World Development Report 1988, p. 187.

the year 2000, 19 of the 25 largest cities in the world will be in the developing nations (United Nations, 1987). These 19 cities had a total population of 58 million in 1950; by 2000 they are expected to have 261 million inhabitants. This rapid urbanization of the developing countries is having major impacts on the national and international food distribution systems and the composition of demand for food, and consequently on the agricultural systems that supply the basic foods and other agricultural commodities.

Concern about the future world food situation will continue to focus on the basic issues of adequate food production and its distribution to a rapidly growing population, especially in the low income countries. There are, however, a number of interrelated issues, such as poverty, hunger, malnutrition, income generation, employment creation, regional inequalities in agricultural development, the possibility of climatic change, and the overall sustainability of agricultural development, that are part of the overall concern about future food production and its distribution. All of these issues underlie the urgent need to expand research on the technical and socioeconomic aspects of agricultural production, distribution, and consumption.

To provide the background for the remaining chapters of the report, trends in world agriculture, both past and anticipated, are explored in the next section. These trends are especially useful for identifying constraints on agricultural development and the emerging research issues that need to be evaluated in formulating the Bureau of Science and Technology, Office of Agriculture's research strategy for the 1990s.

Trends in World Agriculture

For a comprehensive understanding of the world food and agricultural situation, a review of the evolving trends in economic growth, agricultural production and consumption, agricultural trade, resource use, and agricultural policy is essential. Because of the enormous diversity in the world, only a broad view of these trends by major geographic regions and economic groupings of countries can be presented. Individual country experiences will be cited as examples of broader trends or as exceptions to general patterns.

The variability of past agricultural performance and the greater diversity of agriculture in the LDCs than in the industrialized countries cannot be overemphasized. Agriculture in many developing countries is characterized by technological dualism or pluralism: modern production and distribution systems juxtaposed against traditional systems, frequently with a continuum of systems between the two extremes. In these situations there are always exceptions to the general trends, and averages often obscure important realities. The adequacy of food production per capita in the presence of hunger and malnutrition is an example of how trends and averages might be misconstrued.

Economic Growth

Agriculture continues to play an important role in the economic growth and development of most Third World countries. In many countries, poor performance of the agricultural sector is associated with low levels of economic growth simply because of the large weight of the agricultural sector in the gross national product. In other countries the agricultural sector is the leading sector in successful programs of development. The agricultural sector, in

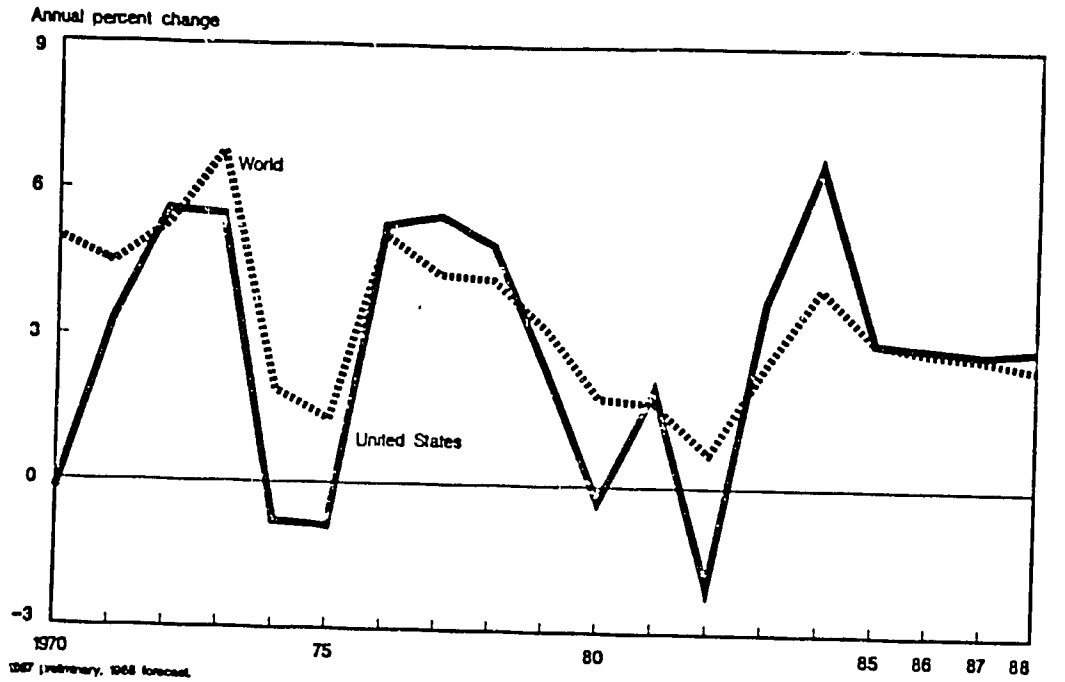
addition to providing food and raw materials for domestic consumption by farmers and the rapidly increasing non-farm populations, often provides needed foreign exchange through the export of processed and raw products, is a potential source of income generation for the rural poor, is a major source of employment in most developing countries, has an important role to play in natural resource conservation and management, and is a source of demand, due to rising incomes, for food and other goods, including manufactured inputs, from the non-agricultural sector.

The most outstanding features of world economic growth during the past two decades have been its periodic variability and its downward trend (Figure 1.3). Rates of growth that were 4.0 percent and larger during the late 1960s and early 1970s fell to below 1.0 percent and in some cases became negative during the 1980-84 period (Table 1.3). The recent recovery in the industrialized countries, though modest, has not been accompanied by similar recovery in the developing countries. Future economic growth is constrained by domestic deficits and balance of trade deficits that have forced many industrialized and developing countries to adopt austerity programs. Rising world prices for food would further aggravate the problem for food-deficit poor countries.

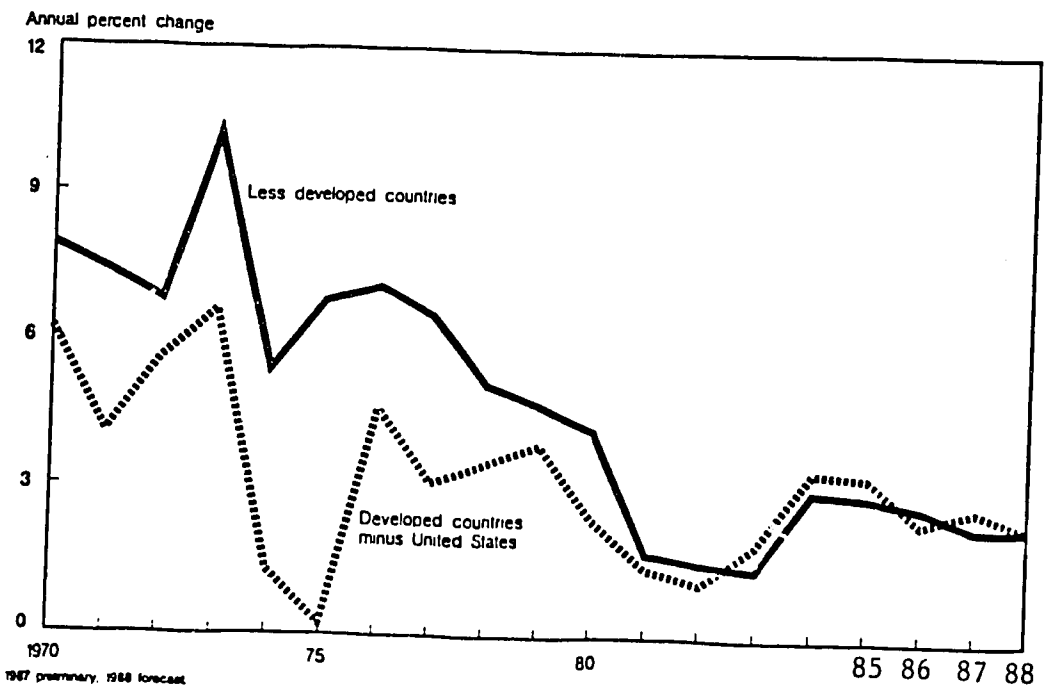
Changes in the rates of economic growth have important impacts on the demand for food. In low income countries where a high proportion of consumer income is devoted to food, increases in income can add significantly to the demand for food. For example, if per capita income is growing at 5.0 percent per year and the income elasticity of demand for food is 0.5, then the growth of food demand due to income growth is 2.5 percent; added to a population growth rate of 2.0 percent per year results in a potential increase in food demand of 4.5 percent per year. Lower economic growth and a lower income elasticity of demand can alter the situation considerably. In high income countries and among the wealthier classes of the developing countries, the impacts of economic growth on food demand are much less because of the lower income elasticities of demand for food. And since population growth rates are significantly lower in the high income countries and among the wealthier classes of the developing countries, the growth of total food demand is expected to be much less in these populations. The future growth of food demand therefore is expected to come primarily from the lower income classes of the developing world.

The distribution of income is also an important variable in determing the impact of economic growth on the potential demand for food. Using the above example, if the assumed 5.0 percent growth of the per capita income is concentrated among the wealthier 20 percent of the population, the impact on food demand will be much different than if the growth of income is widely distributed or is realized primarily by the lower income classes. Not only will the quantity of food demanded be different, but its composition will differ as well. Higher incomes for the poor will result primarily in increased demand for staple foods such as cereals and tubers, whereas income growth by the middle and upper economic classes will tend to increase the demand for meat, milk, eggs, fruit, vegetables, and processed food. The poor, however, will shift to the diets of the middle class once their basic food needs are met. Overall, higher incomes are associated with more varied diets that include higher proportions of animal products, fruit, vegetables, and processed foods.

Figure 1.3--World and U.S. Economic Growth



Economic Growth Abroad



Source: USDA, 1988 Agricultural Chartbook, p. 4.

Table 1.3--Population and GNP per capita, 1986, and growth rates, 1965 to 1987

Country Group	1986 GNP (billions of $)	1986 Population (millions)	1986 GNP per capita ($)	Average annual growth of GNP per capita (%) 1965-73	1973-80	1980-84	1985	1986*	1987*
Developing Countries	2,294	3,761	610	3.9	3.1	0.7	3.3	3.1	1.8
Low-Income countries	673	2,493	270	2.9	2.6	5.1	7.2	4.2	3.1
Middle-income countries	1,611	1,268	1,270	4.5	3.1	- 1.4	1.1	2.3	1.1
Oil exporters	501	538	930	4.8	3.1	-2.4	1.3	-1.7	-1.3
Exporters of manufactures	1,151	2,132	540	4.7	3.9	3.4	6.4	5.8	3.5
Highly indebted countries	797	570	1,400	4.5	2.8	-3.7	1.7	1.9	-0.5
Sub-Saharan Africa	157	424	370	3.7	0.7	-4.9	2.9	-0.2	-4.6
High-income oil exporters	129	19	6,740	4.2	5.6	-7.7	-8.2	-10.1	5.7
Industrial countries	9,611	742	12,960	3.6	2.1	1.3	2.4	2.0	2.2

* Preliminary

Source: World Bank, World Development Report 1988, pp. 187, 222 and 223.

Understanding the dynamics of population growth, economic growth, income distribution, and the demand for food is extremely important for designing an appropriate agricultural research strategy for the coming decade. In the broadest sense, the above analysis suggests that major research efforts will be needed to maintain the growth in output of staple food crops to meet the demand of the rapidly growing low income populations of the developing countries. At the same time, the growing demand for agricultural products with higher income elasticities of demand suggests that research efforts to increase productivity and output of animal products, fruits, nuts, and vegetables are needed and justified. Poor farmers as well as consumers benefit from more efficient production of higher value crops and livestock products because these products normally require substantial amounts of labor and have relatively high returns to labor and land. Finally, the burgeoning urban populations of the developing nations underlie the enormous need for efficient food distribution systems.

Agricultural Production

Although the growth of agricultural production on a global basis has exceeded the growth of population, there are significant differences among and within the major regions of the world. Appendix Figures 1 through 6 show the growth of agricultural production and production per capita between 1950 and 1986 for six regions of the developing world: Latin America, Southeast Asia, South Asia, West Asia (Middle East), North Africa, and Sub-Saharan Africa (see Appendix Table 2 for a list of the countries in each of the regions). Of these regions, South Asia, West Asia, North Africa, and Sub-Saharan Africa have experienced the most difficulty in maintaining per capita agricultural production, especially in the period from 1977 to 1986. For West Asia, North Africa, and Sub-Saharan Africa, agricultural production per capita has actually declined during the past decade.

The impact of population growth is evident in these figures. In all of the regions, total agricultural output has increased by more the 2.0 percent per year over the 36 year period (over 3.0 percent for three of the regions), yet population growth has left most of the regions with modest or negative growth of per capita production.

Variation in agricultural performance by countries within the regions is even greater than the variation among the regions. Appendix Tables 3-6 give the indices of per capita agricultural production, by country and region, for the period 1977 through 1986. Among the Latin American countries, the poor performance of the Central American nations is most notable. Some of the Caribbean countries as well as Bolivia, Peru and Guyana also experienced declines in per capita agricultural production (Appendix Table 3). In South Asia, Afghanistan, Bangladesh and Nepal stand out because of declining per capita production (Appendix Table 4). And even in those few Sub-Saharan nations with some improvement in per capita production, hunger and malnutrition are still widespread.

Recent declines in world grain production, both total and per capita, have caught the attention of some observers and may be a source of concern (Brown, 1988). It is difficult to determine if the declines in total world grain production in 1987 and 1988 represent a temporary reversal of previous trends or signal a major change in the global food situation. At present, it appears that the former interpretation is most likely and the observed declines are primarily the result of the interaction of low world grain prices, adverse

weather in China, Argentina and the North American grain producing areas, and U.S. policies to reduce grain acreage. The 1989 season will be critical since higher world grain prices and reductions in the U.S. acreage controls should result in greater output. Weather conditions however, will be important, and the effects of global changes in climate (the greenhouse effect) loom as unknowns in the future of world food production.

The decline in world grain production has been accompanied by a rapid reduction in carryover stocks (Brown, 1988). Although the absolute level of carryover stocks is greater than during the lean years of the early 1970s, increases in consumption associated with population and income growth leave the equivalent days of consumption from stocks (estimated at 54 days by Brown) at the lowest level in recent history.

Part of the concern about the world grain situation is derived from the slowdown in the rate of growth of grain yields in many parts of the world (Brown, 1988). An important element of this concern is the closing gap between actual national yields and potential yields obtained on research stations (Herdt, 1988). Rice is a frequently cited example for which there has been no increase in maximum yields at IRRI since 1965. The history of semi-dwarf wheat varieties closely parallels that of rice. In slight contrast to rice, there is an indication that yield potential for improved wheat varieties has continued to increase since 1965, but the increase has been modest compared to the sharp increase between 1961 and 1966 (Herdt, 1988). It is not clear if the slowdown in the growth of rice and wheat yields is associated with increased yield stability; if so, an important aspect of more recent plant breeding strategies, i.e., increased yield stability, may be having an effect.

The data on cereal yields in Table 1.4 indicate a range of experiences when growth rates for 1960-70 are compared with 1970-84. The overall rates of growth of yields for wheat, maize, and rice in the developing countries were greater during 1970-84 than during 1960-70; millet and sorghum, on the other hand, experienced declines in the growth of yields. Among the income and regional sub-divisions of the developing countries, a wide range of yield changes between 1960-70 and 1970-84 are observed. In some cases, the rate of increase in yields has declined, and it has become negative in a few places such as for maize, rice, millet, and sorghum in East Africa south of the Sahara. In other cases, yields have been increasing more rapidly than in the earlier period.

Interestingly, with the exception of millet, which is a very minor crop, the rates of growth of cereal yields in the industrialized market economies have all declined between 1960-70 and 1970-84 (Table 1.4). Since a large amount of the scientific knowledge and agricultural research and development activity originates in the industrialized countries, the declines in the rate of annual increase in cereal yields in those countries suggest that the availability of economically viable technologies has been reduced and that the existing viable cereal technologies have been adopted by most of the farmers. The decline in the rate of yield increases in the industrialized nations plus the slowdowns in yield growth in many developing countries portends a tightening of the world cereal markets. This observation is consistent with the fact that experiment station yields for cereals have leveled off substantially in recent years.

Table 1.4--Growth in Yields of Cereal, 1960-84

(average annual percentage change)

Region	*Years*	*Wheat*	*Maize*	*Rice*	*Millet*	*Sorghum*
Developing countries	1960–70	3.54	2.47	2.20	3.19	3.53
	1970–84	3.87	2.91	2.44	0.13	1.43
By income						
Low-income Africa	1960–70	2.05	0.04	0.54	0.17	0.16
	1970–84	2.10	0.96	0.09	−1.56	−0.78
Low-income Asia	1960–70	5.14	4.09	2.61	4.59	4.58
	1970–84	4.68	4.62	2.60	0.51	0.64
Middle-income oil importers	1960–70	1.63	2.16	0.67	0.22	3.27
	1970–84	2.42	1.48	1.45	−0.00	3.15
Middle-income oil exporters	1960–70	1.61	1.55	1.44	−0.57	−0.02
	1970–84	1.63	2.39	3.08	2.91	4.11
By region						
East Africa south of Sahara	1960–70	2.28	0.96	1.10	1.11	0.68
	1970–84	2.73	−0.58	−0.42	−1.00	−0.90
West Africa south of Sahara	1960–70	1.10	1.76	0.15	−0.41	−2.87
	1970–84	1.86	−0.26	1.55	0.03	2.31
East Asia and Pacific	1960–70	6.40	4.30	3.30	7.18	8.82
	1970–84	6.38	4.73	2.85	3.58	4.04
South Asia	1960–70	3.59	1.09	0.89	2.05	0.16
	1970–84	2.86	1.03	2.15	1.40	3.20
Middle East and North Africa	1960–70	1.91	5.00	3.29	1.24	−1.13
	1970–84	0.87	1.87	0.96	5.51	−0.48
Latin America and the Caribbean	1960–70	0.47	1.74	−1.33	−2.46	2.09
	1970–84	2.42	2.19	1.64	−0.12	2.58
Industrial market economies	1960–70	2.22	3.67	1.63	−3.77	2.71
	1970–84	1.56	1.88	0.42	0.16	0.29
East-European nonmarket economies	1960–70	4.07	3.94	5.34	2.35	—
	1970–84	0.73	2.81	0.59	−2.37	−1.48

a. U.S.S.R. and Eastern Europe.

Source: World Bank, Poverty and Hunger, p. 60.

The slowed growth of cereal yields becomes even more worrisome when combined with the fact that the growth of food production in recent years has become more and more dependent on yield increases rather than the traditional reliance on area expansion. Paulino (1986) estimates that 80 percent of the production increase of major food crops in the developing nations between 1971 and 1980 was due to yield increases and only 20 percent resulted from area expansion. In some parts of the developing world, such as Asia, the contribution of yield increases was greater than 80 percent, whereas in parts of Africa and South America expanding the area harvested is still the principal means of increasing food production (Appendix Table 7). Economically viable technologies that increase crop yields and animal productivity are an essential part of a research strategy for future agricultural development.

Analyses of trends in feed grain and livestock production and consumption in the developing nations document the rapid growth that occurred in recent decades and point to large supply-demand imbalances by the year 2000 (Sarma and Yeung, 1985; Sarma, 1986). Between 1961-65 and 1973-77 production of meat in the developing countries increased at an average annual rate of 2.9 percent, milk at 2.5 percent, and eggs at 5.3 percent; population increased at an average rate of 2.6 percent per year during the same period (Sarma and Yeung, 1985). The high growth rates for egg production reflect technological advances in poultry farming and the rising demand for poultry in developing countries. During the same period, poultry's share of total meat production nearly doubled in Latin America and increased by 75 percent in North Africa and the Middle East, by 40 percent in sub-Saharan Africa, and by 30 percent in Asia.

Consumption of meat, milk and eggs in the developing countries from the early 1960s to the mid 1970s tended to increase more rapidly than production, hence imports rose steadily (Sarma and Yeung, 1985). Projections of production and consumption for the years 1990 and 2000 indicate that, except for eggs in Latin America, all of the developing regions are expected to have net deficits in the major livestock products by 1990 (Appendix Table 8). By 2000 the projected gaps could be two or three times larger in all the regions for meat and in the regions of Asia, North Africa/Middle East, and Sub-Saharan Africa for milk. The supply and demand of eggs in the developing countries could be in balance by 2000. These projections serve, given the assumptions underlying the analysis, as indicators of the domestic supply gap, or alternatively as indicators of the import requirements from world markets.

In summarizing the results of their study, Sarma and Yeung state:

> Unless the large gaps projected between supply and demand in the developing countries are filled by accelerating output growth or by transferring food from the developed countries or other developing regions through trade or aid, prices will rise, possibly causing poor consumers in some of the Third World countries to suffer. In countries where large imports of livestock products are not feasible because of foreign exchange constraints, every effort must be made to accelerate domestic production. In many countries, potential for rapid growth of output exists through application of new technology and labor-intensive livestock production, especially for poultry. In those countries where land is not a constraint, large-scale development of ruminant production is feasible. Even here

> the productivity of existing pasture and grazing lands needs to be improved. Livestock policies need to be reoriented with a view to providing improved access to institutional credit, production inputs, veterinary and health services, marketing facilities, and appropriate input and output price policies. Allocations of resources to livestock research need to be increased. (Sarma and Yeung, 1985, p. 10, underlining added).

Trends in feedgrain production and consumption are closely associated with trends in the livestock industry. A recent study by Sarma (1986) analyzes past trends in feedgrain production and use and develops projections for the year 2000. In general, the use of cereals in livestock feed in developing countries has increased much faster than direct food use during the last two decades. Feedgrain use in the developing countries also grew faster than the production and consumption of livestock products, such as meat, milk, and eggs, indicating an increase in the intensity of cereal use for producing livestock.

In 1980, about 680 million metric tons of cereals, including by-products, were used as livestock feed in the world (Sarma 1986). The developed countries used about three-fourths of the livestock feed and produced nearly two-thirds of the global livestock in that year. The remaining one-fourth was fed to livestock in developing countries (including China). Among the developing regions, Latin America used the most cereals for feed--about 43 million metric tons in 1980, of which 86 percent was coarse grains. Asia accounted for 30 percent, nearly half of which was paddy and rice by-products. Sub-Saharan Africa used the least, only 4 percent of the Third World total (Sarma, 1986).

Sarma's projections of the growth of demand for cereal feed to the year 2000 vary, depending on the method of projection, from 4.7 to 5.5 percent per year, based on an average growth in livestock products of about 3.7 percent. If the production of livestock products grows even more rapidly because of additional growth in demand, the derived demand for cereal feed could be even larger than projections based on trend estimates of output. Improvements in the productivity of pastures, however, could reduce the demand for feedgrains. Feed balance studies indicate that for ruminant animals, grazing of pastures, stubbles, and fallows provide about sixty percent of total feed intake.

Sarma summarizes the issues surrounding the demand for cereals and livestock products as follows:

> As per capita incomes increase, the income elasticity of demand for cereals for direct consumption as food declines. The much higher income elasticity of demand for feedgrains may also decline but less rapidly. In some developing countries, such as Brazil, the amount of cereals used for feed already exceeds that used for food. As this trend becomes more widespread, the aggregate demand for cereals in developing countries will continue to increase, the decline in consumption as food being more than compensated for in the rise in feed use . . .
>
> Where gaps between the projected demand and supply of cereals used for feed cannot be met by imports, market forces could lead to higher meat and cereal prices, which

might worsen the food situation for the poor. Therefore, policies concerning cereals and livestock need to be reviewed and modified. For example, in countries with a surplus of rural labor a conscious decision should be made to adopt labor-intensive livestock production strategies to meet equity objectives: increased employment, improved nutrition, and food security for low-income people in developing countries. Improvements in the yields of feedgrains and in feed efficiency through emphasis on research and development of feed technology could also partly alleviate the situation. In addition, the scope for substituting noncereals, such as cassava supplemented with proteins, for cereals in compound and mixed feeds needs to be explored. Increased production of fodder also should be considered.

However, as growing demand for feeds and fodder increase competition for land, it will have to be used more intensively. And large allocations of research resources will have to be made to development of new sources of feed, greater use of by-products and agricultural wastes, and of compound and mixed feeds. (Sarma, 1986, pp. 10-11, underlining added).

Agricultural Trade

The growing gap between food consumption and production in many countries of the world has been filled by imports coming primarily from North America, Western Europe, lower South America and Australia. Food aid has been an important component of developing country imports, especially for the Sahelian countries of Africa (World Bank, 1988). The overall growth in agricultural trade illustrated in Figure 1.4 shows approximately a doubling in world grain imports between 1970/71 and 1987/88.

Changes in food imports and exports by the developing countries during the past two decades have been dramatic. Between 1966-70 and 1976-80, net imports of major food staples by the developing countries have more than tripled, and the average annual growth rate of imports was 6.3 percent (Table 1.5).* Of the four major regions of the developing world, Sub-Saharan Africa and Latin America both switched from being net exporters to net importers of basic foods between 1966-70 and 1976-80. South Asia was the only subregion of the developing world to reduce imports between the two periods. Paradoxically, South Asia was also the region with by far the largest number of malnourished people in 1980 (Table 1.1). Reduction of food imports should not be taken as evidence that hunger has been overcome in South Asia. All of the subregions export basic food staples, and some of these regions (South Asia, East and Southeast Asia, Western Asia, and lower South America) increased their exports between 1966-70 and 1976-80. Lower South America, however, was the only subregion with net exports of basic foods in 1976-80.

Although basic food imports by developing countries have increased substantially, imports still constitute a relatively small, but important,

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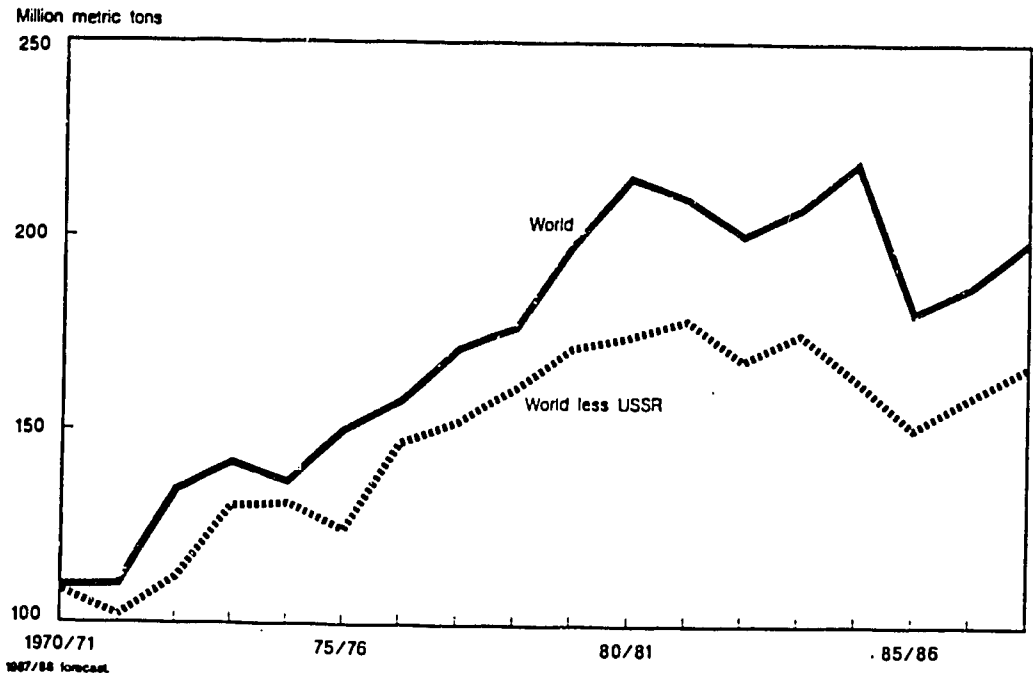
* Major or basic food staples include cereals, roots and tubers, pulses, groundnuts, and bananas and plantains (Paulino, 1986).

Figure 1.4--World Grain Imports



Source: USDA, 1988 Agricultural Chartbook, p. 14.

Table 1.5--Exports, imports, and net trade of major food staples, by region and subregion, 1966-70 and 1976-80 averages

Country Group	Exports			Imports			Net Trade[a]		Average Annual Growth Rate, 1966-70 to 1976-80[b]	
	1966-70	1976-80	Change	1966-70	1976-80	Change	1966-70	1976-80	Exports	Imports
	(million metric tons)		(percent)	(million metric tons)		(percent)	(million metric tons)		(percent)	
Developing countries	28.83	37.47	30	40.99	75.36	84	-12.16	-37.89	2.7	6.3
(Excluding China)	(26.85)	(35.80)	(33)	(35.16)	(63.06)	(79)	(-8.31)	(-27.26)	(2.9)	(6.0)
Asia	9.61	15.98	66	23.78	32.24	36	-14.17	-16.26	5.2	3.1
(Excluding China)	(7.63)	(14.31)	(88)	(17.95)	(19.94)	(11)	(-10.32)	(-5.63)	(6.5)	(1.1)
China	1.98	1.67	-16	5.83	12.30	111	-3.85	-10.63	-1.7	7.8
South Asia	1.88	3.18	69	10.07	5.73	-43	-8.19	-2.55	5.4	-5.5
East and Southeast Asia	5.75	11.13	94	7.88	14.21	80	-2.13	-3.08	6.8	6.1
North Africa/Middle East	1.95	2.22	14	6.74	19.28	186	-4.79	-17.06	1.3	11.1
Northern Africa	1.37	0.82	-40	3.98	10.76	170	-2.61	-9.94	-5.0	10.5
Western Asia	0.58	1.40	142	2.76	8.52	209	-2.18	-7.13	9.2	11.9
Sub Saharan Africa	3.89	1.86	-52	2.60	6.25	140	1.29	-4.39	-7.1	9.2
West Africa	2.51	1.08	-57	1.11	3.37	203	1.40	-2.29	-8.1	11.7
Central Africa	0.26	0.06	-78	0.39	0.87	124	-0.13	-0.82	-13.9	8.4
Eastern and Southern Africa	1.13	0.72	-36	1.10	2.00	82	0.03	-1.28	-4.4	6.2
Latin America	13.38	17.41	30	7.87	17.59	123	5.51	-0.18	2.7	8.4
Mexico and Central America[c]	1.71	0.87	-49	2.34	6.65	184	-0.63	-5.78	-6.6	11.0
Upper South America	1.99	1.79	-10	4.82	9.69	101	-2.83	-7.90	-1.0	7.2
Lower South America	9.68	14.76	52	0.71	1.25	76	8.97	13.50	4.3	5.8

Sources: Food and Agriculture Organization of the United Nations, "Agricultural Supply Utilization Accounts Tape, 1981," Rome, 1982; People's Republic of China, State Statistical Bureau, *Statistical Yearbook of China*, various issues (Hong Kong: Economic Information Agency, various years); and Republic of China, Council for Agricultural Planning and Development, "Taiwan, Food Balance Sheets, 1935-80," Taiwan, 1981 (computer printout).

Notes: Trade in bran and cakes for feed use is included. Parts may not add to totals due to rounding.

[a] Net trade is exports minus imports.

[b] Calculations are based on the midpoints of the indicated periods.

[b] Mexico and Central America includes the Caribbean.

Source: Paulino, Food in the Third World: Past Trends and Projections to 2000, p. 32.

portion of total consumption for most developing nations (Table 1.6). For the 1976-80 period, imports represented 8.9 percent of the total domestic use of basic foods in the developing countries. There is considerable variation in the dependence on imports among and within the major regions of the developing world. North Africa (36.5%), Middle East (16.6%), and Mexico and Central America (21.2%) have the highest levels of dependence on food imports. Asia, the largest consumption region in the world, has the lowest relative dependence on staple food imports (5.5%). Although Asia has made creditable progress in increasing agricultural production and stablizing food imports, it still has the largest absolute dependence on food imports of any developing region--five times as great as that in Sub-Saharan Africa.

Although small relative to total consumption, imports of basic food staples are an important component of total food supply and can make the difference between adequate nutrition and malnutrition for a large number of people. Imports however cannot solve the basic problems of hunger and malnutrition illustrated by the estimates in Table 1.1. Increased purchasing power by the poor, better health care and sanitation, and increased domestic production are key elements in the battle against hunger and malnutrition.

The availability of foreign exchange and the prices of food in world markets are critical elements in determining the level of food imports by developing countries. In recent years, world prices for basic food products have tended to decline, creating a favorable import situation for many developing countries (Figure 1.5). However, since 1987 world prices have increased sharply in response to reduced production and stocks. Increased trade deficits and reductions in available foreign exchange are, along with higher world prices, making the import of needed food more and more difficult.

The export of agricultural products by poor developing countries, often criticized as inappropriate and inconsistent with food needs, nevertheless happens because of the forces of comparative advantage and the need to generate foreign exchange to purchase basic food staples and other goods. The trade-offs between domestic food production, agricultural exports, and food imports represent the most difficult choices facing most developing countries. Sound economic analyses to support short-term and long-term self reliance in food are essential for agricultural and economic development of Third World countries. Careful study of the impacts of domestic agricultural policies, macroeconomic policies and trade policies form the basis of the needed economic analyses.

Food Consumption

Various aspects of food consumption have been discussed in previous sections. The prevalence of malnutrition, the impacts of population and income changes on the growth and composition of food demand, and trends in the consumption of livestock products and livestock feed have all been treated in detail. This section focuses on the broad issue of potential food gaps resulting from projections of food production and consumption in the developing world. Knowledge of these potential gaps is important for setting agricultural research priorities and for developing other strategies designed to achieve food self-reliance.

A study by Paulino (1986) provides the best available projections of possible food deficits and surpluses for the year 2000. Two tables from

Table 1.6--Basic Staple Food Consumption and Imports, by Region and Subregion, 1976-80 Averages

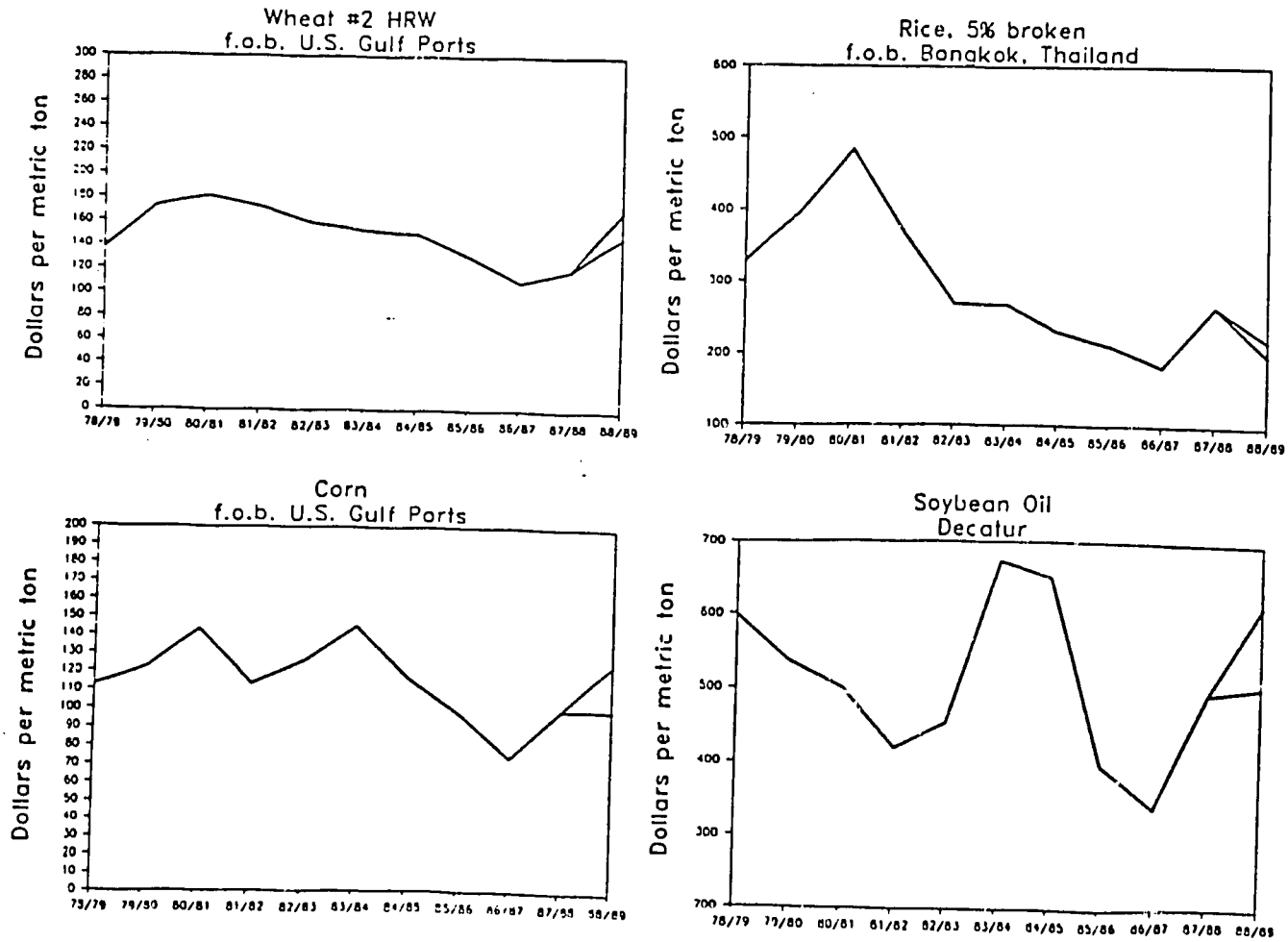
Country Group	Consumption	Imports	Percent/a
	(million metric tons)		(%)
Developing Countries	846.5	75.36	8.9
Asia	583.9	32.24	5.5
China	296.9	12.30	4.1
South Asia	183.6	5.73	3.1
East and South Asia	103.3	14.21	13.8
North Africa/Middle East	80.9	19.28	23.8
North Africa	29.5	10.76	36.5
Western Asia	51.4	8.52	16.6
Sub-Saharan Africa	74.9	6.25	8.3
West Africa	35.3	3.37	9.5
Central Africa	12.6	0.87	6.9
Eastern and Southern Africa	27.1	2.00	7.4
Latin America	106.8	17.59	16.5
Mexico and Central America	31.3	6.65	21.2
Upper South America	59.9	9.69	16.2
Lower South America	15.5	1.25	8.6

Source: Paulino, Food in the Third World: Past Trends and Projections to 2000, pp. 32 and 70.

/a Imports as a percentage of consumption.

Figure 1.5--Selected world cereal and oilseed prices

Product	Marketing year	1983/84	1984/85	1985/86	1986/87	1987/88 Forecast	1988/89 Forecast
	---------- Dollars per ton ----------						
Wheat, #2, HRW, f.o.b. U.S. Gulf ports	June/May	153	150	132	110	120	148-170
Rice, 5% broken, f.o.b. Bangkok Thailand	Aug/July	269	232	213	184	267	200-220
Corn, f.o.b. U.S. Gulf ports	September/August	145	117	98	74	100	100-125
Soybean oil, Decatur	October/September	674	651	397	339	496	507-617



Source: USDA, World Food Needs and Availabilities, 1988/89: Summer, p. 15.

Paulino's study summarize the results of his trend analyses. Table 1.7 presents the results by major regions and subregions of the developing world, whereas Table 1.8 groups the developing countries by income and food self-sufficiency categories. The major food crops included in Paulino's study are cereals, roots and tubers, pulses, groundnuts, bananas and plantains. Production trends were based on the period from 1961 to 1980, and income growth was based on per capita income trends between 1966 and 1980.

If the 1961-80 production trends and the 1966-80 per capita income trends continue, there could be an overall net deficit of about 70 million metric tons of food in the developing countries by the year 2000 (Table 1.7). The largest projected deficit--60 million tons-- would be in North Africa/Middle East, then Sub-Saharan Africa with close to 50 million tons, followed by Latin America with 10 million tons. Asia, in contrast, is projected to achieve a net surplus of slightly more than 50 million tons.

When grouped by average income, a total basic food deficit in 2000 of nearly 10 million metric tons is projected by the 19 countries that in 1980 formed the lowest income group and where the growth of food production had lagged behind population increase (Table 1.8). Deficits two to three times larger than those during 1980 are also projected for the middle- and high-income developing countries.

When grouped by historical rates of per capita growth, the slow growth countries (< 1.0 percent) and the fast-growing developing nations (> 5.0 percent) account for the largest potential food deficits, 29 and 51 million metric tons respectively (Table 1.8).

Developing countries which had low rates of food and calorie sufficiencies in the late 1970s are projected to have much larger deficits by the end of the century. One difficulty of the projections based on calorie sufficiency is that they don't indicate the magnitude of the basic food deficits if the calorie deficient countries were able to reduce hunger and malnutrition. In other words, they assume the same relative amount of calorie deficiency as existed in 1979-81, a level considered undesirable by most developing nations.

An uncertain element in the food supply-demand equation is the availability of unrecorded sources of food to rural people. These include many roots and tubers, vegetables, fruits, nuts, herbs, and wild plants; as well as small domestic livestock, fish, and wild animals. These are particularly important in heavily forested regions and upland areas where conventional agriculture is more difficult. However, good scientific data on the contribution of these unrecorded food sources to human nutrition is very limited.

Paulino adds other important qualifications to the projections presented in Tables 1.7 and 1.8:

> The projections are based on the assumption that historical trends in production and per capita income will continue. But because of the long projection period, even slight changes in these and other related factors could cause the size of the projected food gap to differ substantially. Production trends include the unusually rapid growth in the late 1960s and the 1970s that resulted

Table 1.7--Production and consumption of major food crops, by region and subregion, 1980 and projections to 2000

Country Group	1980			Projections to 2000				
					At 1980 Per Capita Consumption		With Trend Income Growth[a]	
	Production	Consumption	Net Surplus/ Deficit	Production	Consumption	Net Surplus/ Deficit	Consumption	Net Surplus/ Deficit
	(million metric tons)							
Developing countries	841.9	893.7	-51.8	1,471	1,315	156	1,540	-69
(Excluding China)	(543.1)	(579.8)	(-36.8)	(970)	(910)	(60)	(1,046)	(-76)
Asia	593.8	612.7	-18.9	1,035	847	187	983	51
(Excluding China)	(295.0)	(298.8)	(-3.8)	(534)	(442)	(91)	(489)	(44)
China	298.9	313.9	-15.0	501	405	96	494	7
South Asia	184.8	188.0	-3.3	323	282	41	310	13
East and Southeast Asia	110.2	110.8	-0.5	211	160	51	180	31
North Africa/Middle East	68.0	86.9	-18.9	119	145	-26	183	-64
Northern Africa	21.1	31.7	-10.6	35	55	-20	68	-33
Western Asia	46.9	55.2	-8.3	83	90	-7	114	-31
Sub-Saharan Africa	72.4	78.3	-5.9	114	149	-35	160	-47
West Africa	32.7	37.3	-4.7	39	69	-30	76	-36
Central Africa	12.1	13.0	-0.9	25	24	1	25	...
Eastern and Southern Africa	27.6	27.9	-0.3	49	56	-7	60	-10
Latin America	107.7	115.9	-8.2	204	174	30	214	-9
Mexico and Central America[b]	29.7	34.1	-4.4	57	55	2	65	-7
Upper South America	55.6	67.0	-11.5	100	97	3	126	-26
Lower South America	22.4	14.8	7.7	47	22	25	22	24

Sources: Food and Agriculture Organization of the United Nations (FAO), "Agricultural Supply Utilization Accounts Tape, 1981," Rome, 1982; FAO, "Estimates of Income Elasticities for Various Commodities by Country," Rome, 1979 (computer printout); FAO, "Production Yearbook Data Tape, 1975, 1979, 1981, and 1983," Rome, 1976, 1980, 1982, and 1984; People's Republic of China, State Statistical Bureau, *Statistical Yearbook of China*, various issues (Hong Kong: Economic Information Agency, various years); Republic of China, Council for Agricultural Planning and Development, "Taiwan Food Balance Sheets, 1935-80," Taiwan, 1981 (computer printout); Republic of China, Executive Yuan, Directorate General of Budget, Accounting, and Statistics, *Statistical Yearbook of the Republic of China, 1982* (Taiwan: Republic of China, 1983); United Nations, Department of International Economic and Social Affairs, "World Population Prospects as Assessed in 1982," New York, 1983 (computer printout); and World Bank, "Gross National Product by Country Data Tape, 1961-80," Washington, D.C., 1981. Consumption data for the People's Republic of China were provided by Bruce Stone of the International Food Policy Research Institute.

Notes: The ellipsis indicates a negligible amount. For aggregation purposes, rice is in husked form and the noncereal components are in wheat equivalents. Parts may not add to totals due to rounding; see also Appendix 3, Table 23.

[a] Based on the 1966-80 average annual growth rate of real GNP per capita.

[b] Mexico and Central America includes the Caribbean.

Source: Paulino, Food in the Third World: Past Trends and Projections to 2000, p. 42.

Table 1.8--Production and consumption of major food crops, by income, food self-sufficiency, and calorie sufficiency country groups, 1980 and projections to 2000

Country Group	1980			Projections to 2000				
				At 1980 Per Capita Consumption			With Trend Income Growth	
	Production	Consumption	Net Surplus/ Deficit	Production	Consumption	Net Surplus/ Deficit	Consumption	Net Surplus/ Deficit
	(million metric tons)							
Developing countries	842	894	-52	1,471	1,315	156	1,540	-69
Grouped by 1980 per capita income[a]								
Less than $250	215	216	-1	348	328	19	357	-9
$250 - $499	377	394	-17	656	536	120	634	22
$500 - $1,999	145	165	-19	271	269	3	324	-52
$2,000 and over	104	119	-15	197	183	14	226	-29
Grouped by 1961-80 income growth[b]								
Less than 1.0 percent	73	82	-9	111	136	-25	140	-29
1.0 - 2.9 percent	246	242	4	448	381	67	422	26
3.0 - 4.9 percent	460	484	-24	798	672	127	812	-14
5.0 percent and over	63	86	-23	114	126	-12	165	-51
Grouped by food self-sufficiency in 1976-80[c]								
Less than 75 percent	38	75	-37	63	117	-55	144	-82
75 - 94 percent	191	212	-21	327	334	-7	384	-57
95 - 104 percent	519	535	-16	903	752	150	881	22
105 percent and over	94	72	22	179	112	67	131	49
Grouped by calorie sufficiency in 1979-81[d]								
Less than 90 percent	52	56	-5	77	98	-21	102	-25
90 - 99 percent	209	213	-4	371	332	39	364	6
100 - 109 percent	416	440	-24	711	603	109	738	-27
110 percent and over	166	185	-20	313	283	30	335	-23

Sources: Food and Agriculture Organization of the United Nations (FAO), "Agricultural Supply Utilization Accounts Tape, 1981," Rome, 1982; FAO, "Estimates of Income Elasticities for Various Commodities by Country," Rome, 1979 (computer printout); FAO, "Production Yearbook Data Tape, 1975, 1979, 1981, and 1983," Rome, 1976, 1980, 1982, and 1984; People's Republic of China, State Statistical Bureau, *Statistical Yearbook of China*, various issues (Hong Kong: Economic Information Agency, various years); Republic of China, Council for Agricultural Planning and Development, "Taiwan Food Balance Sheets, 1935-80," Taiwan, 1981 (computer printout); Republic of China, Executive Yuan, Directorate General of Budget, Accounting, and Statistics, *Statistical Yearbook of the Republic of China, 1982* (Taipei: Republic of China, 1983); United Nations, Department of International Economic and Social Affairs, "World Population Prospects as Assessed in 1982," New York, 1983 (computer printout); and World Bank, "Gross National Product by Country Data Tape, 1961-80," Washington, D.C., 1981. Consumption data for the People's Republic of China were provided by Bruce Stone of the International Food Policy Research Institute.

Note: Parts may not add to totals due to rounding.

[a] In U.S. dollars per capita, using 1980 trend values of real GNP based on 1961-80 data (1979-81 = 100) and population estimates.

[b] Average annual growth rate of real GNP per capita during 1961-80.

[c] Ratio of domestic production to total consumption of major food crops during 1976-80.

[d] Average per capita calorie supply during 1979-81 relative to the FAO-WHO recommended levels.

Source: Paulino, Food in the Third World: Past Trends and Projections to 2000, p.50.

> from the effects of the "green revolution." Both the rate of area expansion and the increase in crop yields, which jointly form the trend rate of food output growth, will need to be maintained. If area expansion continues to slow, as shown by data for the 1960s and 1970s, future increments in output may depend much more on continued gains from agricultural technology--the spread of current technical know-how and an additional flow of improvements in output per hectare.
>
> On the consumption side, maintaining 1966-80 growth rates of per capita income and, hence, of food demands also poses problems in view of changes in the world economy after this period. Unless offset by faster-than-trend increases in income in the years ahead, the slower income growth in Third World countries due to the recession in the industrialized economics during the early 1980s is bound to reduce the projected food demand. Although the effects on developing countries may be mixed, the more recent rapid decline in energy prices can also be expected to affect food demand trends. The effects of these slowdowns in production growth and income-induced demand growth could offset each other, but the resultant change in the projected food gap is difficult to determine because of the close relationship between agricultural production and incomes in developing countries. (Paulino, 1986, pp. 10-11.)

Paulino also indicates how the projection results are sensitive to potential changes in the livestock industry, especially relating to the conversion of feed to livestock products. Alternative assumptions about input-output relationships in livestock production (essentially more intensive feeding systems), widen the projected food gap by 40 million metric tons.

The importance of China in the world food situation is illustrated in Paulino's projections. Slight changes in China's output and demand projections could easily affect the size of the food deficit for the developing countries as a whole. Present concerns about the growth of food production and changes in population growth and its age distribution could shift China from a surplus to a deficit country by the year 2000.

The projection results also reinforce the historical trends in food production per capita presented earlier in this chapter. Unless Sub-Saharan Africa's production trends improve or its population growth decreases, countries in this region face serious food shortages. Most of the countries in the region have not benefited from the seed-fertilizer technologies of the 1960s, and constraints presented by the region's natural, political and economic environment, especially in the Sahel, may stand in the way of substantial gains from existing green revolution technologies (Eicher, 1982 and 1988b). Food aid has provided a major portion of the food imports of the Sub-Saharan region in the past. It is unlikely that future food aid will be able to meet the growing needs. Increased domestic production based on economically and ecologically viable technologies is urgently needed (Eicher, 1988a).

The importance of fish is often overlooked in studies of food consumption and food needs. Fish is the world's largest single source of animal protein, exceeding the contributions of chicken, pork or beef (Idyll and Norton, 1988). Worldwide, fish supplies 16 percent of the direct human consumption of animal protein; an additional eight percent is consumed as fish meal by livestock. Over half the population in the developing countries obtain 40 percent or more of their animal protein from fish. In many developing countries fish represents the cheapest or only affordable source of animal protein.

The demand for fishery products is certain to increase. By the year 2000, the world per capita consumption of fish, at current price relationships, is expected to rise from the present level of 12.5 kg. to 15.1 kg. This represents a global consumption of fish of 113 million metric tons in 2000 compared to a catch of 85 million metric tons in 1985 (Idyll and Norton, 1988).

Nearly all the fish harvest comes from the ocean; aquaculture produces only about 10 percent, but its production rose 38 percent from 1978 to 1985. In the 1950s and 60s fish landings increased about six percent per year. In the 1970s this rapid advance came up against the barrier of resource limitations as nearly all commercially valuable fish stocks became fully exploited (Idyll and Norton, 1988).

Fish landings are expected to increase slowly during the remainder of this century. Because of natural limitations, the production of fish from the world's oceans is expected to level off at about 100 million metric tons. Aquaculture does not have the same constraint, since ponds and other enclosed water bodies can be fertilized and intensively managed. Production by fish farms is therefore expected to increase proportionately faster than by fishing. The expansion of aquaculture can be complementary or competitive with agricultural production. Small-scale aquaculture projects that are complementary with existing agricultural activities have the potential for utilizing underemployed labor and land, increasing income, and improving diets.

Resource Use

The resources used for agricultural production can be broadly classified into three major categories: physical, biological, and social. In a global sense the basic physical resources of land, air, water, and energy are relatively fixed in quantity. The productivity of these physical resources however is greatly influenced by changes in the biological and social resources that can be modified by man's actions. Plants, animals, microbes, and other biological organisms necessary for or inimical to agricultural production are subject to modification through the application of science, thereby altering their requirements for and association with the physical resources. New cultivars of existing plants can, for example, greatly increase the productivity of a given physical environment. Social resources, such as capital, labor, institutions, laws, scientific and practical knowledge, allow people to interact with the physical and biological environment to attain individual and collective goals. In agriculture that basic goal is the production of food and other agricultural products to meet consumption needs and to provide a surplus for the market or for other social institutions (government, landlord, monarch, etc.) that represents the demand for agricultural products.

Because of the multitude and complexity of the resources used in agricultural production, it is difficult to assess their status and to predict their future availabilities and uses. Some of the physical resources, such as sunlight, rainfall, molecular oxygen, and carbon dioxide, have no economic value yet they are absolutely essential for agricultural production. These resources have no economic value because they are plentiful (e.g., CO_2 in the atmosphere) or no social institutions have been developed to create a market for them (e.g., rainfall; of course markets exist for rainwater once it becomes surface or groundwater). Other physical resources, such as agricultural land, have economic value that reflects their current and expected productivity in agriculture as well as other factors such as pride of ownership, prestige, and nonagricultural potential. Discussions of resource problems and limitations facing world agriculture deal with all three categories of resources--physical, biological and social--including those with economic value and those without markets. The current concern over ozone depletion and carbon dioxide buildup in the atmosphere represent examples of the latter, whereas concern about the availabilities of arable land, irrigation water, and fertilizer involve resources with economic value, even though the markets may not be well-developed as in the case of land and irrigation water in many developing nations.

Some of the major economic resources necessary for agricultural production in the developing countries are discussed in this section. It is important to remember that the uses and productivities of these resources often change rapidly and are difficult to forecast. Changes in technology that alter input-output relationships can dramatically change the use of certain resources. The use of farm machinery for example has greatly reduced the use of agricultural labor in some industrialized countries, whereas the adoption of green revolution technologies has increased the aggregate and per hectare use of labor in several areas of the world (Pinstrup-Anderson and Hazell, 1987). These same technologies have been associated with large increases in fertilizer use and irrigation water resulting in yield increases that allow for aggregate output expansion with only minimal increases in area.

Land--The use of potential arable land varies a great deal among the major regions of the world. Also, the estimates of the amount of arable land seem to vary depending on the criteria applied in classifying different categories of land. One estimate of cultivated and potential arable land areas by regions is presented in Table 1.9. Cultivated area as a percent of potential arable land in 1965 was estimated at 44 percent for the world as a whole and ranged from 11 percent in South America to 88 percent in Europe. The relatively low percentages of arable land in use in Africa (22%), Oceania (10%), and South America (11%) have led some observers to conclude that land is not a constraint to future agricultural development, at least in the foreseeable future. This observation overlooks several fundamental points: the available arable land is not located where population is concentrated (Asia, for example, had 83% of its arable land in cultivation); the lack of infrastructure may limit the distribution of inputs and access to markets; health problems of humans and livestock may limit the development of large areas of Africa; and there is no indication of the costs of bringing available arable land into cultivation. Costs of clearing, removing rocks, providing irrigation water, etc., may be prohibitive and certainly vary greatly in different regions of the world. Given the possibility of increasing output through more intensive use of existing cultivation, farmers will generally choose the path that costs the least for a given increase in output or stated in another way, give the

Table 1.9--Cultivated and Potential Arable Land, World Region, 1965.

Region	Total	Area (million hectares)			Cultivated Land	
		Potential Arable	Cultivated	Potential Arable, Not Cultivated	As Percent of Area Potential Arable	Per Person (hectares)
Africa	3,019	732	158	574	22	0.5
Asia	2,736	627	518	109	83	0.3
Oceana (Australia and New Zealand)	822	154	16	138	10	1.2
Europe	478	174	154	20	88	0.4
North America	2,108	465	239	226	51	0.9
South America	1,752	679	77	602	11	0.4
U.S.S.R.	2,234	356	227	129	64	1.0
World	13,149	3,189	1,388	1,801	44	0.4

Source: Stevens and Jabara, Agricultural Development Principles, 1988, p. 30.

greatest increase in output for a given cost. In focusing on arable land for crop production it should be recognized that the use of non-arable land and natural vegetation can also be important to livestock production.

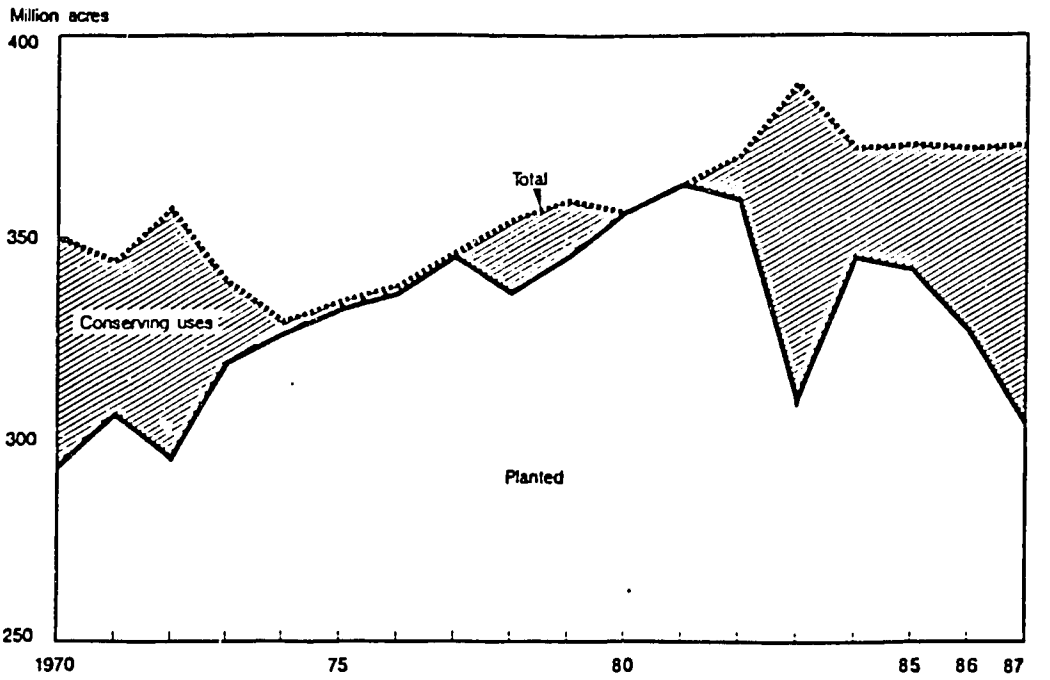
There are other aspects of land use and availability that need to be mentioned. Much of the available arable land exists in the tropical and semi-arid regions of the world. Although scientific knowledge about crop and livestock production in these regions is increasing, there is still a big gap between what is known about tropical agriculture and the accumulated knowledge about temperate agriculture. This is especially true for basic food crops and is true for some crops such as maize that are produced in several climatic zones. The need for more knowledge about tropical and semi-arid agriculture is both a problem and an opportunity. Major discoveries that can be applied in these areas could benefit large numbers of poor and undernourished people.

The impact of economic policies, especially in the high-income agricultural exporting countries, also needs to be considered. The high agricultural price supports and tariffs in the European Community contribute to the overuse of arable land relative to what it would be under a lower, world price regime. In the United States, farm programs create incentives for withdrawing farm land from production and increasing the intensity of cultivation, with possible negative environmental effects, of the remaining land. U.S. acreage idled under Federal programs in 1987 totaled more than 69 million acres, second only to the 78 million acres put in conserving uses in 1983 (Figure 1.6). Land put in conserving uses may contribute to environmental improvements that offset the negative impacts of more intense cultivation of the remaining cropland. Changes in the utilization of Federal farm programs in the U.S. contribute to the observed variations in the output of cereals and cotton. In a year such as 1988, the withdrawal of land via government programs plus the drought combined to severely reduce cereal production.

Finally, there is the problem of land being withdrawn or eliminated from cultivation because of desertification, erosion and conversion to non-agricultural uses. On a global basis, about 17 million hectares of cultivated land have been lost because of the above factors (Grove, 1989). Although 17 million hectares represents only slightly over one percent of the world's cultivated land in 1965 (Table 1.9), there are some areas, such as the Sahel, where these losses have been significant.

Water--Agriculture is the principal user of ground and surface water throughout the world. The introduction of green revolution cereal technologies was accompanied by major increases in irrigated land area. It is now recognized that investments in irrigation projects and the growth of irrigated land area have declined. The decline in growth in irrigated area is depicted in Table 1.10, which on a global level fell from a growth of 41 percent between 1960 and 1970 to 26 percent for 1970-80 and 8 percent for the shorter 1980-85 period. Asia contains about two-thirds of the world's irrigated area and the slowdown in the growth of irrigated area in that region is a focus of concern. IFPRI research indicates that in recent years, there has been a sharp reduction in irrigation investment in Asia, which is likely to further slow the rate of growth in area irrigated (IFPRI, 1988). Aggregate lending by the four principal donors (World Bank, Asian Development Bank, USAID and the Japanese) for irrigation projects in Asia reached its peak in real terms in 1977-79 and by 1986-87 was about 50 percent of the 1977-79 level. These trends raise

Figure 1.6--U.S. Crop Acreage Planted and Placed in Conserving Uses



Source: USDA, 1988 Agricultural Chartbook, p. 12.

serious concerns about the direction and future of irrigation in Asia and its implications for agricultural development.

The data in Table 1.10 also indicate the relatively low amount of irrigated areas in Africa, South America, and Oceania. These three continents contain only nine percent of the world's irrigated area. Although the potential for irrigation varies immensely in Africa, South America and Oceania, the economic and technical viability of alternative irrigation schemes for these regions needs greater attention. The conclusion by the World Bank and other donors that irrigation projects are too expensive needs to be reexamined and alternative, less expensive means of irrigation need to be investigated.

The existing irrigated areas of the world are subject to problems that need research and practical solutions. Waterlogging, salinity, and the silting of reservoirs are but three of the problems that need attention. There is an urgent need to learn from the mistakes that have resulted in high costs and poor utilization of existing irrigation projects, such as in some of the projects in Northeast Brazil (Hall, 1978). Improved management of irrigation systems and on-farm water use as well as increased irrigation efficiencies are elements of the problem that need attention.

Fertilizer--Fertilizer use also has expanded rapidly in the developing countries. Between 1969-71 and 1985 the use of fertilizer in the developing countries, measured in terms of grams of plant nutrients per hectare of arable land, nearly tripled (World Bank, 1988). In the low income countries of the developing world there was a four-fold increase in fertilizer during the same period, and in India and China the increase was about 4 1/2 times the 1969-71 average. The growth of fertilizer use in the industrialized market economies, about 15 percent between 1969-71 and 1985, has been much slower than in the developing nations, and, as a result, total world fertilizer use in 1985 was about double what it was in 1970 (Brown, 1987). Future gains in agricultural productivity in many parts of the developing world will require the use of greater amounts of fertilizer.

There are two basic concerns relative to fertilizer availability and use for agriculture. The first relates to the future availability of fossil fuel and minerals used to produce chemical fertilizer, and the second concerns the environmental impact of chemical fertilizer use, especially the impact of nitrogen fertilizers on water quality. The current low relative price for petroleum has reduced the alarm over fertilizer prices that permeated much of the discussion in the mid- and late-1970s. There appears to be time in which technological alternatives to the current dependency on chemical fertilizers can be investigated. Research on these alternatives is following many lines--nitrogen fixation in plants, more efficient use of fertilizers, better management and use of plant and animal residues that are returned to the soil, etc.--and needs to be continued since the long-term outlook is for increased real prices of petroleum and other nonrenewable resources used in fertilizer production. It should be recognized, however, that such approaches may reduce, but not eliminate the need for chemical fertilizer.

The problem of nitrate contamination of water from chemical fertilizer use is a hotly debated topic that may not represent a major concern at this point. Ground and surface water contamination from other sources (chemical spills, pesticide use, industrial wastes, etc.) however is becoming a serious problem

Table 1.10--Growth in Irrigated Area, by Continent, 1950-85.

Region	Total Irrigated Area, 1985	Growth in Irrigated Area			
		1950–60	1960–70	1970–80	1980–85
	(million hectares)	(percent)			
Asia[1]	184	52	32	28	8
North America	34	42	71	14	−11[2]
Europe[3]	29	50	67	33	9
Africa	13	25	80	27	13
South America	9	67	20	28	17
Oceania	2	0	100	0	0
World	271	49	41	26	8

[1]Includes the Asian part of the Soviet Union. [2]This number, which is for 1980–84 and the United States only, is from U.S. Department of Agriculture, *Farm and Ranch Irrigation Survey-1984*. [3]Includes the European part of the Soviet Union.

Source: Brown, Sustaining World Agriculture, p. 125.

for human and animal populations in many parts of the industrialized and developing world (Batie, 1988).

Energy--Agriculture, broadly defined, is a major user of energy, especially in developed countries, such as the United States, where large amounts are used for production, processing, packaging and distribution of food. Future increases in agricultural production will almost certainly require increased use of energy (Brown, 1987). Although human and animal power still contribute a high proportion of energy for agriculture in developing countries, one of the concerns about the future of the green revolution technologies centers on their dependency on fossil fuel for the production of fertilizer, pesticides, herbicides, etc. Increased urbanization in the developing countries also means greater energy needs for the transportation, processing, storage and distribution of food. Under current petroleum and other fossil fuel prices, the concern over this type of energy for the food and agricultural sector is not urgent.

There is, however, an urgent energy problem in the developing countries that is associated with the use of dung and fuelwood for heating and cooking. As much as 80 percent of the domestic energy in rural households in developing countries comes from these sources (Arnold and Jongma, 1977). The use of dung for domestic energy competes with its use as organic material in farming. The increased use of fuelwood competes for agricultural labor because of the greater hauling distances and is a factor in deforestation, erosion and desertification in some parts of the world. In other parts of the world, the expansion of traditional agriculture is associated with deforestation (Kumar and Hotchkiss, 1988). The emphasis on agroforestry, reforestation, charcoal production, and more efficient stoves is one aspect of the energy problem facing developing countries. Given the long-term outlook for real increases in energy prices, continuing the search for alternative energy sources and more efficient uses of energy for food production, processing, and distribution is important.

Genetic resources--Crop and animal genetic resources are fundamental to agricultural development. The development of high-yielding varieties of wheat, rice and other crops has demonstrated the importance of maintaining and developing germplasm. New genotypes of high-yielding wheat in Mexico seem to have a productive life of about five years before they suffer yield loss due to disease, etc. Since it takes at least four years to develop a new crop variety, there is a constant need to draw upon the existing gene pools. Maintenance of gene banks is an important aspect of continuing successful crop breeding programs. The preservation of genetic diversity in both plants and animals has great implications to efforts to meet growing demand for food in developing countries. Moreover, questions of "rights" to genetic materials have become of increasing significance.

Human resources--The quality of the human resources is probably the most important item in the list of social resources used in agricultural production. The other social resources, such as capital, institutions, laws, and scientific knowledge, result from the creative abilities and labor of people. In a general sense there have been improvements in the quality of life in the developing countries. Life expectancy has increased significantly in the past few decades. Infant mortality rates are declining. Levels of illiteracy are dropping. The availability of health services and sanitation is better than what it was three decades ago. Population growth rates have started to decline

in many developing countries. However, with respect to all of these and other indices of the quality of human life, there is a large gap between the developing countries and the high-income industrialized countries. For example, the absolute number of malnourished people in low income countries has increased and there is continued concern about the long-term effects of malnutrition on mental retardation, disease resistance, etc.

The role of women in agriculture has been more fully recognized in recent years. Agricultural development projects financed by AID and other donors now include the explicit recognition of the needs of women farmers and marketers of agricultural products. Development and implementation of projects targeted for women, however, has lagged in most countries. There is a continuing need to develop effective means of addressing the unique problems of rural women. Many of these problems involve cultural beliefs and practices, such as the division of work, land, and money according to gender, that change very slowly. There is a need to expand the focus created by the women in development efforts to include the whole family, especially children.

At the level of science and technology, the low level of investment in agricultural research in many developing countries continues to be the norm rather than the exception. A detailed discussion of the trends in agricultural research expenditures is contained in Chapter 4.

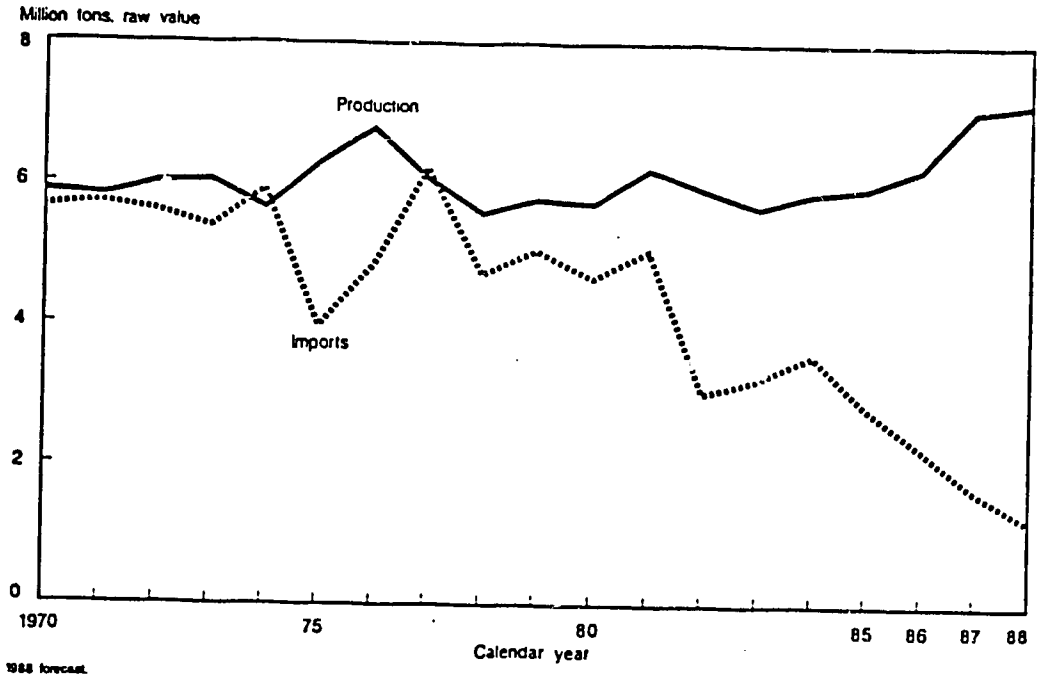
Policy Reforms

The importance of appropriate policies to provide incentives to producers, handlers and processors of agricultural products has received increasing attention during the 1980s. The full recognition that these agents of agricultural development respond to economic incentives has resulted in policy reforms correcting previous distortions of incentives in some developing countries. Although there are adjustment problems associated with restructuring incentives, the responses appear to be positive in terms of greater output and better functioning markets.

Privatization has been a popular element of policy reform. In agriculture, privatization has frequently been directed towards the large state and parastatal firms established to market agricultural inputs and products. For bureaucratic and political reasons privatization has moved very slowly in most countries, but in others (e.g., Mexico, Colombia and Thailand) significant progress has been made. Previous research on government run agricultural marketing firms have found them to be inefficient (Stewart, 1988; Lele, 1979). When combined with rigid pricing regimes these state marketing organizations often end up losing business to private competitors who develop parallel markets for their products. In some cases these parallel markets are illegal, but they still conduct a significant portion of the transactions.

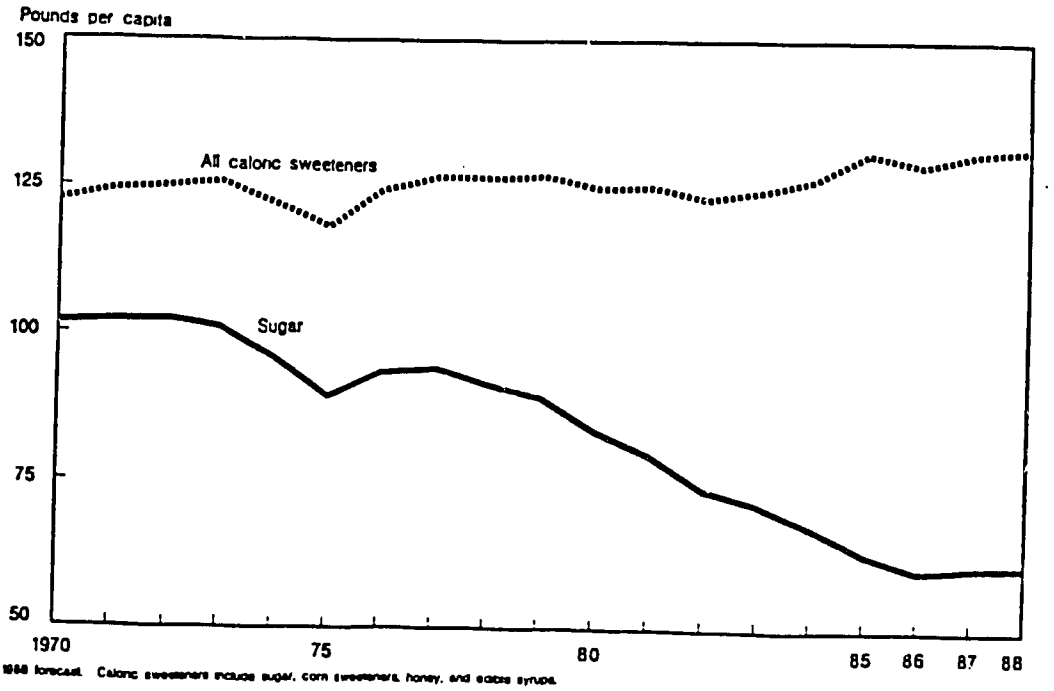
The developing countries have for many years protested that the policies of the industrialized countries are detrimental to their agricultural development efforts. Part of this protest has involved political rhetoric, yet there are clear cases where U.S. and other developed country policies have restricted markets for developing country products. U.S. sugar policy is a good example. By maintaining high prices to domestic producers and a system of quotas on imports, the U.S. has managed to increase production and drastically reduce imports (Figure 1.7). The U.S. sugar import quota was reduced to 758,000 tons for 1988, compared to 1 million tons in 1987 and 3 million tons in

Figure 1.7--U.S. Sugar Production and Imports



Source: USDA, 1988 Agricultural Chartbook, p. 20.

Figure 1.8--U.S. Caloric Sweetener Consumption



Source: USDA, 1988 Agricultural Chartbook, p. 20.

1984 (USDA, 1988). Since U.S. sugar imports traditionally come from tropical areas of the developing world, the U.S. policy has directly affected their export opportunities. Interestingly, within the U.S. high sugar prices have provided the incentives for rapid expansion of other sweeteners, especially those derived from corn (Figure 1.8).

A further example of government protection of agriculture and the distortion of incentives is provided by the estimates of producer subsidy equivalents in Figure 1.9. Producer subsidy equivalents (PSEs) measure levels of support (or taxation) provided to producers by domestic farm programs and agricultural trade barriers. PSEs report the value of government support as a percentage of producers' agricultural income. As indicated in Figure 1.9 the highest level of support for producers of wheat, sugar, dairy products and beef is provided by the developed countries (Japan, U.S., Canada). Some of the middle income countries such as Taiwan, Brazil and South Korea also maintain policies that heavily support some of these products. India and South Africa are the only two countries in the list that have net taxation of their producers through price and trade policies.

Policy reforms in developed and developing countries have not been as rapid or widespread as many analysts would prefer. Land reform, which is frequently considered a pre-condition for agricultural development, has been effectively introduced in only a few countries. Environmental policies in support of sustainable agriculture are practically non-existent. Many laws and regulations still act as constraints on agricultural development. These and other institutional and policy constraints are addressed in Chapter 2.

Summary

The review of past trends and anticipated changes in the world agricultural economy has identified several areas of major concern that clearly indicate the necessity for rapid agricultural development based on a sustainability approach. Important among these trends and concerns are the following:

- Significant portions of the developing countries' populations suffering from hunger and malnutrition because of lack of purchasing power to acquire food and other basic necessities for life.

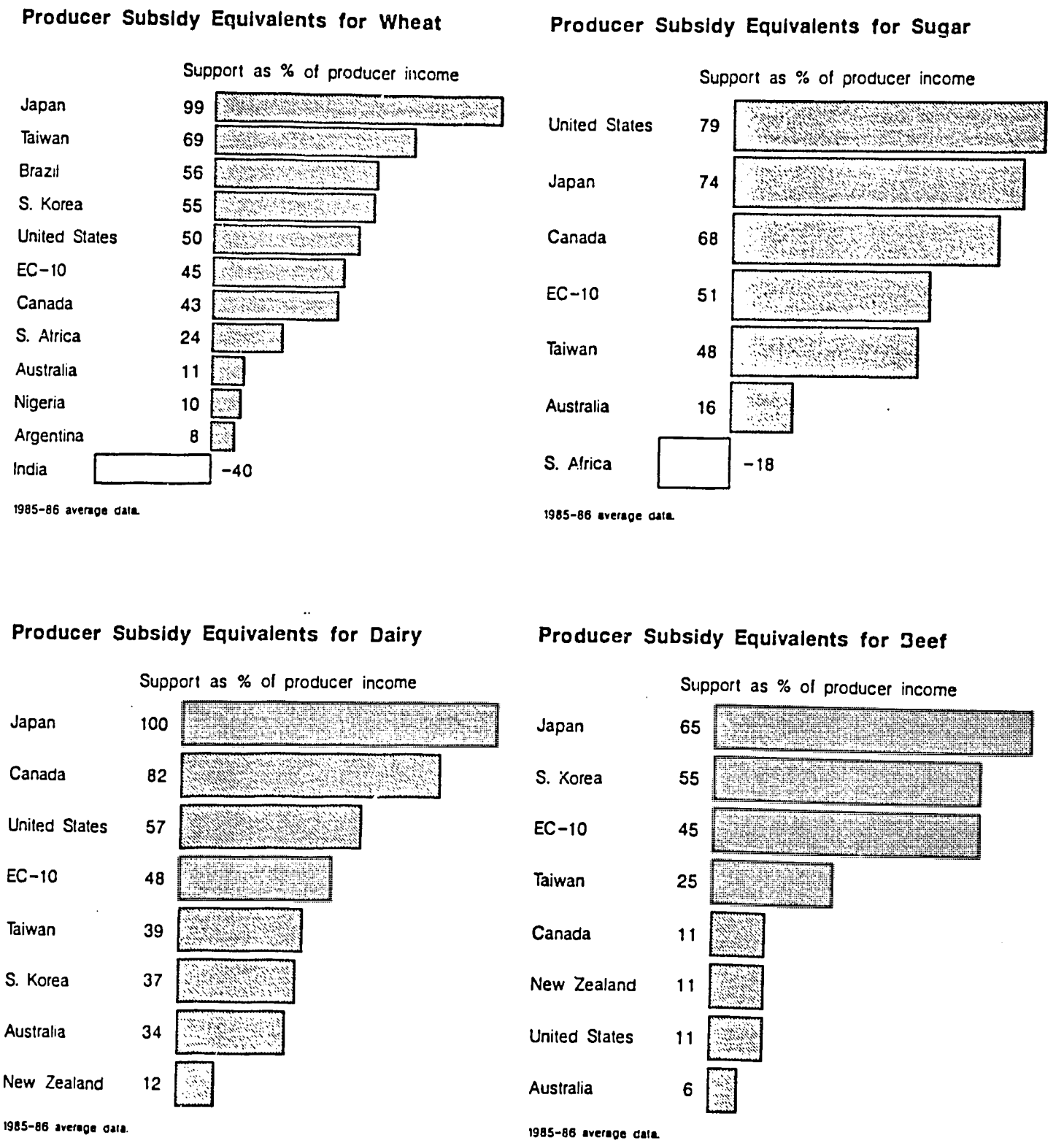
- Reduction in per capita agricultural production in several areas of the world--Middle East, North Africa, Sub-Saharan Africa, Central America and some countries in South Asia.

- Increased dependence on imports by those countries with lagging production per capita.

- Slowdowns in the growth of cereal yields in both developing and developed countries.

- Low levels of investment in agricultural research and inadequate human resources for improving agricultural research and development in many developing countries.

Figure 1.9--Producer Subsidy Equivalent for Wheat, Sugar, Dairy and Beef, 1985-86 Average Data.



Source: USDA, 1988 Agricultural Chartbook, p. 73.

- Resource problems and limitations in some agricultural regions arising from shortages of arable land, degradation of natural resources, and reduced investments in irrigation.

- Economic policies and programs in many developing countries that continue to provide disincentives to producers while many high-income countries continue to protect and subsidize their farmers.

- Continued rapid population growth in the developing countries with the most rapid growth occurring in the urban areas.

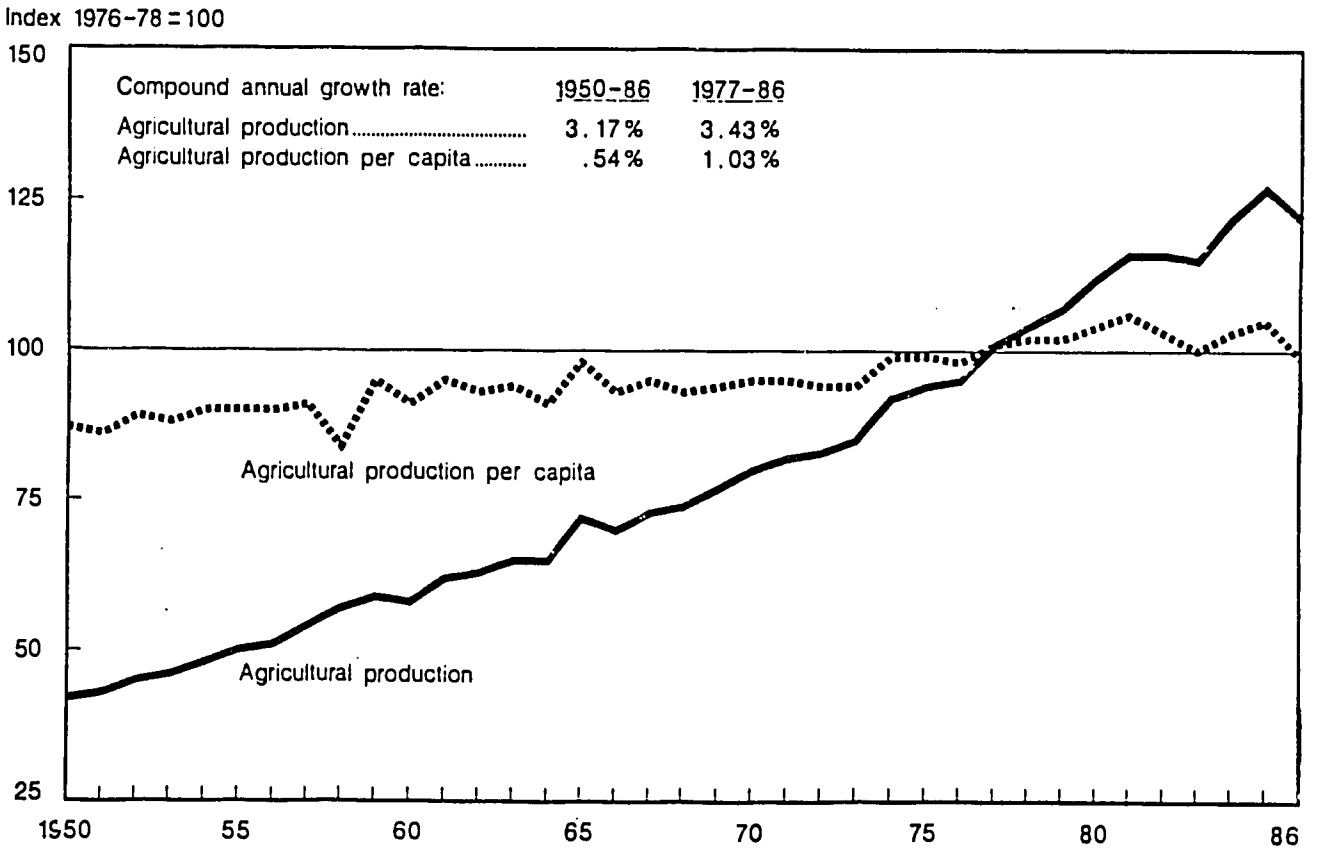
- Continued rapid growth in the demand for food resulting from population and income growth.

- Changing composition of the demand for food as incomes rise, with potentially large increases in the demand for animal products, fish, fruits, and vegetables.

- Rapidly increasing demand for livestock feed resulting from the increased demand for animal products.

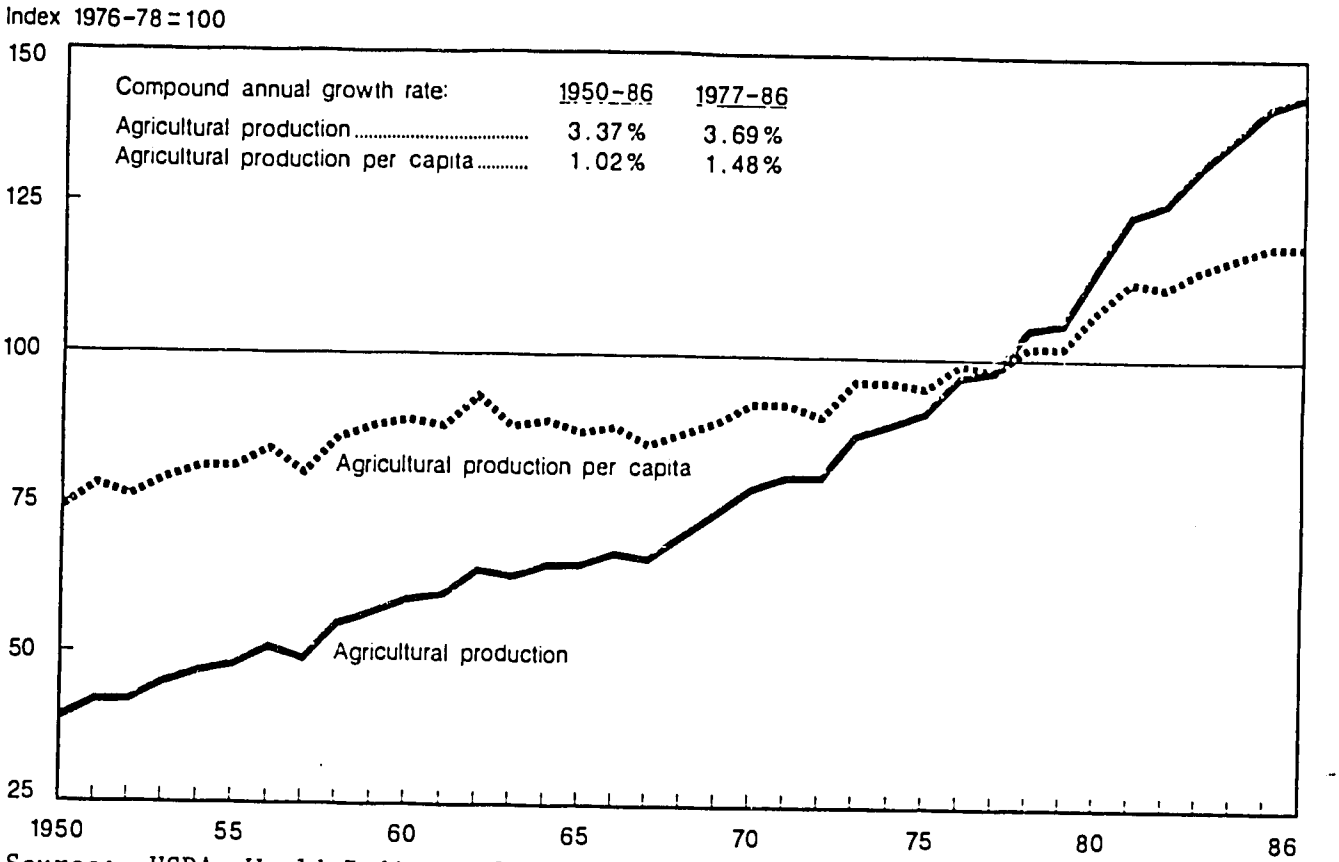
- Potentially large increases in supply/demand imbalances in North Africa, Middle East, and Sub-Saharan Africa.

Appendix Figure 1--Latin America: Index of Agricultural Production



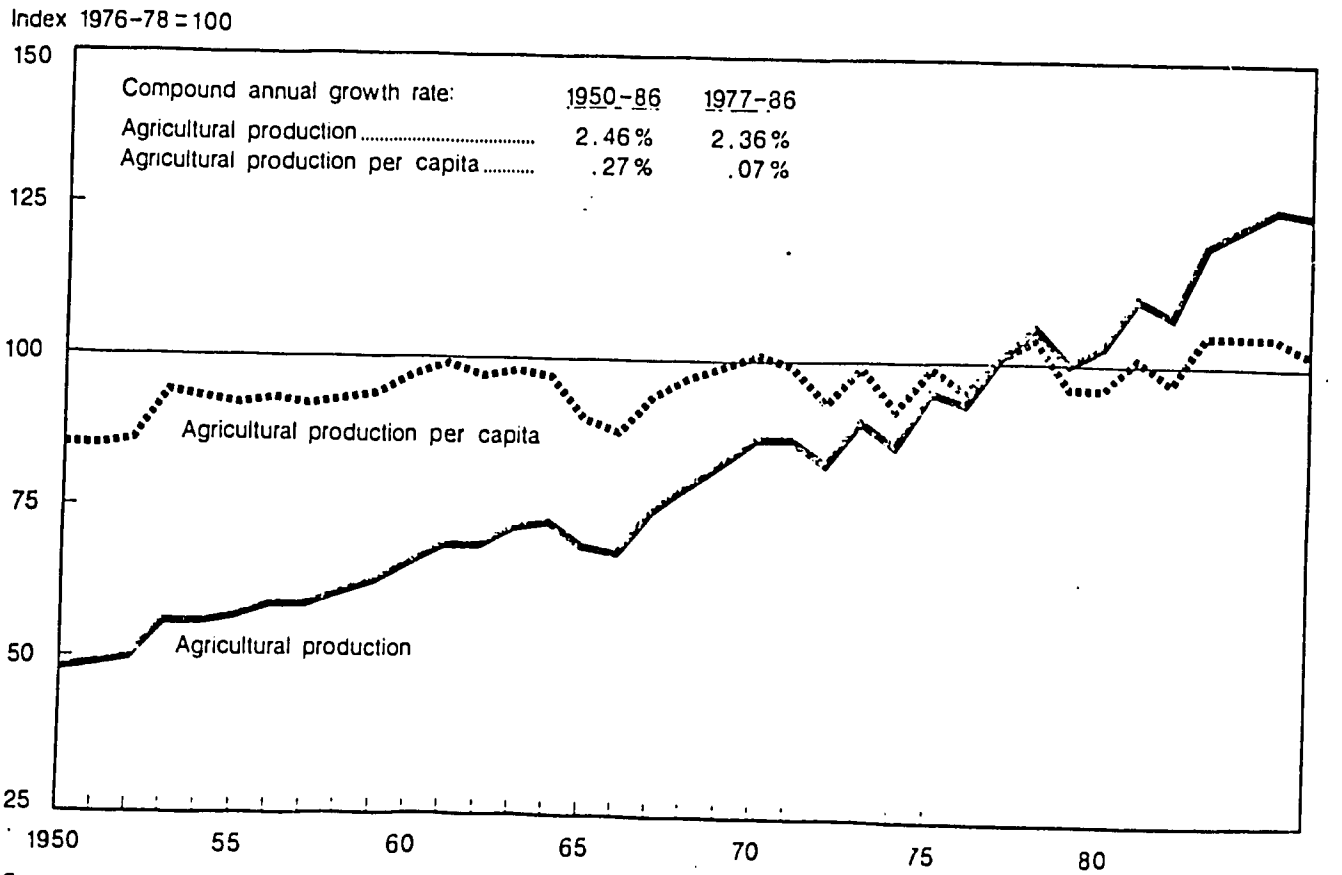
Source: USDA, World Indices of Agricultural and Food Production, 1977-86, p. 17.

Appendix Figure 2 --Southeast Asia: Index of Agricultural Production



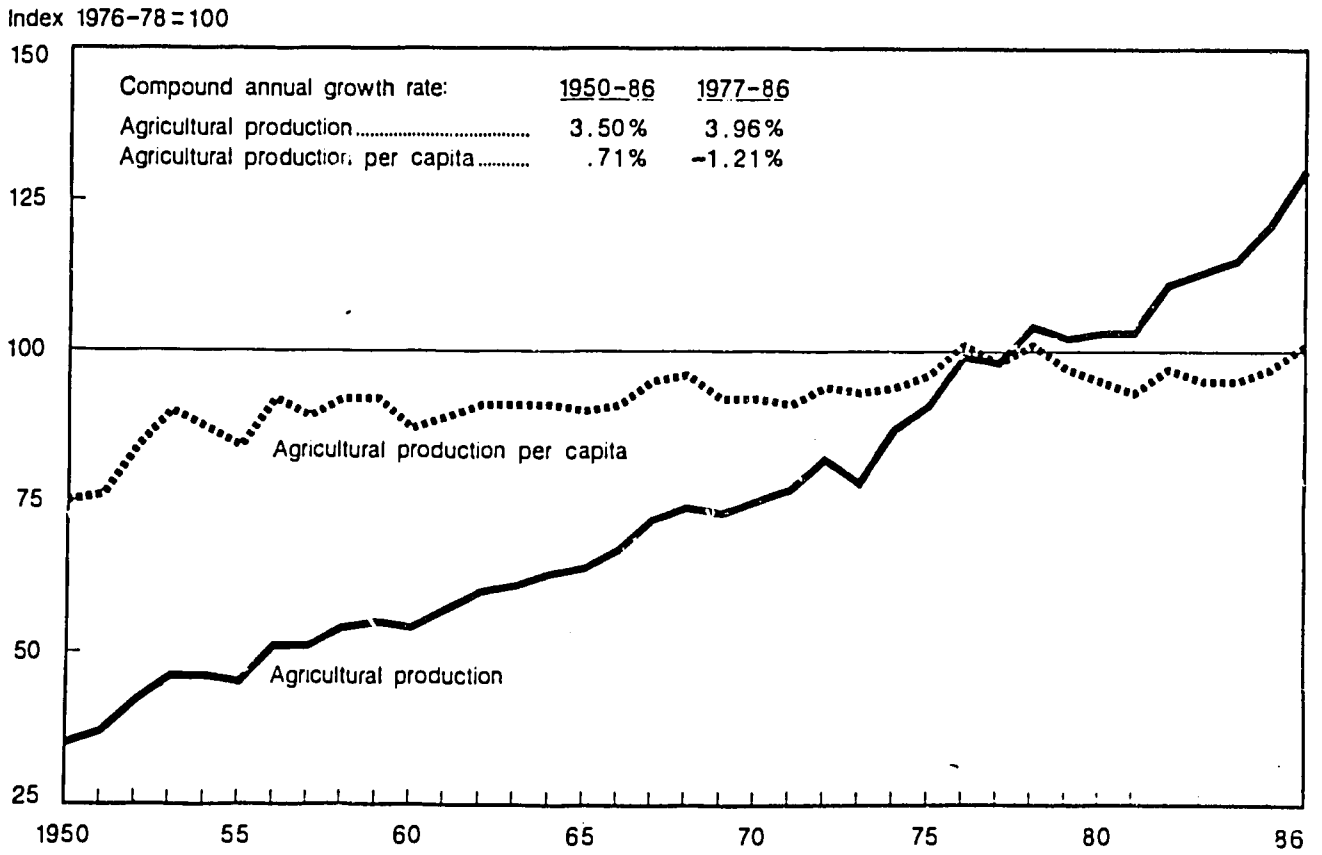
Source: USDA, World Indices of Agricultural and Food Production, 1977-86, p.85.

Appendix Figure 3 --South Asia: Index of Agricultural Production



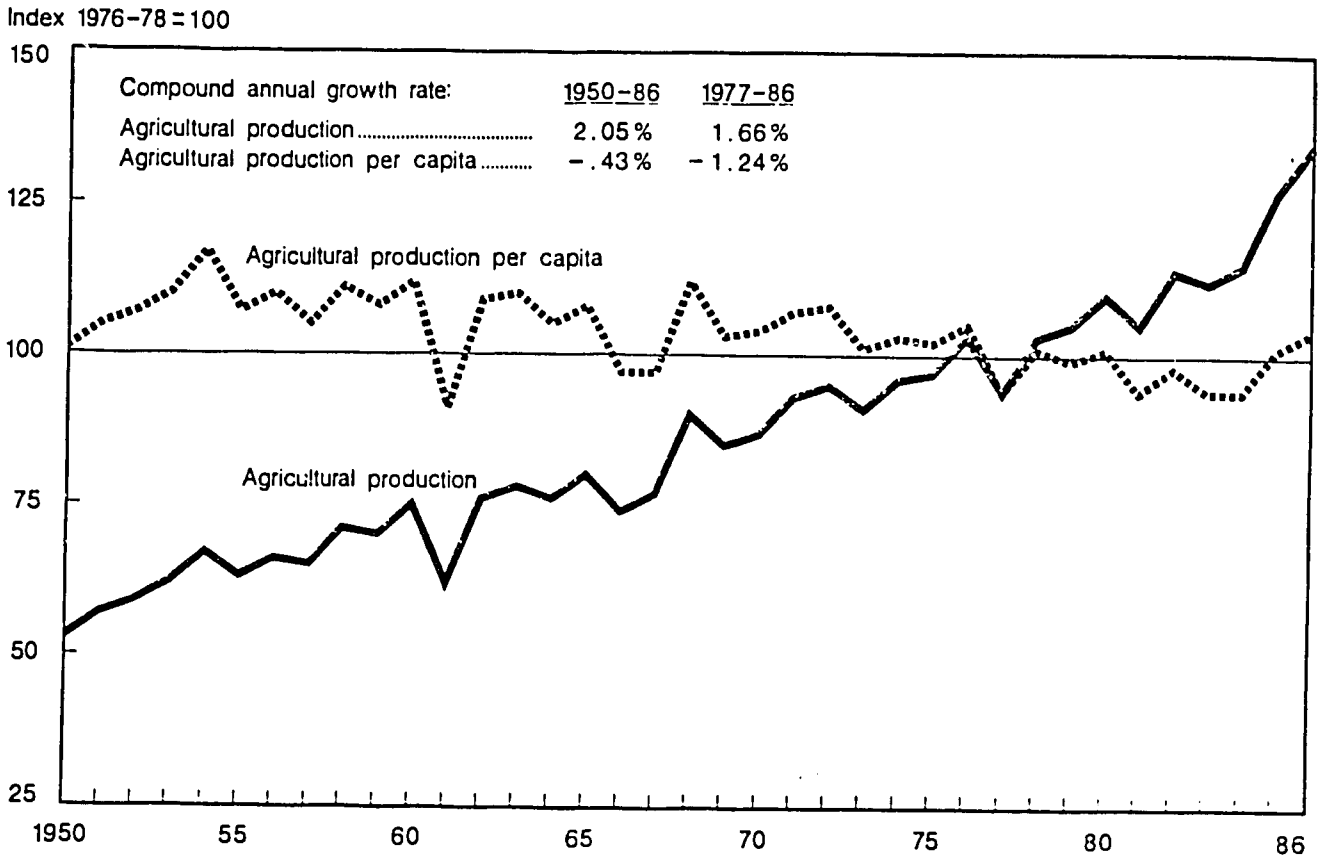
Source: USDA, World Indices of Agricultural and Food Production, 1977-86, p.84.

Appendix Figure 4 --West Asia: Index of Agricultural Production



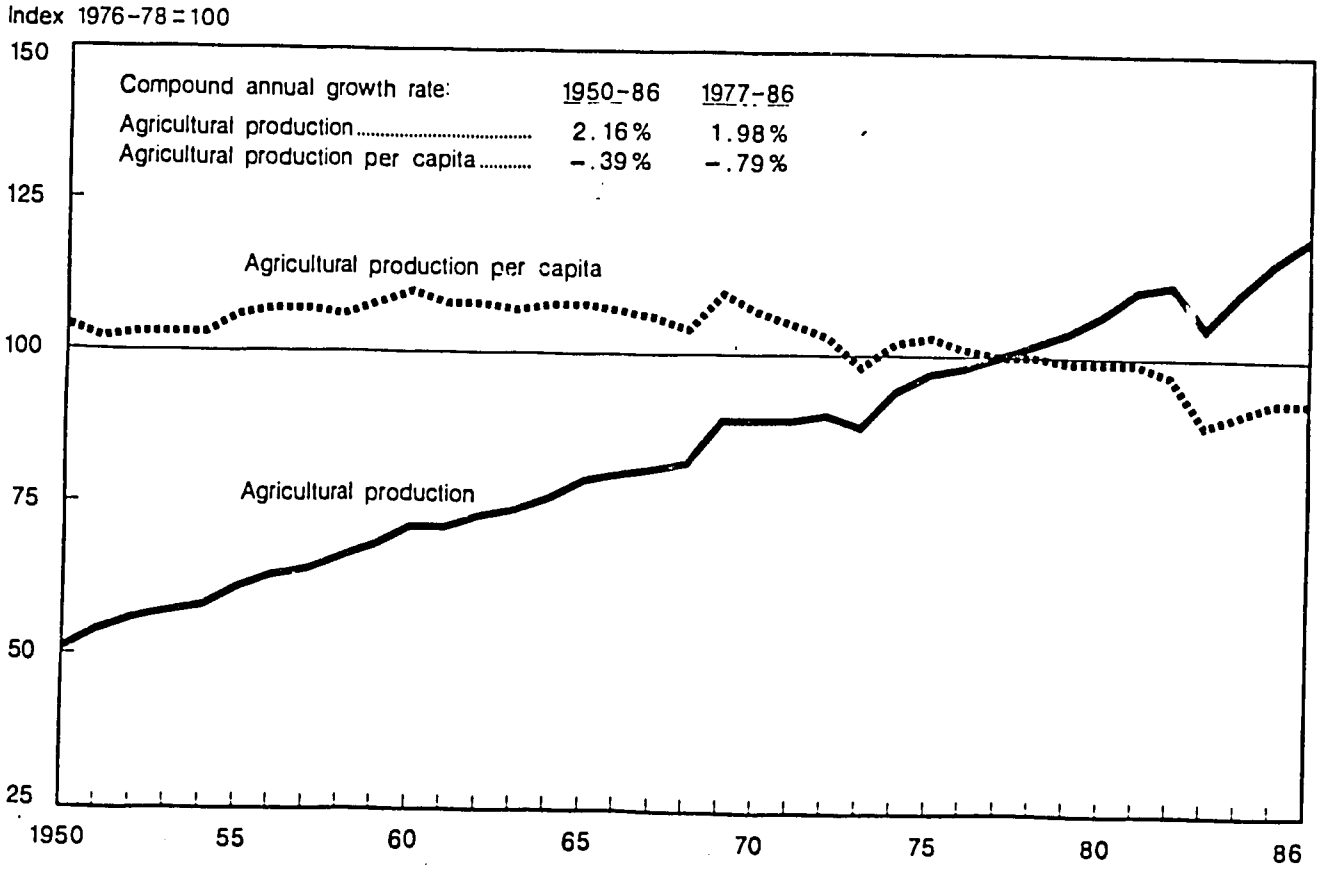
Source: USDA, World Indices of Agricultural and Food Production, 1977-86, p. 109.

Appendix Figure 5 --North Africa: Index of Agricultural Production



Source: USDA, World Indices of Agricultural and Food Production, 1977-86, p. 123

Appendix Figure 6--Sub-Sahara Africa: Index of Agricultural Production



Source: USDA, World Indices of Agricultural and Food Production, 1977-86, p. 122

Appendix Table 1--Countries Included in the Estimation of Energy-Deficient Diets

Sub-Saharan Africa		*Latin America and the Caribbean*	
Benin	Mali	Argentina	Guyana
Botswana	Mauritania	Bahamas	Honduras*
Burkina Faso	Mauritius	Barbados	Jamaica*
Burundi	Mozambique	Bolivia	Mexico*
Cameroon	Niger	Brazil*	Nicaragua
Cape Verde	Nigeria	Chile*	Panama*
Central African Rep.	Rwanda	Colombia*	Paraguay
Chad	Senegal*	Costa Rica*	Peru*
Congo, People's Rep.	Sierra Leone	Dominican Republic*	Suriname*
Ethiopia	Somalia	Ecuador*	Trinidad and Tobago
Gabon*	Sudan*	El Salvador*	Uruguay*
Gambia, The	Swaziland	Guatemala*	Venezuela*
Ghana	Tanzania*		
Ivory Coast*	Togo		
Kenya*	Uganda		
Lesotho	Zaire		
Liberia	Zambia*		
Madagascar	Zimbabwe		
Malawi*			
East Asia and Pacific	*South Asia*	*Middle East and North Africa*	
Fiji	Afghanistan	Algeria	Morocco
Hong Kong	Bangladesh	Egypt	Syria
Indonesia*	Burma	Iran	Tunisia*
Korea, Rep. of*	India*	Iraq*	Turkey*
Malaysia*	Nepal	Jordan	Yemen Arab Republic
Papua New Guinea	Pakistan*	Lebanon	
Philippines*	Sri Lanka*		
Thailand*			

*Income distribution data were available for these thirty-five countries.

Source: World Bank, Poverty and Hunger, p. 56.

Appendix Table 2--List of Countries by Regions, Appendix Figures 1-6, Indices of Agricultural Production

Latin America (Appendix Figure 1)

ARGENTINA
BARBADOS
BOLIVIA
BRAZIL
CHILE
COLOMBIA
COSTA RICA
CUBA
DOMINICAN REPUBLIC
ECUADOR
EL SALVADOR
GUATEMALA
GUYANA
HAITI
HONDURAS
JAMAICA
MEXICO
NICARAGUA
PANAMA
PARAGUAY
PERU
SURINAM
TRINIDAD AND TOBAGO
URUGUAY
VENEZUELA

South Asia (Appendix Figure 3)

AFGHANISTAN
BANGLADESH
SRI LANKA
INDIA
NEPAL
PAKISTAN

Southeast Asia (Appendix Figure 2)

BURMA
INDONESIA
MALAYSIA
PHILIPPINES
THAILAND
VIETNAM

West Asia (Appendix Figure 4)

CYPRUS
IRAN
IRAQ
ISRAEL
JORDAN
LEBANON
SAUDI ARABIA
SYRIA
TURKEY

North Africa (Appendix Figure 5)

ALGERIA
EGYPT
LIBYA
MOROCCO
TUNISIA

Sub-Sahara Africa (Appendix Figure 6)

ANGOLA
BENIN
BURKINA FASO
BURUNDI
CAMEROON
ETHIOPIA
GHANA
IVORY COAST
KENYA
LIBERIA
MADAGASCAR
MALAWI
MALI
MOZAMBIQUE
NIGER
NIGERIA
RWANDA
SENEGAL
SIERRA LEONE
SOUTH AFRICA
SUDAN
TANZANIA
TOGO
UGANDA
ZAIRE
ZAMBIA
ZIMBABWE

Appendix Table 3--Western Hemisphere

INDICES OF PER CAPITA AGRICULTURAL PRODUCTION, BY COUNTRY AND REGION, 1977-86

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
					1976-78 = 100					
UNITED STATES	102	101	106	98	108	107	86	101	106	99
CANADA	100	102	96	99	107	111	105	101	109	118
MEXICO	100	104	100	109	108	100	102	98	98	95
BARBADOS	106	96	110	121	103	93	96	107	110	112
CUBA	97	108	115	104	112	118	112	121	114	115
DOMINICAN REPUBLIC	91	103	90	96	96	92	96	94	86	84
HAITI	103	107	99	107	93	95	96	97	86	86
JAMAICA	97	107	99	89	87	81	84	85	78	82
TRINIDAD AND TOBAGO	100	91	96	87	80	84	76	70	72	75
CARIBBEAN	97	106	105	100	103	104	102	106	98	99
CARIBBEAN, LESS CUBA	96	104	95	98	94	91	94	93	85	86
COSTA RICA	98	103	99	95	96	102	102	108	84	98
EL SALVADOR	95	110	106	91	91	82	74	83	68	64
GUATEMALA	98	99	101	92	90	83	80	84	79	75
HONDURAS	99	104	107	103	100	102	97	87	81	82
NICARAGUA	99	101	79	76	73	82	67	66	59	55
PANAMA	102	99	96	95	103	100	99	97	99	95
CENTRAL AMERICA	98	104	98	91	90	88	82	86	75	75
CENTRAL AMERICA, LESS PANAMA	98	104	98	91	89	88	81	85	73	73
ARGENTINA	97	104	106	95	101	108	103	111	105	105
BOLIVIA	98	95	96	96	96	99	67	87	91	85
BRAZIL	103	98	101	109	111	106	102	108	118	105
CHILE	104	95	89	101	105	104	99	104	106	109
COLOMBIA	96	105	110	113	114	109	106	106	104	103
ECUADOR	103	99	101	111	116	112	93	94	110	112
GUYANA	99	108	88	88	102	99	84	90	85	82
PARAGUAY	105	103	104	106	112	108	102	106	116	96
PERU	102	91	92	83	88	84	60	87	84	79
SURINAM	99	104	121	130	143	141	141	141	141	137
URUGUAY	92	96	95	100	116	108	109	99	109	110
VENEZUELA	103	103	99	101	96	100	96	97	101	103
SOUTH AMERICA	101	101	102	104	107	106	101	106	110	104
LATIN AMERICA (25 COUNTRIES)	101	102	102	104	107	103	100	103	105	99

Source: USDA, World Indices of Agricultural and Food Production, 1977-86, p. 19.

Appendix Table 4--Asia and Oceania

INDICES OF PER CAPITA AGRICULTURAL PRODUCTION, BY COUNTRY AND REGION, 1977-86

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
					1976-78 = 100					
AFGHANISTAN	96	97	91	80	82	83	84	82	81	78
BANGLADESH	101	101	98	100	97	98	98	96	98	94
SRI LANKA	100	105	105	102	108	103	108	106	116	110
INDIA	101	104	95	95	101	97	107	107	107	103
NEPAL	97	98	87	96	97	82	102	99	99	90
PAKISTAN	105	98	106	104	108	105	99	103	104	114
SOUTH ASIA	101	104	96	96	102	97	105	105	105	102
BURMA	96	105	104	107	116	123	124	125	131	134
INDONESIA	98	103	104	111	119	114	121	127	127	124
MALAYSIA	101	96	108	109	110	115	108	111	118	122
PHILIPPINES	100	100	90	101	104	100	98	93	97	100
THAILAND	93	109	99	103	110	109	116	117	118	107
VIETNAM	98	97	101	106	108	112	115	118	114	113
SOUTHEAST ASIA	98	103	101	107	113	113	115	117	119	118
CHINA, PEOPLE'S REPUBLIC	95	106	114	114	121	117	142	155	155	154
JAPAN	103	100	99	88	89	90	89	94	94	93
KOREA, REPUBLIC	101	104	103	81	91	93	93	95	95	96
TAIWAN	100	95	98	98	96	96	95	96	96	89
EAST ASIA, LESS CHINA	103	101	100	87	90	91	90	94	94	93
ASIA ABOVE, LESS CHINA	101	102	98	95	98	96	100	102	101	99
ASIA, LESS JAPAN AND CHINA	100	103	99	98	103	101	107	107	108	106
AUSTRALIA	93	108	104	93	101	88	108	106	105	104
NEW ZEALAND	99	97	97	101	105	104	105	103	108	104
OCEANIA	95	106	103	95	101	92	107	105	106	104

Source: USDA, World Indices of Agricultural and Food Producetion, 1977-86, p. 67.

Appendix Table 5--West Asia (Middle East)

INDICES OF PER CAPITA AGRICULTURAL PRODUCTION, BY COUNTRY AND REGION, 1977-86

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
					1976-78 = 100					
CYPRUS	105	93	107	121	123	119	119	124	123	131
IRAN	96	100	92	80	78	82	79	76	81	86
IRAQ	98	103	99	90	80	85	84	82	99	102
ISRAEL	100	101	95	96	93	101	100	98	94	79
JORDAN	73	129	75	150	89	127	87	106	77	103
LEBANON	95	119	103	130	98	130	116	116	111	123
SAUDI ARABIA	102	104	108	97	106	137	178	225	267	300
SYRIA	86	102	77	119	103	102	93	80	85	90
TURKEY	98	100	99	98	99	102	99	98	94	99
WEST ASIA (MIDDLE EAST)	98	101	97	95	92	97	96	95	97	101

Source: USDA, World Indices of Agricultural and Food Production, 1977-86, p. 110.

Appendix Table 6--Africa

INDICES OF PER CAPITA AGRICULTURAL PRODUCTION, BY COUNTRY AND REGION, 1977-86

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
					1976-78 = 100					
ANGOLA	102	89	85	88	79	79	76	74	72	70
BENIN	101	100	102	90	86	83	79	98	101	98
BURUNDI	99	100	98	92	103	92	96	86	89	89
CAMEROON	102	95	97	95	93	86	79	87	87	88
ETHIOPIA	97	105	112	104	102	110	98	86	91	95
GHANA	96	93	98	94	89	80	66	90	76	85
GUINEA	101	98	94	94	91	96	93	91	88	90
IVORY COAST	95	104	107	116	109	102	84	112	112	101
KENYA	106	98	90	90	95	91	88	84	86	91
LIBERIA	100	96	93	95	96	92	90	98	87	87
MADAGASCAR	104	91	96	96	92	92	91	92	90	88
MALAWI	100	103	102	99	101	107	101	102	99	94
MALI	93	106	103	96	106	105	98	87	99	93
MOZAMBIQUE	99	103	99	98	99	95	72	76	78	78
NIGER	98	103	108	110	102	100	96	61	83	85
NIGERIA	99	100	100	103	99	98	84	93	91	92
RWANDA	100	98	105	100	105	105	107	80	89	90
SENEGAL	78	110	84	73	9	98	70	77	88	83
SIERRA LEONE	96	103	96	92	92	92	87	81	84	82
SOUTH AFRICA	101	102	97	101	108	94	80	86	89	88
SUDAN	101	103	84	85	95	82	82	74	88	83
TANZANIA	99	99	98	95	95	92	91	89	89	88
TOGO	92	104	111	106	105	102	90	101	98	93
UGANDA	102	92	76	74	81	87	90	87	92	92
BURKINA FASO	99	103	105	95	104	103	96	93	113	122
ZAIRE	101	96	97	97	100	100	100	95	96	97
ZAMBIA	101	90	86	86	93	83	91	91	98	98
ZIMBABWE	97	98	90	93	96	88	74	85	102	93
AFRICA, SUB-SAHARA	100	100	98	98	100	96	88	90	92	92
SUB-SAHARA, LESS REP.SO.AFRICA	100	99	98	98	99	97	89	91	92	93
ALGERIA	94	96	94	102	95	89	83	83	112	122
EGYPT	98	99	101	102	99	99	97	96	97	98
LIBYA	95	100	91	92	98	98	95	98	98	97
MOROCCO	85	105	99	99	78	97	91	90	91	104
TUNISIA	96	97	95	101	106	117	108	118	139	112
AFRICA, NORTH	94	100	99	101	93	98	94	94	101	104
ALL AFRICA	99	100	98	99	98	97	89	91	94	95
AFRICA, LESS REP.SO.AFRICA	98	100	98	99	97	97	90	92	95	95

Source: USDA, World Indices of Agricultural and Food Production, 1977-86, p. 125.

Appendix Table 7--Average growth rates of production, area harvested, and output per hectare of major food crops, by region and subregion, 1961-70 and 1971-80.

Country Group	Period	Average Annual Growth Rate			Contribution to Production Increase	
		Production[a]	Area Harvested	Output Per Hectare	Area Harvested	Output Per Hectare
				(percent)		
Developing countries	1961-70	3.6	1.1	2.5	30	70
	1971-80	2.9	0.6	2.3	20	80
(Excluding China)	1961-70	(2.9)	(1.5)	(1.4)	(51)	(49)
	1971-80	(2.6)	(0.8)	(1.8)	(32)	(68)
Asia	1961-70	3.8	0.5	3.4	13	87
	1971-80	3.3	0.5	2.8	16	84
(Excluding China)	1961-70	(2.7)	(0.8)	(1.8)	(31)	(69)
	1971-80	(3.1)	(0.9)	(2.2)	(30)	(70)
China[b]	1961-70	5.2	-0.1	5.4	...[d]	100
	1971-80	3.4	-0.2	3.6	...[d]	100
South Asia	1961-70	2.7	0.8	1.9	29	71
	1971-80	2.7	0.7	2.0	25	75
East and Southeast Asia	1961-70	2.7	1.1	1.6	40	60
	1971-80	3.9	1.7	2.2	44	56
North Africa/Middle East	1961-70	2.4	1.2	1.2	51	49
	1971-80	2.6	0.7	1.9	26	74
Northern Africa	1961-70	3.3	1.4	1.9	43	57
	1971-80	0.9	1.5	-0.6	100	...[d]
Western Asia	1961-70	2.0	1.1	0.9	57	43
	1971-80	3.5	0.3	3.2	8	92
Sub-Saharan Africa	1961-70	2.2	2.4	-0.2	100	...[d]
	1971-80	1.6	0.8	0.8	50	50
West Africa	1961-70	1.1	2.2	-1.1	100	...[d]
	1971-80	1.9	1.1	0.7	61	39
Central Africa	1961-70	4.4	4.8	-0.4	100	...[d]
	1971-80	1.8	2.3	-0.5	100	...[d]
Eastern and Southern Africa	1961-70	3.0	2.2	0.8	72	28
	1971-80	1.4	-0.3	1.6	...[d]	100
Latin America	1961-70	4.2	2.8	1.4	66	34
	1971-80	1.8	0.6	1.2	33	47
Mexico and Central America[c]	1961-70	5.7	2.2	3.5	39	61
	1971-80	3.0	-0.2	3.2	...[d]	100
Upper South America	1961-70	4.6	3.7	0.8	82	18
	1971-80	1.8	1.8	0.0	100	0
Lower South America	1961-70	2.5	1.6	0.9	63	37
	1971-80	0.6	-1.3	2.0	...[d]	100

Sources: Food and Agriculture Organization of the United Nations, "Production Yearbook Data Tape, 1975, 1979, 1981, and 1983," Rome, 1976, 1980, 1982, and 1984; People's Republic of China, State Statistical Bureau, *Statistical Yearbook of China*, various issues (Hong Kong: Economic Information Agency, various years); Republic of China, Executive Yuan, Directorate General of Budget, Accounting, and Statistics, *Statistical Yearbook of the Republic of China, 1982* (Taiwan: Republic of China, 1983).

Notes: Unlike in Table 5, negative rates also occurred for area during subperiods.

[a] The production data exclude bananas and plantains, for which area estimates are not available.

[b] The data on area for China are for area planted.

[c] Mexico and Central America includes the Caribbean.

[d] Negative. The contribution to the production increase is assigned totally to the other source of increase.

Source: Paulino, Food in the Third World: Past Trends and Projections to 2000, p. 22.

Appendix Table 8.--Projected gross and net surpluses and deficits in livestock products, by region, 1990 and 2000

Livestock Product/Region	1990 Gross Surplus	1990 Gross Deficit	1990 Net Surplus or Deficit	2000 Gross Surplus	2000 Gross Deficit	2000 Net Surplus or Deficit
	(1,000 metric tons)					
Meat						
Asia	196.6	2,932.2	-2,735.6	642.1	7,342.4	-6,700.3
North Africa/Middle East	60.8	3,096.7	-3,035.9	276.8	7,082.8	-6,806.0
Sub-Saharan Africa	511.5	1,895.3	-1,383.8	903.1	5,633.9	-4,730.8
Latin America	990.6	1,871.8	-881.2	1,893.3	4,520.8	-2,627.5
All study countries	1,759.5	9,796.0	-8,036.5	3,715.3	24,579.9	-20,864.6
Milk						
Asia	285.1	13,688.9	-13,403.8	945.5	27,624.4	-26,678.9
North Africa/Middle East	356.1	10,424.0	-10,067.9	854.6	21,515.6	-20,661.0
Sub-Saharan Africa	15.6	6,149.9	-6,134.3	0.0	13,584.5	-13,584.5
Latin America	1,977.0	7,360.8	-5,383.8	7,568.8	11,033.5	-3,464.7
All study countries	2,633.8	37,623.6	-34,989.8	9,368.9	73,758.0	-64,389.1
Eggs						
Asia	156.8	273.1	-116.3	739.0	649.5	89.5
North Africa/Middle East	92.9	321.7	-228.8	367.8	766.5	-398.7
Sub-Saharan Africa	54.5	272.9	-218.4	128.1	839.4	-711.3
Latin America	412.2	148.9	263.3	1,334.8	285.5	1,049.3
All study countries	716.4	1,016.6	-300.2	2,569.7	2,540.9	28.8

Source: Sarma and Young, 1985, p.52.

Notes: These projections are based on trend income growth. A minus sign indicates a net deficit.

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Chapter 2

CONSTRAINTS TO ACCELERATING AGRICULTURAL DEVELOPMENT

In the broadest sense there are, for a given biological and physical environment, three forces or factors that interact and contribute to agricultural development: (1) technical improvements, (2) institutional and policy improvements; and (3) human improvements. The improvement and interaction of these factors can lead to growth in the stocks of physical and biological capital, increased agricultural production, increased consumption, and the possibility of enhancement and conservation of the natural and physical environment. The absence or inadequacy of any one or more of the three factors will be detrimental to agricultural development. Agricultural development requires all three of the factors. Furthermore, efficient agricultural development requires an optimum mix of the three elements. When any one of the three factors is missing, and it is introduced, there is a tendency to attribute all the increase in agricultural development to the introduction of the missing factor. For example, an education and training program may have a large impact if the appropriate technical agricultural knowledge is present, the institutional system is effective, and incentives exist for investment in physical and human capital. In another setting, a similar education and training program may have no impact because one or more of the other forces is missing. Consequently, all of the factors must be given attention.

Because the presence and quality of the three factors varies enormously among developing countries, the identification of specific constraints to agricultural development needs to be location and time specific. The identification of specific constraints is, in fact, one of the goals of agricultural research and often requires a multidisciplinary approach such as that utilized in farming systems analysis. Since it is not possible to analyze all of the developing countries, a general discussion of the issues and a broad picture of the constraints are presented.

The discussion in Chapter 1 of past and future trends in world agriculture provides a background for identifying the important constraints to future agricultural development. Not all of the constraints can be modified or eliminated by agricultural research. The potential contributions of agricultural research, broadly defined, need to be assessed in determining research priorities for accelerating agricultural development.

Biological and Physical Constraints

Technical improvements in agriculture are constrained by the biological and physical environment. Limitations imposed by a lack of suitable genetic resources, soil characteristics, water quality and availability, the climate, plant and animal pests and diseases, and other aspects of the environment can all influence the development of agriculture. There is a tendency to think that some aspects of the biological and physical environment, such as land resources, are given and fixed. These resources, however, are subject to modification through investment and management that can improve or reduce their potential for agricultural production.

Genetic Resources

Much of the improvement in agricultural production in both developing and industrialized countries has resulted from the identification, manipulation, and use of desirable plant and animal germplasm. For example, plant breeders tap a wide array of genetic resources to help increase and sustain yields and to tailor crops to marginal areas, such as those suffering from erratic rainfall or difficult soils. Livestock breeders are also increasingly interested in obtaining sources of genetic resistance to diseases, such as African trypanosomiasis, a debilitating sickness of cattle and small ruminants which threatens one-fifth of the cattle population south of the Sahara. If appropriate genetic resources are not available to breeders, productivity of crops and livestock may greatly suffer.

Modern farms are characterized by a relay race of new crop varieties. Farmers change varieties when higher yielding material becomes available or when their current varieties become susceptible to insects, diseases, or other stresses. Unless new varieties are waiting in the pipeline, farmers can experience wide swings in productivity. For example, production fluctuation in yields, although temporary, are common in parts of India where high yielding varieties are grown. Some of India's yield instability is attributed to the launching of a pearl millet hybrid in the early 1980s that proved susceptible to powdery mildew. However, releases in the mid-1980s of pearl millet hybrids that resist the fungal disease have helped restore the superior yield levels typical of hybrids. The lesson suggested by such experience is that the work of crop breeders never ceases and that a wide range of genetic resources are crucial to the success of their efforts. The absence of such resources may serve as a major constraint to improving agricultural production and accelerating agricultural development.

Considerable progress has been made in the last two decades in the gathering and conservation of crop genetic resources, but much remains to be done. The International Board for Plant Genetic Resources (IBPGR) is currently emphasizing more careful planning of future germplasm collecting missions so that a wider range of diversity is obtained. IBPGR is also emphasizing the need for more evaluation and documentation of collections so that they are more useful to breeders.

Soil Resources

One of the major factors impacting agricultural development is the nature of the soil resources available for crop production. This resource provides the nutrient elements essential for plant growth, and a deficiency of such nutrients may seriously limit production. Furthermore, an excess of nutrients and other chemicals can be toxic and also limit production. Soils which are either too acid or too alkaline may impose further limitations on crop production. Soil physical characteristics may also greatly influence crop productivity by limiting root growth and development, by restricting germination of seed, by having a low water-holding capacity, and thus being more susceptible to drought, and by having poor drainage characteristics which lead to inadequate aeration.

The manner in which soils are managed can have tremendous impact on productivity and ultimately upon agricultural development. For example, population pressures are forcing farmers to cultivate increasingly marginal

lands. In Malawi, for example, escarpment land that has a slope of more than 12 percent is being cultivated, causing serious erosion and the flooding of fertile croplands below. This erosion is threatening the future of one of the few countries in Africa that is successfully feeding itself (FAO, 1986).

Such soil erosion is truly a global blight, affecting developed as well as developing countries. In the U.S., for example, the loss of soil through erosion is estimated to exceed tolerable levels on some 44 percent of the cropland. This represents a loss of 1.7 billion tons annually, with over 90 percent coming from less than one-fourth of the total cropland. In India, a study has indicated that 60 percent of the cropland is eroding excessively, constituting a loss of 4.7 billion tons of topsoil annually (Brown and Wolf, 1984). Research in Nigeria on land with 15 percent slope has demonstrated that when planted to cassava, there was an annual loss of 221 tons of topsoil per hectare--a rate which would erode away the entire topsoil in ten years (Lal, 1982).

In many parts of the world, soil erosion has increased to the point where losses exceed the formation of new soil through weathering. When this occurs, the soil is, in effect, being mined, converting renewable resources to nonrenewable ones. When topsoil is lost through erosion, there is a loss of fertility and a deterioration of physical properties, resulting in a decline in productivity. But the effects of erosion extend far beyond the farm as soil is carried away in the streams and canals--with negative consequences on aquatic life as well as on irrigation and hydroelectric systems and even on navigable waterways (Brown and Wolf, 1984).

One of the greatest constraints to increasing productivity of agricultural systems is the lack of certain nutrients essential for plant growth and crop production. While most soils may be deficient in some nutrients, harvested crops can also, in effect, exhaust the soil of its supply of nutrients unless these are replaced. For example, FAO estimates that in Africa some ten times as many nutrients are being removed in crops as are being put back in the soil through the use of organic and mineral fertilizers. Such serious depletion of soil nutrients will make the achievement of agricultural development goals impossible unless the nutrients are replenished through external inputs.

Most soils in developing countries are low in phosphorus and nitrogen. Under intensive cropping systems, even where phosphorus and nitrogen needs are met, the soil may not be able to supply enough potassium or certain other nutrients (secondary and trace elements) to sustain high yields. Furthermore, some soils, under even low cropping intensity, may be deficient in certain nutrients--while others may have toxic levels of chemicals. Low or high acidity conditions may influence the solubility of certain chemical elements in soil and, thereby, contribute to either deficiencies or toxicities of certain chemical elements.

For some traditional production systems in the tropics, land was, at one time, allowed to remain fallow for up to 25 years in forest areas to allow the soil to accumulate organic matter and nutrients before being cleared for cropping. After clearing, crops were grown for two to four years before allowing the land to go back to forest cover for another period of nutrient regeneration. Growing population pressures throughout the tropics are forcing farmers to shorten many of these rotation/fallow cycles. The consequences of such a reduction in the fallow cycles is indicated as follows: "There is

abundant evidence. . .that with growing population pressure, the fallow period is becoming increasingly shorter so that soil fertility is not restored before recropping. This leads to a fall in the organic content and the waterholding capacity of the soil. Soil structure deteriorates and compaction becomes more common. . .in other words, with the population of modern times, formerly stable, shifting cultivation systems are now in a state of breakdown" (Watters, 1971).

Population pressures are also contributing to other difficulties in maintaining soil productivity. As fuelwood supplies are diminished, expanding populations in many areas have been increasingly dependent upon crop residues and animal manures for fuel, thereby eliminating these materials as soil regenerating amendments. These organic materials are important not only as sources of plant nutrients, but also as sources of organic matter which improves soil physical characteristics and add to water retention capabilities.

Water Resources

Water resources present a global paradox. It is estimated that the volume of fresh water, annually renewed through its cyclic flow between sea, air and land is sufficient to meet the material needs of five to ten times the existing world population. Despite such apparent abundance, periodic shortages of water threaten millions with famine, and water tables in parts of India, China, Mexico, and the U.S. are falling precipitously (Postel, 1984).

Agriculture is the principal user of global water supplies. From historic times, irrigation techniques have been used to help farmers secure adequate and timely water supplies to sustain agricultural production. Approximately one-third of today's agricultural production comes from the 17 percent of the world's cropland that is irrigated. As productive lands become more scarce, irrigation enabled farmers to increase production on existing land, "essentially substituting water for new cropland" (Postel, 1984). The decline in the growth of irrigated areas throughout the world is a major reason for concern about the growth of future agricultural output.

Nonsustainable use of water is occurring in a number of agricultural areas throughout the world. This involves both the use of fossil water as well as the overdrafting of rechargeable aquifers. In both instances, the results involve declining water tables and unsustainable production systems. The determination of socially desirable levels of water use in those cases is complicated by the common property nature of most groundwater aquifers. There is also much evidence that irrigation water is used very inefficiently, with much more water usually transported and applied to fields than crops require (Postel, 1985). A part of this inefficiency grows out of the poor design of the systems and not, necessarily, from poor management.

Poor irrigation practices result in severe problems of land degradation through waterlogging and salinization. In fact, it is estimated that waterlogging and salinization are rendering unproductive some 1.0-1.5 million hectares of good crop land annually. The problem is particularly acute in India and Pakistan where it is estimated that 12 million hectares have been seriously degraded through such processes. In many areas of the world, "waterlogging and/or salinization threaten to diminish the very gains in food production that costly new irrigation projects are intended to yield" (Postel, 1984).

In the vast area of tropics, agricultural productivity is greatly affected by the amount, distribution and reliability of rainfall. Although it is unlikely that science will find ways of controlling the supply of rainfall, at least in the foreseeable future, science has much to contribute to its efficient use. The efficient use of water is crucial to raising and sustaining yields in areas where irrigation is impossible. Management to control run-off is essential for making effective use of available rainfall as well as for controlling erosion (TAC, 1988).

Atmosphere

Human activities are responsible for releasing into the earth's atmosphere chemicals which may have serious deleterious effects upon all forms of life and diminish man's ability to maintain or increase agricultural production systems. For example, coal burning for heating and power generation as well as the combustion of fossil fuels in the smelting of metallic ores results in the release of large quantities of sulfur and nitrogen oxides into the atmosphere where they may be carried for great distances to come down, ultimately, as acid-contaminated rainfall. This acid rain may be harmful to both terrestrial and aquatic organisms. Acid rain also contributes to the acidification of soils, especially in humid regions where soils may already be too acid for optimal crop performance. This acidification may increase the solubility of some elements in the soil to the extent that they become toxic to plants. Although acid rain has been primarily a problem in industrialized countries, its impacts are spreading to other parts of the world.

Lead released into the atmosphere by gasoline combustion is also potentially toxic to living organisms, particularly in areas of high concentration such as those near to highways. Some industrial processes and consumer goods release gases into the atmosphere that may damage the ozone layer around the sun, enabling more of the harmful ultraviolet radiation of the sun to reach the surface of the earth.

The combustion of fossil fuels and wood releases carbon dioxide at such a rate that its concentration in the atmosphere may double in the next 60 to 80 years. Together with some other gases, the carbon dioxide contributes to the so-called "greenhouse effect" by reducing the losses of long wave radiation from earth. Various mathematical models suggest that this "greenhouse effect" may contribute to a warming trend of 2.5 degrees C. during the next century, accompanied by change in rainfall distribution. Coastal lowlands may suffer increased risk of flooding due to a greater melt of polar ices.

The impact of the warming trend upon precipitation is more speculative, although there appears to be considerable agreement that the U.S. cornbelt could become drier as well as warmer, pushing the effective climate zone for corn production to the north (Oram, 1987). Although the consequences of the "greenhouse effect" are still speculative, many believe that changes associated with this phenomenon could have significant impact upon agricultural productivity in many parts of the developing world.

Insects, Diseases, Weeds and Other Pests of Crops

If the agricultural needs of rapidly increasing populations are to be met, both yields and cropping intensity must be substantially increased. Such intensified production favors a buildup of insects, diseases, and other pests

which, unless contained or controlled, can seriously limit production. In fact, it is estimated that insects, diseases, weeds, rodents and other pests contribute to field losses of some 35 percent in the production of major food crops--with the greatest losses occurring in developing countries (Wittwer, 1986). Moreover, pests also contribute to very large post-harvest losses of crops.

Several hundred species of insects (out of nearly 10,000 known to damage agricultural crops) are estimated to inflict severe losses in agricultural production. These pests feed on different parts of the plant, transmit diseases and damage food products in storage (Pathak and Dhaliwal, 1986). With severe infestations of certain insects, losses can be severe--even to the extent of destroying the entire crop.

The situation with plant diseases is somewhat similar to that with insects where tropical and subtropical environments are more favorable to the survival and buildup of many disease organisms. Furthermore, such buildup is also enhanced under more intensive production systems. There are widespread examples of circumstances where crops have been completely destroyed by heavy infestations of various pathogens. In fact, disease epidemics have caused widespread famine (e.g., the potato famine in Ireland in the mid-1840s). While there are many examples of such extreme effects of plant diseases, it is estimated that, overall, plant diseases contribute to a 10 percent reduction in crop yields (Nagarajan, 1986).

Although high priority is often given to diseases and arthropod pests, perhaps the most persistent cause of depressed yields in tropical environments is competition from weeds. This would suggest that developing means of controlling weeds could make some of the most effective contributions to improved crop productivity in tropical regions. The economics of weed control, however, is important since the availability of cheap labor may favor manual and simple mechanical measures of weed control over the use of herbicides, etc. Knowledge of seasonal labor demands is an important aspect of studying the economic alternatives for controlling weeds.

Other pests including nematodes, birds and rodents may also seriously reduce crop production and limit the achievement of agricultural development objectives. Such problems are often much more severe in developing countries where control measures are less satisfactory.

Animal Diseases and Parasites

The control of animal diseases and parasites is also important in improving livestock production. It is estimated that, globally, diseases and parasites are responsible for the death of 50 million cattle and water buffalo and 100 million sheep and goats each year (Wittwer, 1986). These figures do not indicate the full extent of the problem, however, since diseases and parasites may seriously reduce the productivity of animals without causing death. More effective control of animal diseases and parasites would, therefore, contribute greatly to meeting animal production needs in the developing world.

Problems of health in animals are closely linked to their nutrition and to the interactions of crops and livestock. There is a continuing need to study balanced systems of production that exploit the benefits of both crops and

livestock as well as to develop techniques for supplying supplemental feed at costs the farmers can afford. Improved management of pasture and avoiding overgrazing are key factors in achieving animal production goals, especially in the dry regions (TAC, 1988).

Institutional and Policy Constraints

Poorly functioning institutions and inappropriate policies also can limit technical improvements in agriculture and the attainment by developing countries of broad agricultural development goals. Improvements in institutions and policies require a much different approach than conducting research on limitations associated with the biological and physical environment. Although both sets of constraints involve effective interaction with people, institutional and policy issues are almost exclusively people centered. The ability of an outside agency, such as USAID, to successfully influence developing country institutions and policies is limited. Feelings of national sovereignty, national pride, suspicion, and self-interest affect the ability to influence institutional and policy reforms. The goal in this area should be to help developing countries conduct their own research on policy alternatives so that officials will have a better basis for intelligent decision making.

Some of the policies and institutions that constrain agriculture in the developing countries are not even under their control. Industrialized country policies that limit access to markets or otherwise influence international markets and prices, such as the U.S. sugar policies discussed in Chapter 1, are examples. Issues such as these may have to go before an international forum, like GATT, for resolution. In spite of their complexity and intractability, institutional and policy constraints are extremely important and deserve full recognition and attention within the context of promoting agricultural development.

Political Instability

Political instability in some developing countries has been a major deterrent to sustained agricultural development. It has been noted that of 16 African countries which failed to achieve an annual agricultural growth rate of one percent or more during the 1965-80 period, 13 of them had one or more major political crises during that period (civil war, invasion, or major coup). In most cases, the instability that is created by political crises compounded difficulties arising from the transition from colonial status to independence (Oram, 1987).

Idachaba suggests that "high political instability has made sustained agricultural growth and development performance almost impossible in most African countries." He illustrates this point by the frequent changes in political leadership in Nigeria which had six heads of state along with nine political heads and seven administrative heads of the federal Ministry of Agriculture between 1969 and 1986 (Idachaba, 1987). Political instability has had a major impact on agricultural development in a number of Latin American and Asian countries as well as in Africa.

Not only do such changes cause discontinuities and inconsistencies in policies and their implementation, but there is a tendency for each new

administration to disassociate itself from previous administrations and go through a time-consuming learning process before it can formulate and implement new policies. On the other hand, "political regimes may be stable, but inflexible or repressive, placing a premium on conformity and servility, rather than innovation and initiative" (Oram, 1987). In either case, agricultural development may be impeded.

Low Priority Afforded Agriculture

In many developing countries, sustained agricultural development is hampered by the low priority afforded agriculture by national and local governments. Such low priority is reflected in many ways, including a low level of investment in the development of the agricultural sector as well as trade, taxation, and pricing policies which often tend to favor the urban consumer at the expense of the farmer. The result is that in many countries, agriculture is not provided the financial and institutional support that its central role in the economy warrants.

This is especially true in Africa where many governments allocate a relatively small proportion of their available resources to agriculture. For example, in Botswana, 80 percent of the labor force depend primarily on agriculture but the government allocates only one to three percent of its gross, fixed investment in this sector. Kenya has 75 percent of its labor force in agriculture; yet the government invests about eight percent in the agricultural sector (Mellor, 1986).

The development strategies adopted by many developing countries in the past have resulted in a greater flow of public resources to other sectors than to agriculture. For example, 10 out of 21 African states, covered in a recent FAO review, budgeted less than 10 percent of their agricultural GDP in 1978-82 for public expenditures on agriculture. The FAO further suggests that an urban-biased development strategy is responsible for many developing countries failing to supply agriculture with the financial and administrative resources as well as the political support that the central role in the economy would justify. Such a bias seems to represent a formidable obstacle to agricultural development in many countries (FAO, 1986).

The urban bias has not only been a deterrent to agricultural development, it has also reduced demand for domestic products in relation to imported commodities. For example, in many countries, there has been a marked shift in consumer tastes in favor of processed and "new" foods such as bread, and in some cases, rice and milk--which have often been satisfied largely by imports. These shifts result partly from growing urban affluence, the greater convenience of the new food, and, in some cases, their lower costs (FAO, 1986). Food aid, especially emergency aid, also has had an important influence on shaping new dietary habits.

Economic Policies Unfavorable to Agriculture

The low priority which many developing countries give agriculture has often reflected in policies which could represent deterrents to the achievement of development objectives. For example, "it is widely agreed that overvalued exchange rates, artificially low internal prices (for agricultural commodities) that favor urban consumers, and deterioration in the external as well as the internal terms of trade for agricultural products, create serious disincentives

to agricultural producers" and serve as deterrents to the achievement of development objectives (Oram, 1987).

Many countries have pursued a strategy in which the domestic terms of trade are sharply skewed against the rural sector. Overvalued currencies have made imports of food artificially cheap in relation to domestic production. For example, overvalued exchange rates in Nigeria at one time caused local maize delivered to Lagos to be three times as expensive as imported maize (FAO, 1986).

The bias of agricultural development strategies can be illustrated by contrasting agriculture's role as a source of government revenues and as a recipient of public expenditures. Taxes on exports of agricultural commodities have been the most important component of agricultural taxation in many developing countries; in some they have been a major source of total government revenues. Taxation becomes a major problem if it penalizes agriculture by reducing the resources available for investment in the sector or acts as a major disincentive to farmers in their efforts to enhance productivity.

These are only a few examples of how government economic policies influence agricultural development. Most developing countries maintain a large number of commodity policies, sector policies, macroeconomics and trade policies that affect farmer incentives. The nature of these incentives is a primary factor in farmers decisions to change their production practices. Some of the economic policies unfavorable to agriculture in a particular developing country may originate from the industrialized countries or from other developing countries.

Inadequate Infrastructure and Markets

In many developing countries, weak infrastructure, including roads and rail systems, is a major constraint to agricultural development, particularly from the standpoint of the delivery of inputs and the transportation of farm commodities to market. Problems of inadequate infrastructure are particularly severe in Africa (Oram, et al., 1979).

Improved access to channels of marketing and processing can act as a major incentive to increased production and overall development. Marketing networks are inadequate in many developing countries and must be reinforced in quality as well as in quantity (FAO, 1981).

An IFPRI study has shown that in areas of Bangladesh with good infrastructure, there were significant increases in the level of adoption of new technology, in the proportion of land devoted to high valued crops, in employment, and in prices of marketed produce, as well as in wage rates--compared to areas with poorly developed infrastructure. The study further shows strikingly lower marketing costs and thus greater competitive power on the international markets in Asian countries when compared to Africa (Ahmed, 1987).

Inadequate Inputs and Financial Institutions

The elimination of some of the major constraints to agricultural development will require the use of purchased inputs such as seed, fertilizers, pesticides, implements and equipment. The lack of availability of such inputs

at reasonable prices as well as the lack of credit to purchase them can be serious deterrents to the achievement of development goals.

In some instances, declining export revenues and the high priority governments attach to other imports, including food, result in inadequate importation of needed inputs. Furthermore, in many developing countries, because of poor systems of marketing and distribution, farmers have difficulty in obtaining inputs on a timely basis. Some inputs, such as pesticides and pharmaceuticals, reach the farmers after their expiration dates.

Inputs are often overpriced in relation to the prices received for farm products. Governments have resorted to subsidies to compensate for high production or marketing costs and to encourage use of inputs. However, experience in a number of countries indicates that such subsidies may not be necessary if producer prices are set sufficiently high to provide some incentive for the farmer to use the inputs.

In many developing countries, institutions to provide financial services to farmers are weak and ineffective or inaccessible. They commonly provide credit for export crops rather than staple food crops. Small resource-poor farmers--and especially women--often have great difficulty in securing credit because of lack of collateral or for other reasons. Furthermore, institutions to mobilize savings are often nonexistent or else they offer low rates of interest that are not attractive to potential savers (Adams and Graham, 1984).

Inadequate or Inappropriate Laws and Regulations

In general, developing countries have not promulgated adequate laws and regulations to control the use of land or to protect forests and range lands from indiscriminate exploitation. Neither is there adequate control of the use of water resources and catchments, rivers, lakes, and aquifers, nor legislation to facilitate schemes for land improvement or irrigation. Some countries have introduced legislation that is adequate in principle but they have been unable to enforce it in a satisfactory manner. Without appropriate public control or regulations enforced by mutual consent, chances of maintaining or achieving environmental stability and rising agricultural development goals are considerably diminished (TAC, 1988).

Problems Related to Land Tenure

Laws, regulations, practices and customs related to land tenure may significantly impact agricultural development. A few specific issues bear further elaboration (FAO, 1987).

There is a common belief that a system of communal land ownership tends to discourage the development of long-term, high investment crop operations. This may well be true in many instances. However, in Africa, there have been a number of situations where significant production of perennial crops such as oil palm was developed on lands under customary or communal tenure, where indigenous farmers were able to compete successfully with plantations.

There are cases, however, where communal tenural rights may, in fact, impede long-term agricultural development. For example, in many African and Middle Eastern countries, communal rights permit the communal winter grazing of cattle, sheep and goats on individually cultivated lands. Such overriding

communal rights seem to inhibit longer term advances in land improvement, fencing, and the planting of permanent crops on family-operated lands. Sharecropping and lack of protection of tenure and tenant rights, are other serious disincentives to investment in the improvement in land and buildings by tenant farmers.

Land tenure may have other significant effects upon the degradation of natural resources and the sustainability of production systems. In some Latin American countries, for example, where much of the better land is held by large owners, many of the peasants have to cultivate less productive, more fragile lands on hillsides and mountains with adverse environmental consequences.

Land tenure systems similar to those in many Latin American countries also strongly influence the distribution of income within agriculture. The large number of poor farmers and sharecroppers in those countries remain basically outside the focus and impact of agricultural development programs. In many instances they are essentially under the control or at the mercy of the large, wealthy land owners who control their access to land, credit and markets. The ability of poor, small farmers to adopt new technologies in these circumstances appears to be more restricted than in situations where farm size is uniformly small and farmers are generally poor (e.g., parts of Asia).

Special recognition should be given to the rights of women under various land tenure systems. In many areas, particularly in Africa, women are the primary producers of agricultural products. Yet they often do not own the land they farm. This may serve as a disincentive to long-term improvements in the land and unfavorably impact agricultural development. Furthermore, when women have no legal rights to land, it cannot be used as collateral and, as a result, women are disadvantaged in their ability to secure credit and inputs. This, too, can significantly affect agricultural production and long-term development.

Weak Research, Extension and Educational Institutions

In a recent World Bank symposium, Hayward described the vital role improved technology must play in achieving agricultural development goals: "Improved technology development, diffusion, and adoption is at the heart of sustained agricultural advancement. Traditional agricultural systems, developed by trial and error over generations, could be sustained indefinitely as long as the demands on the resource base did not exceed the rejuvenation capacity of that base. Increased population demands have disrupted the balance, and technology must be continuously pumped into agricultural systems to sustain them above their natural steady state level" (Hayward, 1987).

Strong, effective research, extension and education programs are essential to continued development, dissemination and adoption of improved technology.

Considerable progress has been made in developing effective national research systems in some Asian and Latin American countries. However, "despite substantial investment, performance of national agricultural research centers in Africa has generally been weak" (FAO, 1986).

Several reasons as suggested for such poor performance:

- Political support for national agricultural research systems has fluctuated widely during the past 25 years;

- The demand for improved research performance has not been consistently effective. Furthermore, the demands for improved food research is widely disbursed among millions of unorganized and politically impotent, small scale farmers;

- Research gains have not been sustainable, not only because of inadequate funding but because the funding has been highly unstable, resulting in incompleted and abandoned research projects;

- Many in national research systems have lacked the "critical mass" of experienced researchers to initiate and successfully execute research projects;

- Many national research systems experience very high turnover or instability in research staff;

- Discontinuities in research management;

- The research resource allocation system has not been rationalized in many countries for the national system to have sustained productivity; and

- Discontinuities in technology generation have been compounded by discontinuities in dissemination of technology through extension systems (Idachaba, 1987).

The foregoing reasons for poor performance of national agricultural research systems apply not only to Africa but to many other parts of the world as well. It should be noted, however, that in all major regions there are national systems that have made significant improvements in performance.

Weak, ineffective extension programs in many countries serve as a serious deterrent to agricultural development. Many extension systems tend to be oriented more towards export rather than food crops, and they often fail to reach most small farmers. They generally neglect women who process and market a large proportion of stable foods, especially in Africa. In most countries there are weak linkages between research and extension which pose serious discontinuities in the flow of information from the researcher to the farmer and vice versa. Such problems often grow out of the manner in which research and extension organizations are structured within government (FAO, 1986).

The development of effective research and extension programs as well as other institutions essential to agricultural development efforts requires well-trained, technical and professional personnel. Yet many developing countries have weak education and training institutions, unable to meet adequately the needs for such personnel. It is estimated, for example, that nearly a quarter of African countries will have a major shortage of professional manpower for the next 15 years or more and that more than one-third will have a major shortage of technical (intermediate) level manpower (FAO, 1986).

A major problem in many, if not most, developing countries is that salaries in educational institutions often take up a high proportion of

recurrent expenditures, leaving the staff with limited funds for operation. Many governments have also found it difficult to provide adequate funding for education and training institutions once donor support ends (FAO, 1986).

Human Constraints

The quality of the human resources involved in all phases of agriculture is an important element in agricultural development. Limitations due to lack of knowledge, inadequate training, poor health, inaccurate information, disincentives for work, and other factors can constrain agricultural development efforts. Farmers, marketing agents, extension workers, project managers, policy advisors, policy makers, research workers, and others involved in agricultural development may be limited in their ability because of a lack of investment in their education, skills, health, etc. Schultz's (1961) pioneering work and those that have followed him have demonstrated the high value of education and other improvements in quality of humans. Schultz (1980) also argues that the desire for improvements in human quality is as strongly held by poor farmers as by other segments of the population.

Although the focus of S&T/Agr is on research and not on education and training, the two are highly complementary. National agricultural research centers, policy advisory groups and other organizations involved with developing country agricultural programs and policies cannot function without trained personnel. Some of this training can result from the research programs supported by S&T/Agr, especially if a high priority is placed on collaborative research efforts. Other important AID efforts to improve human resources lie outside of S&T/Agr in other offices in the S&T Bureau and in the regional bureaus.

Priorities

It is not possible for S&T/Agr to support research directed at all of the constraints discussed in this chapter. Important and difficult choices will have to be made in establishing a research strategy and setting research priorities (see Chapter 6). A review of the constraints, however, does indicate that some of them lie outside of the focus of the S&T Office of Agriculture. Among the biological and physical constraints, problems associated with the atmosphere are probably better left for other research and governmental bodies, such as NSF and the U.N.

Of the large number of institutional and policy constraints, the operating rule for selection should be to concentrate on those that have a well-defined impact on the agricultural sector and where it is reasonable to expect that the host governments are sincerely interested in reform. Since knowledge about host government receptivity is contained primarily in the USAID missions and the regional bureaus, it is essential that they be involved in designing projects that address institutional and policy issues. S&T/Agr can, as it has through the Agricultural Policy Analysis Projects (APAP I and APAP II), support broad research on important policy issues and provide technical assistance and collaborative research to the USAID missions to analyze particular institutional and policy issues. Some of the institutional issues, such as political instability, need to be addressed at levels other than S&T/Agr. For other issues, such as the low priority to agriculture and inappropriate laws,

the provision of information based on broad analysis may be instrumental in formenting change.

Improvements in research, extension, and educational institutions are primarily the responsibility of the USAID missions working with the host governments and other donors. The research and technical assistance activities of S&T/Agr can complement these efforts at human and institutional development by emphasizing a collaborative approach whenever possible.

Summary

The ability to accelerate agricultural development in the Third World is constrained by factors that are associated with the biological and physical environment, the institutional and policy setting, and the quality of the human resources. The determination of the actual constraints in a particular situation, a task which in itself requires research, is the first step in establishing research priorities and designing research programs to reduce or eliminate the constraints. The process is continuous since new constraints are likely to appear once a solution to the initial set has been discovered and applied. Furthermore, not all of the constraints can be modified or eliminated by research.

Because of the diversity among developing countries, only a general picture of the constraints is presented. Major biological and physical constraints to technical improvements in agriculture are associated with the availability of genetic resources, the nature of the soil resources, the quality and availability of water, the earth's atmosphere, plant and animal pests and diseases, and other aspects of the environment.

Important among the institutional and policy constraints on agricultural development are political instability, the low priority afforded agriculture by national and local governments, economic policies of developed and developing countries that are unfavorable to agriculture, inadequate infrastructure and markets, inadequate inputs and financial institutions, inappropriate laws and regulations (including land tenure laws and customs), and weak research, extension and educational institutions.

The multitude of factors that limit human performance (inadequate training, poor health, disincentives for work, etc) are identified and their importance relative to the amelioration of the other constraints is emphasized.

Finally, some guidelines for selecting those constraints that can be effectively addressed by the S&T Office of Agriculture are presented. The criteria for selection are based on the comparative advantage of the Office, a well-defined impact on the agricultural sector, a reasonable expectation of research success, and a possibility for cooperation with other AID units and donors.

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Chapter 3

THE ROLE OF RESEARCH IN ACHIEVING AGRICULTURAL DEVELOPMENT GOALS

Introduction

Research is one of the key elements in finding solutions to many of the constraints to agricultural development identified in the previous chapter. Problems originating in the physical and biological world, constraints imposed by institutions and policies, and limitations associated with the human resources are all subject to research designed to find alternative means for dealing with the constraints and to contribute to the attainment of agricultural development goals. Research alone, however, cannot provide all the solutions. Inventions, innovation, and direct private and public investment in agriculture (broadly defined) and human resources are some of the other elements required for agricultural development. Research nevertheless is fundamental to identifying constraints and finding solutions to technical problems confronting agriculture and for understanding institutional and policy constraints limiting agricultural development.

Research in agriculture has to be dynamic and oriented to the future. The fact that problems change fairly rapidly underscores the need for a flexible approach to agricultural research. The trends reviewed in Chapter 1 indicate the broad direction of change in world agriculture and are suggestive of general lines of research needed in the future. At the specific level of plants and animals, for example, new diseases are evolving that require continual and flexible research efforts. Because the lags between research and the full realization of its results are long, identification and quick response to new and expected problems is essential for most agricultural research.

The need for substantial public sector investment is also a characteristic of agricultural research, especially in the early stages of agricultural development. Much of the needed agricultural research will not be provided by the private sector because of the high risks, long time lags, and the inability to capture major portions of the benefits of the innovations flowing from the research. Consumers, for example, receive many of the benefits of agricultural research through lower food prices, yet farmers, who are the main users of the research, cannot be expected to pay the full costs of research if they receive only part of the benefits. The private sector, in this case, will tend to underinvest in agricultural research. Where the private sector conducts agricultural research, it usually operates within a system of patents (or another system to protect discovery), supports projects with commercial potential, and uses well-developed markets for its products. These conditions do not exist in many developing countries, and poor farmers are simply unable to pay the full costs of research directly or through the purchase of inputs, when they receive only part of the benefits. Research on institutions and policy is conducted almost exclusively by foundations and public sector organizations.

One of the problems of developing an agricultural research agenda for a given region or country is the determination of the most important constraints and the establishment of research priorities. Hayami and Ruttan (1985) provide a general framework for identifying constraints based on the relative abundance

or scarcity of the basic factors of production, labor and land. Their framework is especially appropriate for identifying constraints that limit technical improvements in agriculture. They observe that in cases where labor is abundant and land is scarce, research and technical improvements in agriculture will follow a chemical-biological path. The effect therefore is to increase the productivity of the scarce resource land and at the same time increase the use of the abundant labor resource. The high-yielding varieties of rice resulting from chemical and biological research are seen as especially appropriate for the land scarce, labor abundant areas of Asia. In cases where labor is scarce and land is abundant, mechanical technologies tend to be developed and are more appropriate because they also, in these cases, increase the productivity of the scarce factor (labor) and use the abundant factor (land). The development of U.S. agriculture up to about World War II followed the path of mechanical innovations. Since World War II, there has been much more emphasis on chemical-biological innovations.

The Hayami and Ruttan framework is but a first step in identifying the important constraints that require research attention. Considerable field research is required to identify the specific constraints and the alternative solutions that need to be investigated through further research. For example, a seasonal labor constraint might be alleviated through the introduction of animal drawn equipment or with tractors and selected machinery. Research is required to determine which of these two alternatives is technically, economically and socially most appropriate for attaining the goals of agricultural development. In situations where land appears to be abundant, for example in parts of Africa, water development and management may be more important than seasonal labor constraints (Nagy, Sanders and Ohm, 1987). Local research is required to understand the constraints limiting the existing farming systems. Farming systems research and extension (FSR/E) type programs have much to offer in understanding constraints and developing new technologies. Multidisciplinary teams are an essential part of the FSR/E approach. Lessons from previous FSR/E experiences need to be considered in implementing future adaptive research efforts (Byrnes, 1988).

It is important to remember that in most of the developing world agriculture is still based on enormous amounts of hand labor assisted by animal traction. The real value of human labor employed in these systems is extremely low, and this is a key factor in explaining why known mechanical technologies have not spread rapidly to agriculture in the developing countries. One of the goals of agricultural development, and therefore the research that is conducted to support this development, must be to increase the returns to agricultural labor and, in most cases, provide more employment in the agricultural sector to accommodate the expected population increases.

Types of Research in Support of Agricultural Development

To insure that research makes a significant contribution to agricultural development requires an appropriate mix of different types of research. Understanding the different types of research needed for agricultural development will help S&T/Agr determine the nature and content of its research portfolio. There are several ways of classifying different types of research. Glenn Johnson (1986) distinguishes between problem-solving, subject-matter, and disciplinary research. These three types of research are parts of a continuum of research activities performed by biological, physical and social scientists.

The CGIAR system uses a different classification of research that is comprised of four types: adaptive, applied, strategic and basic (CGIAR, 1981). The CGIAR system, which also represents a continuum, will be used in the this report. The basic message of the two classification systems, however, is the same. The CGIAR system focuses more on the development and introduction of new technology, whereas Johnson's approach applies to research concerned with all issues of rural development.

Adaptive research is designed to adjust technology to the specific needs of a particular set of environmental and social conditions, for example, incorporating dwarf wheats into farming systems of the rainfed areas of the Pampean Region of Argentina. Effective adaptive research requires knowledge of the local technical, institutional, social, and economic environment. Consequently, adaptive research is multidisciplinary, drawing on the social, biological and physical sciences. Adaptive research is best conducted by local scientists who have adequate training and support to conduct research and disseminate the results to the affected parties and decision makers. The development of local capacity is critical for the conduct of effective adaptive research.

Applied research is designed to create new technology, for example, breeding new varieties of dwarf wheat that can respond to high levels of nitrogen without lodging. Applied research is also multidisciplinary, but involves more generic problems that are not time and location specific. Much of the research conducted by the international agricultural research centers (IARCs) is applied research. The efforts to increase crop yields or to control animal diseases are undertaken with the desire to develop knowledge that is applicable in a wide variety of situations. Thus, ICRISAT's work on sorghum and millet has application outside of India, but its application requires local adaptive research. IFPRI's work on agricultural development policies, although it is often country specific, treats general problems and provides useful knowledge for local researchers and decision makers. For example, a study of the effects of the Egyptian food ration and subsidy system on income distribution and consumption (von Braun and de Haen, 1983) is quite useful for focusing debate on particular policy issues in Egypt, but it is not adequate for specific decision making on food ration and subsidy programs for Egypt in 1989. Furthermore, the analysis and knowledge contained in the Egypt study may be useful for focusing policy dialogue in other countries. This is typical of good applied research.

Strategic research is designed for the solution of specific research problems, i.e., problems that are associated with the research process itself. CGIAR uses the example of developing a technique for detecting dwarfing genes in wheat seedlings. IARCs, universities and other research institutions in the industrialized countries possess most of the capability to conduct strategic research.

Basic research is designed to generate new knowledge and is similar to what Johnson calls disciplinary research. Specialized institutions, which include universities and research facilities in both developed and developing countries, have the unique capacity to conduct basic research. Basic research is conducted by disciplinary specialists working individually or in teams. The development of new theories, research methods, mathematical and physical models, research instruments, and other disciplinary knowledge is the objective of basic research. The application of basic research is often not known.

Basic research that contributes to agricultural development is conducted by agricultural scientists (soil, plant, animal, economics, etc.) and also comes from other disciplines such as physics, mathematics, statistics, and biology. The value of basic research is normally determined by peer review within the discipline.

Successful agricultural development requires all four types of research: adaptive, applied, strategic, and basic. Good basic research and training is needed for effective adaptive, applied, and strategic research. And good applied research is needed in support of adaptive research efforts. Thus, good adaptive research requires strong contributions from the other three types of research. Difficult choices exist relative to the research issues to be addressed within the four categories of research. For example, should applied research be directed towards crop improvement, animal agriculture or agricultural development policies? Or, what is the appropriate mix of research effort on crop improvement, animal agriculture, and agricultural development policies?

S&T's agricultural research strategy has tended to heavily support applied and strategic research through its support of the IARCs, CRSPs, and other directly funded research projects. Continuation of this strategy may be appropriate, but S&T/Agr needs to be aware of the interrelatedness of the four types of research and realize that applied and strategic research will not have its full impact unless adaptive research capacity is developed in the Third World. Under the current AID strategy, the development of adaptive research capacity is primarily the responsibility of the regional bureaus and the missions. Increasing the articulation between these groups and S&T/Agr would tend to increase the benefits of applied, strategic and adaptive research. Also it is important for AID to realize that a continual stream of basic research is required to support the other three types of research. S&T/Agr may choose not to support basic research because of the desire to focus on more practical problems of known relevance. In dealing with universities, however, S&T/Agr administrators should realize that universities are composed primarily of disciplinary departments and that increasingly these departments are under pressure to produce publishable, disciplinary research.

The concept of a <u>research portfolio</u> provides another useful framework for discussing agricultural research strategies, determining research priorities, and establishing funding goals. In terms of the above discussion, the research portfolio might contain a mix of the four types of research or it might contain only one or two of the four types. In any case, a decision should be made as to type of research to be included in the portfolio. Within each type of research included in the portfolio, various research areas (topics) can be evaluated in terms of their risks and time lags, similar to what is done in an individual's investment portfolio. A simple risk/pay-off matrix can be used to illustrate the choices:

Level of risk (R)

Low (L) ⟶ High (H)

Pay-off (P)			
	Low (L) ↓	$L_R\ L_P$	$H_R\ L_P$
	High (H)	$L_R\ H_P$	$H_R\ H_P$

Funders of research will normally prefer low-risk, high pay-off projects with short time lags between initiation and the delivery of results. Projects with high risks and low pay-offs will be carefully avoided. However, projects with high risks may also have potentially high pay-offs. It may be desirable therefore to have both high-risk and low-risk projects in S&T's research portfolio. Research on existing high-yielding varieties, often called maintenance research, is an example of a low-risk research activity. Basic research in the area of biotechnology is likely to involve much longer term lags and greater risks, but may result in high pay-offs. Although the use of the research portfolio framework will not solve all of S&T/Agr's problems in determining future support for agricultural research, it could be a useful element in developing a research strategy and in seeking funding from Congress.

Returns to Agricultural Research

Discussion of a research portfolio and investment in different types of research leads to a consideration of the benefits of expenditures on agricultural research. Economists have conducted a large number of studies designed to estimate the economic benefits from agricultural research. Table 3.1, prepared by Robert Evenson (1984), provides a summary of these studies, including a number of specialized commodity programs. These studies used two basic methods for evaluation: imputation (index number) and econometric. Approximately one-half of the studies were based on developing country experiences. All reported an estimated "internal rate of return" on investment. The flow of increased commodity production, holding all inputs constant, is treated as the benefits stream. The internal rate of return is the rate realized over the entire period during which costs are incurred and benefits realized. The average estimated time lag between research spending and the full realization of its effect is roughly ten years.

The imputation (index number) studies each attempted to measure the costs and benefits to a particular program of research conducted over the time periods indicated. Different methods and data were utilized to measure the benefits. Sometimes statistical procedures were used; in other cases data comparing production using old and new technology were used. The imputation studies reported what might be termed average rates of return--that is, rates of return that hold for the entire research investment.

The econometric studies, on the other hand, estimated a rate of return to an additional or marginal dollar of research spending. They generally employed an aggregate production function that was estimated utilizing data on production, inputs, and public-sector programs such as research and extension. In such studies, the research variables have to be specified carefully as to their timing and spatial dimensions. They are subject to the normal statistical bias for drawing inferences. Most of the studies reported statistically significant estimates of research effects.

In summarizing the key characteristics of the study results presented in Table 3.1, Evenson emphasizes the following points:

- Only four studies out of the 35 included in the review reported low rates of return. All others were in excess of 20 percent in real terms.

- The imputation (index number) and econometric studies yielded similar estimates.

Table 3.1--Summary Studies of Agricultural Research Productivity

Study	Country	Commodity	Time Period	Annual Internal Rate of Return (%)
Index Number				
Griliches 1958	USA	Hybrid corn	1940–55	35–40%
Griliches 1958	USA	Hybrid sorghum	1940–57	20
Peterson 1967	USA	Poultry	1915–60	21–25
Evenson 1969	South Africa	Sugar cane	1945–62	40
Ardito Barletta 1970	Mexico	Wheat	1943–63	90
Ardito Barletta 1970	Mexico	Maize	1943–63	35
Ayer 1970	Brazil	Cotton	1924–67	77+
Schr. itz & Seckler 1970	USA	Tomato harvester	1958–69	
		—With no compensation to displaced workers		37–46
		—Assuming compensation of displaced workers for 50 percent of earnings loss		16–28
Ayer & Schuh 1972	Brazil	Cotton	1924–67	77–110
Hines 1972	Peru	Maize	1954–67	35–40[a]
				50–55[b]
Hayami & Akino 1977	Japan	Rice	1915–50	25–27
Hayami & Akino 1977	Japan	Rice	1930–61	73–75
Hertford, Ardila, Rocha, & Trujillo 1977	Colombia	Rice	1957–72	60–82
	Colombia	Soybeans	1960–71	79–96
	Colombia	Wheat	1953–73	11–12
	Colombia	Cotton	1953–72	0
Pee 1977	Malaysia	Rubber	1932–73	24
Peterson & Fitzharris 1977	USA	Aggregate	1937–42	50
			1947–52	51
			1957–62	49
			1957–72	34
Wennergren & Whitaker 1977	Bolivia	Sheep	1966–75	44.1
		Wheat	1966–75	−47.5
Pray 1978	Punjab (British India)	Agricultural research and extension	1906–56	34–44
	Punjab (Pakistan)	Agricultural research and extension	1948–63	23–37
Scobie & Posada 1978	Colombia	Rice	1957–74	79–96
Production function				
Tang 1963	Japan	Aggregate	1880–1938	35
Griliches 1964	USA	Aggregate	1949–59	35–40
Latimer 1964	USA	Aggregate	1949–59	Not significant
Peterson 1967	USA	Poultry	1915–60	21
Evenson 1968	USA	Aggregate	1949–59	47
Evenson 1969	South Africa	Sugar cane	1945–58	40
Ardito Barletta 1970	Mexico	Crops	1943–63	45–93

(continued)

Table 3.1--continued

Study	*Country*	*Commodity*	*Time Period*	*Annual Internal Rate of Return (%)*
Duncan 1972	Australia	Pasture improvement	1948–69	58–68
Evenson & Jha 1973	India	Aggregate	1953–71	40
Kahlon, Bal, Saxena, & Jha 1977	India	Aggregate	1960–61	63
Lu & Cline 1977	USA	Aggregate	1938–48	30.5
			1949–59	27.5
			1959–69	25.5
			1969–72	23.5
Bredahl & Peterson 1976	USA	Cash grains	1969	36[c]
		Poultry	1969	37[c]
		Dairy	1969	43[c]
		Livestock	1969	47[c]
Evenson & Flores 1978	Asia—national	Rice	1950–65	32–39
	Asia—international		1966–75	73–78
		Rice	1966–75	74–102
Flores, Evenson, & Hayami 1978	Tropics	Rice	1966–75	46–71
	Philippines	Rice	1966–75	75
Nagy & Furtan 1978	Canada	Rapeseed	1960–75	95–110
Davis 1979	USA	Aggregate	1949–59	66–100
			1964–74	37
Evenson 1979	USA	Aggregate	1868–1926	65
	USA	Technology-oriented	1927–50	95
	USA—South	Technology-oriented	1948–71	93
	USA—North	Technology-oriented	1948–71	95
	USA—West	Technology-oriented	1948–71	45
	USA	Science-oriented	1927–50	110
			1948–71	45
	USA	Farm management research & agricultural extension	1948–71	110

SOURCES: The results of many of the studies reported in this table have previously been summarized in the following: Thomas M. Arndt, Dana G. Dalrymple, and Vernon W. Ruttan, eds., *Resource Allocation and Productivity in National and International Agricultural Research* (Minneapolis: University of Minnesota Press, 1977), 6, 7; James K. Boyce and Robert E. Evenson, *Agricultural Research and Extension Systems* (New York: Agricultural Development Council, 1975), 104; Robert E. Evenson, Paul E. Waggoner, and Vernon W. Ruttan, "Economic Benefits from Research: An Example from Agriculture," *Science* 205 (14 September 1979): 1101–7; Robert J. R. Sim and Richard Gardner, *A Review of Research and Extension Evaluation in Agriculture* (Moscow: University of Idaho, Department of Agricultural Economics Research Series 214, May 1978), 41, 42; R. Hertford, J. Ardila, A. Rocha, and G. Trujillo, "Productivity of Agricultural Research in Colombia," in Arndt, Dalrymple, and Ruttan, *Resource Allocation and Productivity*, 86–123; J. Hines, "The Utilization of Research for Development: Two Case Studies in Rural Modernization and Agriculture in Peru" (Ph.D. diss., Princeton University, 1972); A. S. Kahlon, H. K. Bal, P. N. Saxena, and D. Jha, "Returns to Investment in Research in India," in Arndt, Dalrymple, and Ruttan, *Resource Allocation and Productivity*, 124–47; R. Latimer, "Some Economic Aspects of Agricultural Research and Extension in the U.S." (Ph.D. diss., Purdue University, 1964); Y. Lu and P. L. Cline, "The Contribution of Research and Extension to Agricultural Productivity Growth" (Paper presented at summer meetings of the American Agricultural Economics Association, San Diego, 1977); J. G. Nagy and W. H. Furtan, "Economic Costs and Returns from Crop Development Research: The Case of Rapeseed Breeding in Canada," *Canadian Journal of Agricultural Economics* 26 (February 1978): 1–14; T. Y. Pee, "Social Returns from Rubber Research on Peninsular Malaysia" (Ph.D. diss., Michigan State University, 1977); W. L. Peterson, "Returns to Poultry Research

(continued)

Table 3.1--continued

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[a]Returns to maize research only.

[b]Returns to maize research, plus cultivation "package."

[c]Lagged marginal product of 1969 research on output discounted for an estimated mean lag of five years for cash grains, six years for poultry and dairy, and seven years for livestock.

Source: Evenson in Eicher and Statz, Agricultural Development in the Third World, pp.358-360.

- Estimates for research programs in developing countries were of roughly the same order of magnitude as those for more advanced countries.

- The estimate for international rice research was one of the highest reported, and Evenson observes that, "A similar estimate for wheat research at CIMMYT, while not made, would be similar" (Evenson, 1984, p. 360).

One criticism of the commodity specific studies of agricultural research productivity is that they tend to focus on the "success" stories: hybrid corn, wheat, rice, soybeans, cotton, etc. However, the aggregate studies that include all agricultural research, and in some cases agricultural research plus extension, reported rates of return that were as high or higher than for some of the individual commodity studies (Table 3.1). The conclusion therefore is that investment in the production and introduction of appropriate agricultural technologies is less than optimal.

In support of the above conclusion it is frequently pointed out that agricultural research is still widely underfunded despite evidence of high financial returns to research investment. A FAO/UNDP study suggests an allocation to research of between 10-20% of the total funds committed to agricultural development or 1% of agricultural gross domestic product (GDP). Others have suggested targets for research expenditures ranging from 0.5-2.0% of agricultural GDP. It should be noted that even the lower range of 0.5% has not been reached in several Asian countries with relatively large and effective research systems (Oram, 1987). Salaries of scientists and wages for support staff are low in Asia compared to other developing regions, especially Africa.

Recent research indicates that determining the level of research support is more complicated than fixing a percentage of agricultural GDP (Pardey, Kang and Elliott, 1988). In attempting to explain why more funds are not allocated to agricultural research in light of its high pay-off, Pardey, Kang and Elliott conclude that it is not the lack of perception or predisposition on the part of policy makers, but the financial and political constraints imposed by overall and agricultural-specific levels of public spending that limit increased spending. The allocation of spending cuts, however, often falls disproportionately on agricultural research because research administrators frequently lack political clout and have limited contact with policymakers.

Agricultural Development and U.S. Interests

For many years there has been concern by U.S. farmers and agricultural leaders that U.S. support of agricultural development in the Third World would ultimately lead to increased competition and a reduction in U.S. exports. On the basis of this belief, U.S. agricultural groups have lobbied against support for foreign research programs and other AID efforts to stimulate agricultural development in the developing countries.

Although there are many different aspects to the complex relationships between U.S. aid for agricultural development, agricultural growth abroad, and international agricultural trade, recent research supports the hypothesis that in many cases agricultural and economic development abroad is associated with increased agricultural imports, part of which come from the United States (Kellogg, Kodl and Garcia, 1986; Kellogg, 1987; Cummings and Dalrymple, 1988;

Taylor, 1988). The linkages being investigated in these studies are: increased agricultural production leads to broad-based income growth in the developing countries which, in turn, has, along with population growth, a significant positive impact on the demand for agricultural products; part of this increased demand will be met by agricultural imports from the U.S. and elsewhere.

Developing countries that have become net agricultural exporters also can expand their markets for certain agricultural imports. For example, Malaysia, a consistent net exporter of agricultural products, increased its imports of food, feedgrains, and oilseeds from a wheat equivalent basis of about 1 million metric tons in 1967 to almost 2.4 million metric tons in 1983. In addition, Brazil, a country that competes with U.S. in soybean product exports, increased its imports of wheat and wheat products and corn and corn products from the U.S. by 27 percent and 86 percent, respectively, between 1970-72 and 1980-82. In addition, between 1970 and 1984, while Brazil was rapidly expanding its own agricultural production, the quantity of U.S. agricultural exports to Brazil rose 8.7 percent per year, while the value of those exports grew 16.3 percent annually. Finally, while the U.S. is acknowledged as a large net exporter of agricultural commodities, its growth as an agricultural importer is not so well recognized. As these examples show, increasing agricultural production along specialized comparative advantage lines in developing countries can complement increasing agricultural exports to them (Kellogg, Kodl and Garcia, 1986).

Furthermore, in an analysis of 65 developing countries from 1970 to 1982, those countries experiencing growth in per capita agricultural production had a positive and significant correlation between production and per capita agricultural imports. In this study there was no evidence that increasing agricultural production in developing countries had a negative effect on agricultural imports. Those developing countries with the faster-growing farm sectors were the faster-growing markets for U.S. agricultural exports. Thus, American agriculture may have much to gain from efforts to accelerate agricultural development in developing countries (Kellogg, Kodl and Garcia, 1986). Recent research conducted within AID reaches the same conclusions on the basis of comparison between a group of slow-growing and fast-growing developing countries (USAID, no date).

The above evidence and arguments do not ignore the fact that for individual crops, increased production abroad can cut into U.S. export markets. Brazil's rapid increase of soybean production and India's increased production of wheat substantially reduced former U.S. markets in these countries for these products. However, as pointed out above, total agricultural exports to Brazil have increased, and in the case of India, most of the wheat imports had been subsidized by U.S. taxpayers through such programs as P.L. 480 (Schuh, 1988). The overall benefits to U.S. agricultural producers and taxpayers must be recognized.

The expansion of agricultural research abroad has resulted in an increased flow of agricultural technology into the U.S. Within the past couple of years, it is estimated that the U.S. has shifted from being a net exporter of agricultural technology to a net importer (Furtick, 1988). This "reverse technology" flow has been facilitated by the internationalization of agricultural research described in Chapter 4. The international agricultural research centers (IARCs), the Collaborative Research Support Projects (CRSPs), and the development of national agricultural research systems have allowed U.S.

scientists to work abroad and gain valuable experience and knowledge. AID support of these programs has resulted in substantial benefits to U.S. farmers and consumers. The CRSPs, for example, have been jointly financed by AID and the universities on a mutual interest basis, and they have made a significant impact on both Third World and U.S. agriculture. The commodities and problems investigated have produced successful new technologies for the developing countries and have fed important genetic and other improvement into U.S. universities. Many of these are in the hands of U.S. farmers through the use of new germplasm by private sector seed companies. The planting of wheat varieties by U.S. farmers that were developed at CIMMYT in Mexico is another example of the benefits to the U.S. from research undertaken in developing countries and partially funded by AID (Dalrymple, 1988). It appears clear from the above evidence that the benefits to the U.S. from international agricultural research activities are substantial and increasing.

Summary

There is no doubt that agricultural research is one of the key elements in identifying constraints to change and finding solutions to agricultural development problems. Because of the high risks, long time lags, and the inability to capture major portions of the benefits from research, much of the needed agricultural research in developing countries has to be provided by the public sector. To insure that research makes a significant contribution to agricultural development requires an appropriate mix of different types of research ranging from adaptive to basic research. S&T/Agr has tended to heavily support applied and strategic research through its support of the IARCs, CRSPs, and other directly funded research projects. S&T/Agr needs to increase its interaction with the regional bureaus and missions, who are primarily responsible for the development of adaptive research capacity, in order that the full benefits of the different types of research can be realized. In evaluating their research portfolio, S&T/Agr may find it useful to consider the risk/pay-off aspects of the projects they support.

Previous research has documented the high rates of return on investment in agricultural research, both in developing and developed countries. The high rates of return when compared to the trends in agricultural research funding suggest that investment in agricultural research and the introduction of appropriate technologies is still far below optimal. The direct and indirect benefits to U.S. farmers and consumers from agricultural research in developing countries also appear to be substantial and increasing. Likewise, rapid economic and agricultural development in the Third World has tended to increase rather than reduce U.S. agricultural exports to these countries. The nature of the research systems that have provided these benefits to the developing and developed countries is described in the following chapter.

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Chapter 4

AGRICULTURAL RESEARCH FOR THE DEVELOPING WORLD

Agricultural research is the most international of all the sciences. Only the medical sciences approach the complexity of global interactions characteristic of the myriad research activities of agricultural scientists. From the parched fringes of Sahara to the moist jungles of Sumatra, scientists are grappling with a wide variety of problems with the support of the rapidly evolving international agricultural research system. Crop breeders, for example, draw on genetic resources collected in virtually every country and stored in hundreds of gene banks. Agronomists try out technologies often developed by team efforts spanning dozens of countries.

The world is becoming more closely linked by improvements in communications and transportation as countries depend ever more on each other for raw materials and technology. This integrating trend is especially pronounced in the agricultural sciences. Indeed, no country can afford to cut itself off from the flow of ideas, methodologies, and technologies needed to boost the efficiency and productivity of its farmlands. Even the United States, which exports food to over a hundred nations, has become a net importer of agricultural technology (Furtick, 1988).

The major institutional actors in this global research enterprise are national agricultural research systems (NARS), public and private sector institutions in industrial as well as developing countries, and international agricultural research centers. Interactions between these institutions occur on a bilateral basis, such as between a university in the United States and a counterpart institution in a developing country--or as a part of a network that unites the efforts of scientists in many countries to tackle a common problem.

After reviewing the niches occupied by various research institutions in the international agricultural research systems, we examine the supporting role of donor organizations, with particular attention paid to the Agency for International Development.

National Agricultural Research Systems

The national agricultural research systems of developing countries must play the central role in global efforts to improve agriculture through research. The NARS are closest to the problems and needs of agricultural producers and are, therefore, in the best position to develop and adapt technologies to fit farmers' needs. This is done primarily through applied and adaptive research, taking advantage of germplasm, knowledge and component technologies from other sources such as the international centers, other NARS, the private sector and public research institutions in industrialized countries. It should be recognized, however, that some of the more advanced NARS such as those in India and Brazil may become more involved in strategic and basic research. The more advanced national programs are essentially self-sufficient for many agricultural technologies and even provide services for other Third World countries. For example, Brazil is committed to assisting African countries in agricultural research.

Numbers and Education Level of Scientists

The capabilities of many developing countries in research are suggested by the numbers of scientists with masters or doctoral level degrees working in agricultural research (Table 4.1). Apparently India considers only M.S. and Ph.D. holders as scientists. In countries such as Brazil, Bangladesh and Egypt, two-thirds or more of their agricultural scientists have advanced degrees. Many other countries have smaller percentages but still relatively large numbers of researchers with such degrees.

Level of Funding

Table 4.2 reflects changes in the level of funding for a selected group of developing country NARS from 1970 until the most recent year data were available (primarily 1983-86). This information, reported in constant 1980 U.S. $, reflects enormous increases in expenditures in most countries for agricultural research between 1970 and 1980. By 1980, for example, Nigeria, India, Brazil, and Mexico were all funding their agricultural research systems at levels in excess of $150 million annually. On the other extreme, however, were such countries as Burma and Honduras where NARS were funded at less than $2 million and Haiti with only $360,000.

It should be noted that in some of these countries (e.g., India, Nigeria, Pakistan, Philippines, Argentina, Mexico), research expenditures have dropped significantly from 1980 until the most recent reporting date--reflecting the effect of inflation and Third World debt problems.

Levels of Resources Allocated to Agricultural Research

Table 4.3 provides a more comprehensive picture of resources allocated to agricultural research in developing countries, including both financial and scientific personnel, reported by regions. There is also information indicating the level of research expenditures as a percent of the agricultural GDP and the level of donor assistance for research by major regions.

These data indicate that in 1980 about half (47.8%) of developing country expenditures for agricultural research were in Asia--with only 18% in Africa. (The percentage in Africa is undoubtedly much higher today because of the donor interest in Africa in recent years.) The total developing country expenditure for agricultural research was $2.1 billion in 1980. Of that sum 39.1% was supplied by the international donor community. The smallest portion of total expenditures supplied by donors was in Asia (20.2%); the highest was in Africa (80.8%). The heavy dependence of many NARS upon donor funding raises questions about the viability of these national programs when donor funding is withdrawn.

Research expenditures as a percent of agricultural GDP in the four major regions ranged from 0.36% in the Middle East to 0.75% in Latin America. Africa was second with 0.71%. It should be noted that the sub-region having the highest percentage of agricultural GDP spent on research was Southern Africa. The second highest was the Caribbean.

While Asia accounted for almost one-half of the developing country expenditures for agricultural research, that region had approximately two-third of the developing world scientific staff. Africa, with 18% of the research expenditures, had only 7.5% of the scientific staff. This undoubtedly reflects

Table 4.1--Number of Scientists at some national agricultural research systems in developing countries

Country	Year	Masters & Ph.Ds	All Degree Holders	Percentage with MS & PhD
				(percent)
Egypt	1983	2,274	3,553	64.0
Brazil	1983	2,632	4,178	63.0
Bangladesh	1988	1,185	1,553	76.3
India	1984	21,400	21,400	100.0
Indonesia	1984	848	2,082	40.7
Mexico	1982	566	1,573	36.0
Kenya	1986	272	626	43.9
Nigeria	1983	610	1,196	51.0
Colombia	1984	370	711	48.0
Nepal	1983	171	388	44.1
Philippines	1986	1,775	3,549	50.0
Ecuador	1983	75	337	22.3
Peru	1984	40	410	9.8
Burma	1984	43	300	14.3
Guatemala	1984	22	172	12.8
Malawi	1984	74	193	38.3
Costa Rica	1981	11	114	9.6

Source: Peter Oram, IFPRI, 1989.

Table 4.2 - Expenditures by Selected National Agricultural Research Systems

Selected Countries	Funding - (000 U.S.$) in 1980 $ 1970	1980	Latest Year
India	83,093	154,674	106,223 (1986)
Pakistan	4,696	31,757	17,903 (1986)
China	N/A	N/A	62,830 (1982)
Korea	6,621	14,096	14,096 (1980)
Burma	N/A	1,819	2,500 (1983)
Indonesia	9,904	57,241	51,982 (1984)
Philippines	13,000	11,157	6,284 (1984)
Argentina	46,557	56,841	41,029 (1983)
Brazil	39,260	179,100	200,000 (1983)
Peru	9,954	4,311	6,860 (1984)
Costa Rica	1,484	3,065	1,281 (1981)
Honduras	1,580	1,018	1,631 (1984)
Mexico	14,885	188,614	115,835 (1982)
Dominican Republic	1,500	2,315	1,960 (1981)
Haiti	225	360	360 (1980)
Trinidad	1,221	1,650	5,903 (1983)
Egypt	20,854	30,214	32,793 (1983)
Tunisia	2,807	6,770	11,469 (1985)
Syria	2,123	5,290	4,403 (1985)
Turkey	18,530	30,000	29,315 (1981)
Saudi Arabia	N/A	N/A	10,000 (1983)
Cameroon	3,052	10,994	15,065 (1984)
Congo	494	2,800	1,984 (1983)
Nigeria	21,158	235,286	149,000 (1983)
Burkina Faso	1,507	7,730	7,904 (1982/83)
Chad	1,174	1,602	597 (1984)
Senegal	6,574	16,300	14,168 (1984)
Botswana	775	4,977	2,400 (1984)
Malawi	2,443	6,121	6,489 (1984)
Zimbabwe	5,900	16,140	26,838 (1984)
Ethiopia	3,313	3,119	5,471 (1983)
Kenya	7,773	19,895	24,624 (1984)
Uganda	6,444	7,452	8,551 (1983)

Source: Peter Oram, Unpublished Data - IFPRI, Washington, D.C.

Table 4.3 - Resources Allocated to Agricultural Research in Developing Countries - National Expenditures and Scientific Staff 1/

Region	Expenditures in 1980 US $ (000 U.S.$)	% of Total	Research Expend. as $ of Ag. GDP	Donor Assistance (1983)	Scientific Staff Number	Scientific Staff % of Total
South Asia	157,358	7.4	0.20		26,404	31.3%
East Asia	657,651	31.1	0.65		19,452	23.1
S.E. Asia	196,171	9.3	0.38		9,959	11.8
Total Asia	1,011,180	47.8	0.44	205,099	55,815	66.3
South America	374,911	17.7	0.77		8,221	9.8
Cent. America	132,314	6.3	0.67		2,463	2.9
Caribbean	19,457	0.9	1.14		2,669	3.2
Total Latin America	526,682	24.9	0.75	223,097	13,353	15.9
West Africa	254,008	12.0	0.64		3,420	4.1
East Africa	56,025	2.7	0.52		1,648	2.0
Southern Africa	70,219	3.3	2.22		1,268	1.5
Total Africa	380,252	18.0	0.71	307,131	6,336	7.5
North Africa	78,737	3.7	0.55		4,646	5.5
West Africa	101,279	4.8	0.29		3,628	4.3
Arabian Penin.	15,562	0.7	0.50		464	0.6
Total Middle East	195,578	9.3	0.36	91,266	8,738	10.4
Total Developing Countries	$2,113,692	100%	--	826,593	84,242	100%

1/ For latest year available -- primarily 1981-1984

Source: Peter Oram, Unpublished Data - IFPRI, Washington, D.C.

the dearth of well-trained scientific personnel in Africa as well as the cost of conducting research in many African countries.

Changes in Research Expenditures and Personnel

A recent comprehensive study by ISNAR documents changes in support for agricultural research by regions from 1960-64 to 1980-85 (Pardey and Roseboom, 1988). These data are reflected in Figures 1, 2, 3, and 4 showing numbers of researchers and "real" research expenditures for four developing country regions and for "developed countries." Expenditure levels are provided in constant 1980 dollars.

Figure 1 indicates the increase in numbers of researches during the 20-year period from 1960-64 to 1980-85. Significantly, the growth has been much more rapid in the developing countries. For example, there was a 39.4% increase in research personnel in the developed countries during this period and a 331% increase in the developing countries. Developing countries had 26.8% as many agricultural researchers as the developed countries in 1960-64 and 82.9% as many in 1980-85. In 1960-64, developing countries had 78.9% of the world's agricultural scientists; in 1980-85, only 54.7% were found in the developed countries. (These figures involve 22 developed countries and 129 developing countries).

Of the four developing country regions, Asia and the Pacific had the greatest concentration of agricultural scientists--10.3% in 1960-64, increasing to 22.7% in 1980-85. Sub-Saharan Africa had the smallest percentage in both periods--reaching a level still less than 5% by 1980-85 (Figure 4.2).

Figure 4.2 also reflects changes in expenditures for research during the same 20-year period. Figures 4.3 and 4.4 indicate research expenditures measured in constant 1980 U.S. $. Figure 4.3 uses purchasing power parity (PPP) indices. PPPs, by definition, measure the domestic cost of buying a bundle of goods and services in a particular country at its own prices relative to the corresponding costs in dollars of the same bundle in the United States. Figure 4.4. uses World Bank Atlas exchange rates to convert agricultural research expenditures into U.S. dollars. It is obvious that dramatically different regional patterns of "real" expenditures are derived from the use of these two indices. In general the Atlas-converted figures appear to understate the level of "real" expenditures in developing countries relative to the PPP-converted figures, while overstating the level of "real" expenditures in developed countries.

Using the PPP indices, research expenditures in the developed countries increased during this period by 133% while research expenditures in the developing countries went up 292%. Using the World Bank Atlas exchange rates, expenditures in both developing and developed countries increased about the same rate as with the PPP indices. However, developing country expenditures are a much smaller percentage of developed country expenditures, using the Atlas figures.

Figure 4.2 indicates that with PPP indices, developed countries accounted for about 76% of the global research expenditures in 1960-64 and 65% in 1980-85. Among the developing country regions, Asia and the Pacific had the largest increase in research expenditures, reaching a level of 15.2% of the total by 1980-85.

Figure 4.1--Regional Development of the Number of Researchers
(Full Time Equivalent Units)

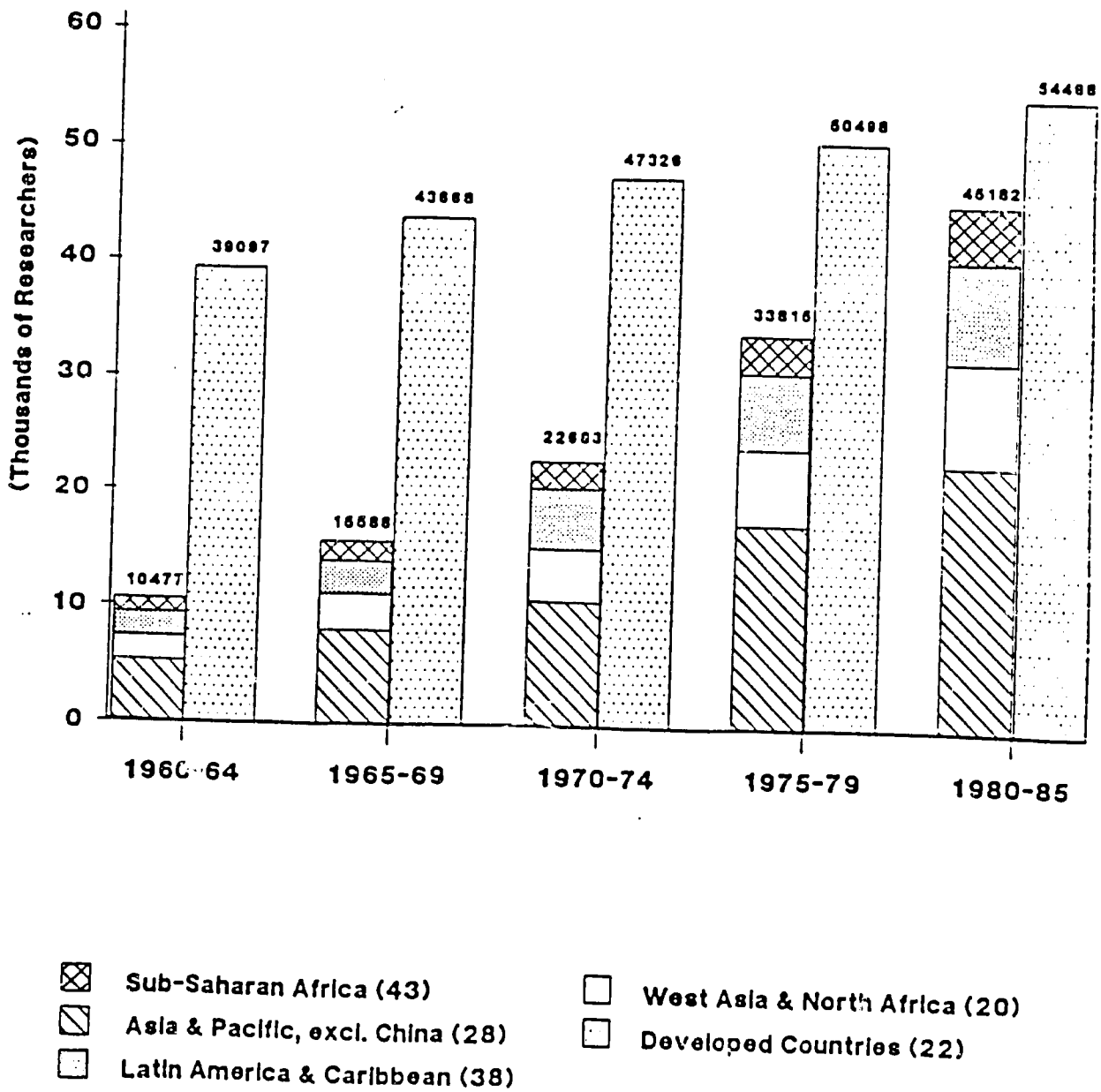


Figure 4.2--Regional Shares of Agricultural Research Personnel and 'Real' Expenditures (1980 PPP US Dollars)

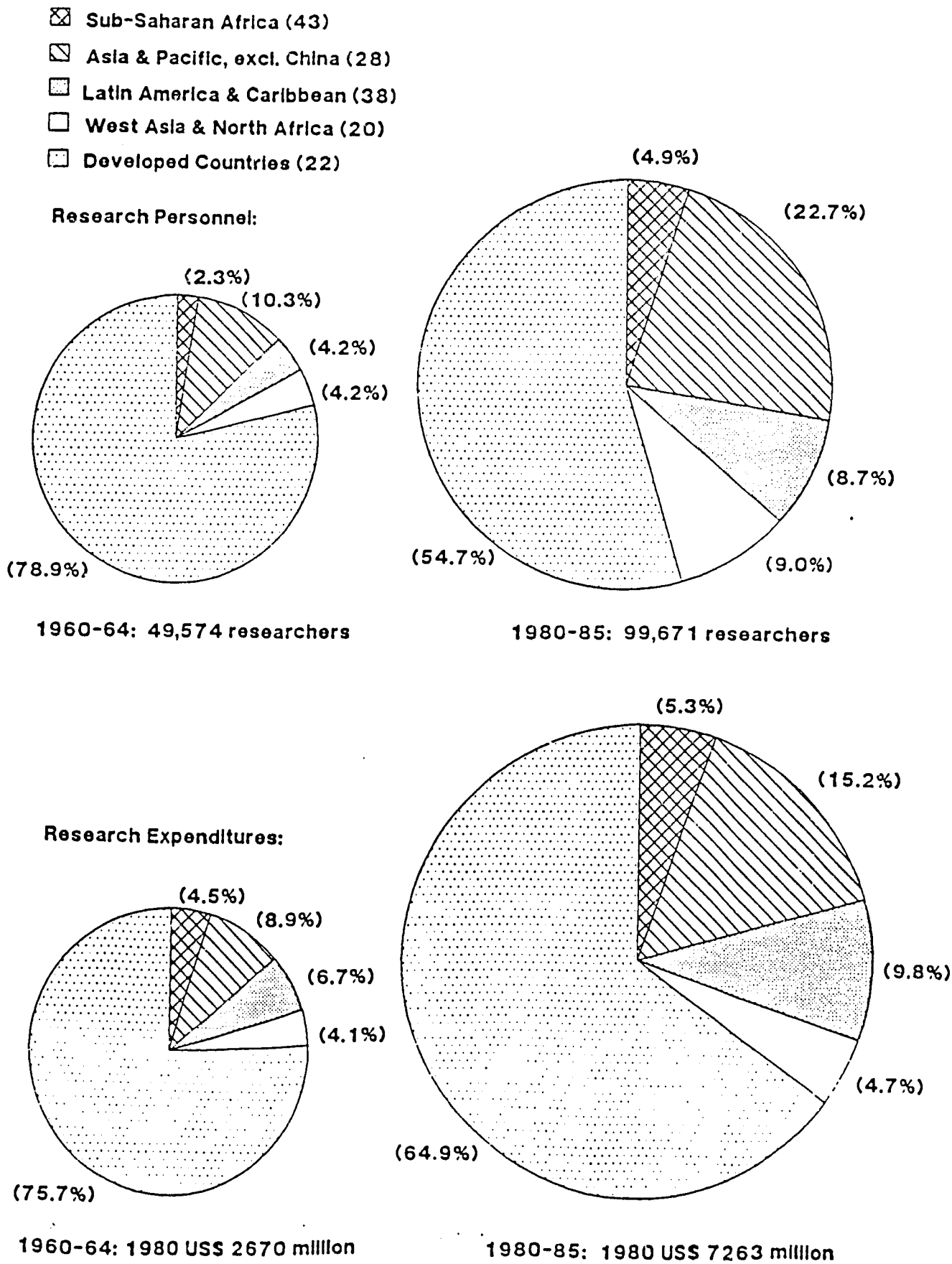


Figure 4.3--Regional Development of 'Real' Research Expenditures Measured in 1980 PPP US Dollars

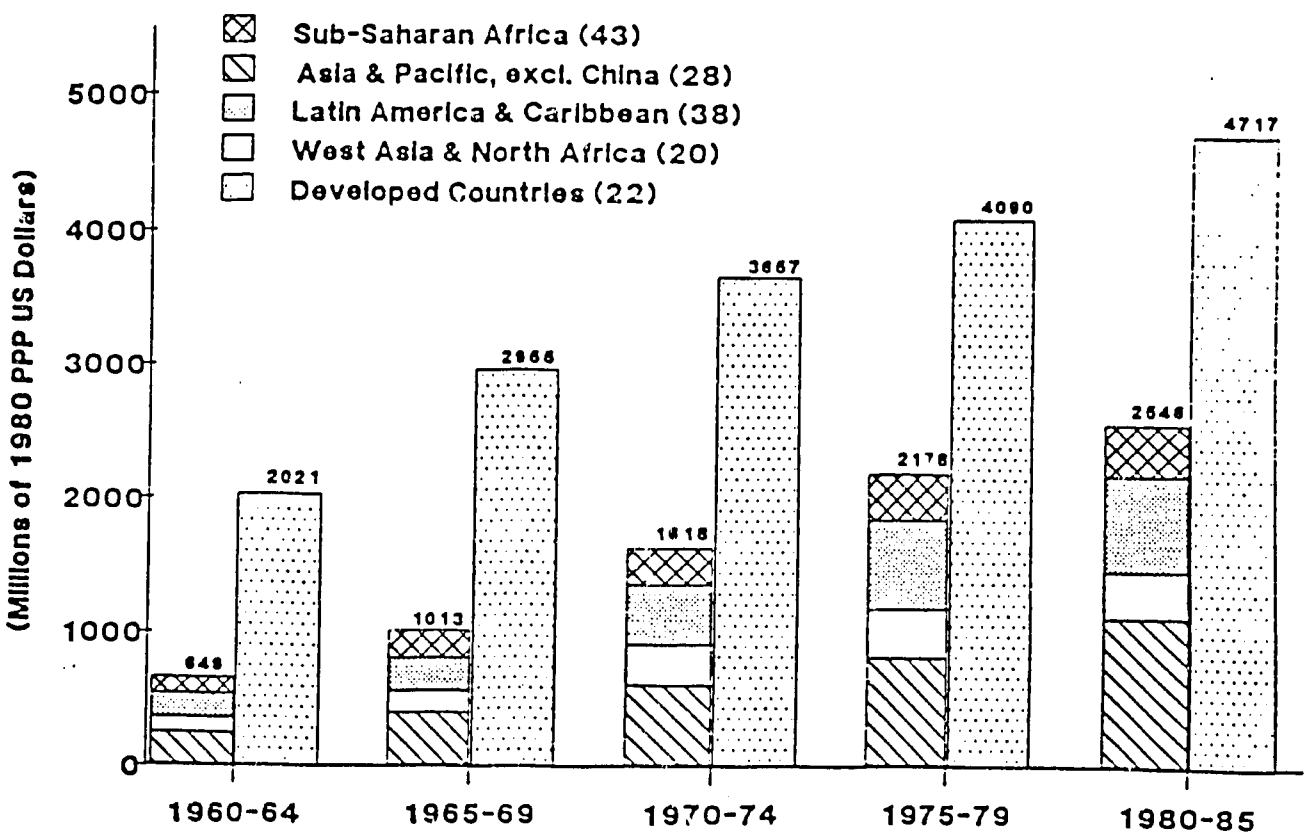


Figure 4.4--Regional Development of 'Real' Research Expenditures Measured in 1980 Atlas US Dollars

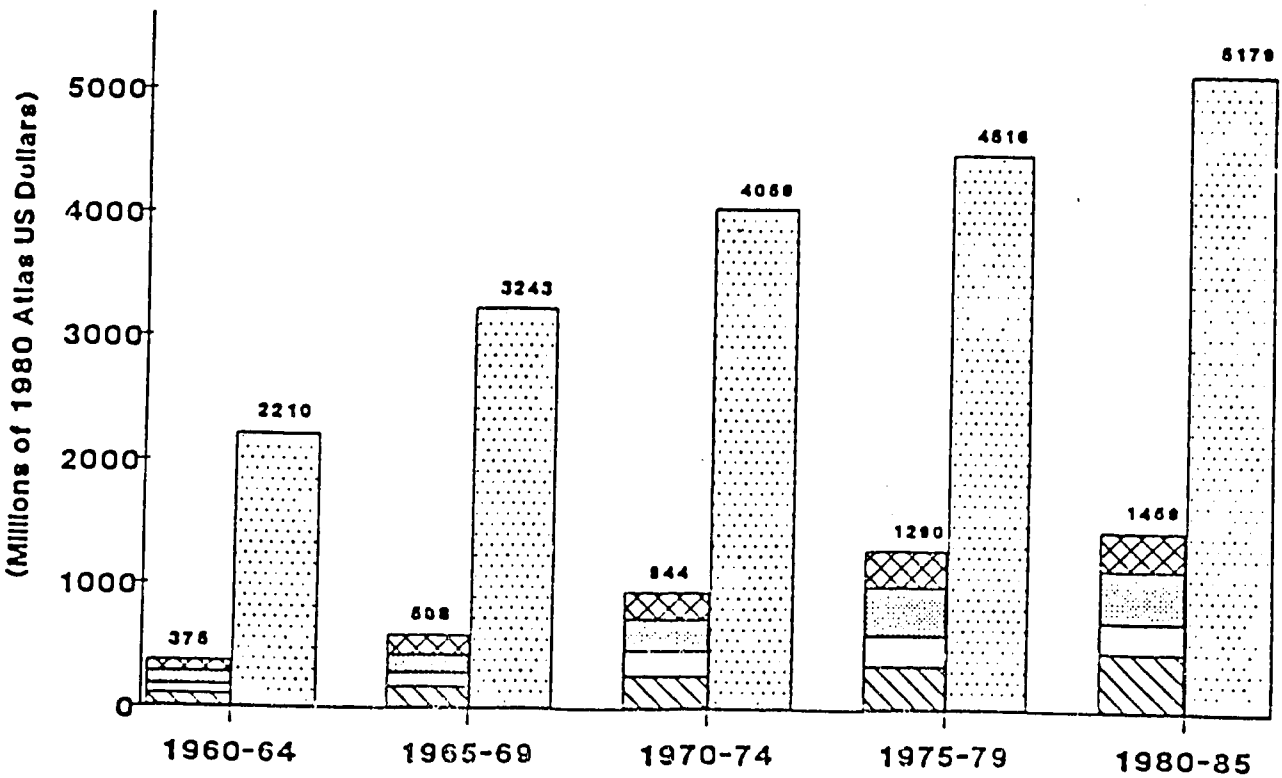


Figure 4.5 provides a comparison of the relative growth in agricultural researchers and agricultural research expenditures in the period from 1960-64 to 1980-85 (Elliott and Roseboom, 1988). It should be noted that in the developed countries, growth in expenditures was at a greater rate than growth in personnel, reflecting a significant increase in support per scientist during this period. In developing country regions, except for Asia and the Pacific, there was a greater percentage increase in scientists than in research expenditures, indicating a declining level of financial support per scientist during this period.

Figure 4.6 indicates the changes in research expenditures per scientist during the 20-year period. The developed country group shows a steady rise from approximately $52,000 per scientist in 1960-64 to more than $86,000 in 1980-85, expressed in constant 1980 US $. The developing countries as a group were spending more per scientist than the developed countries at the beginning of the period (accounted for in part by the high cost of expatriates), but since reaching a peak in the early 1970s, this figure has declined significantly. This downward trend is most striking in sub-Saharan Africa and in West Asia and North Africa. Given its onset in the early 1970s, this decline may also reflect the fiscal crisis of many developing countries during the period of rising oil prices (Pardey and Roseboom, 1988). This decline in operational support funding (per scientist) is becoming a serious constraint to effective research in many developing countries.

It is not sufficient to look only at the number of agricultural scientists in a given country; one must also look at the level of qualifications of those scientists, both in terms of formal degrees and relevant job experience. The Indicator Series Project at ISNAR has made an attempt to add this dimension to the number of agricultural scientists on the basis of formal degrees. When possible, agricultural scientists have been classified by their formal degrees into the category of BSc, MSc, and Ph.D. These terms have been used to refer to the first, second and third university level degrees which exist in most university systems. Such an analysis has led to the development of a "qualification index" for researchers in various developing country regions. The qualification index is stated as the number of Ph.D. and MSc degree holders divided by Ph.D., MSc, and BSc holders. In this particular analysis, expatriates are assumed to hold a Ph.D. or MSc degree.

The application of this "qualification" index is shown in Figure 4.7 for some twelve regions within the developing world. These data reflect qualification indices ranging from approximately 32 to more than 60 in the various regions. The presence of expatriates appear to have the greatest impact upon these measurements in Central and Southern Africa and the Pacific regions (Elliott and Roseboom, 1988).

Figure 4.8 indicates the size distribution of 131 developing country NARS by number of researchers. These data indicate that 38 of the 131 NARS had 25 researchers or less. Seventy-five of the 131 had less than 100 scientists. It is apparent, therefore, that a majority of developing country NARS remain small in relation to the task facing them, and many cannot hope to achieve a critical mass in terms of their ability to develop a comprehensive research effort. This means that cooperation among the NARS as well as with the broader international agricultural research network is an important means of getting the coverage of the great number of problems facing the national system. This is especially true for the very small NARS (with less than 50 scientists) which

Figure 4.5--Pertcentage growth of the number of agricultural researchers and agricultural research expenditures between 1960-64 and 1980-85

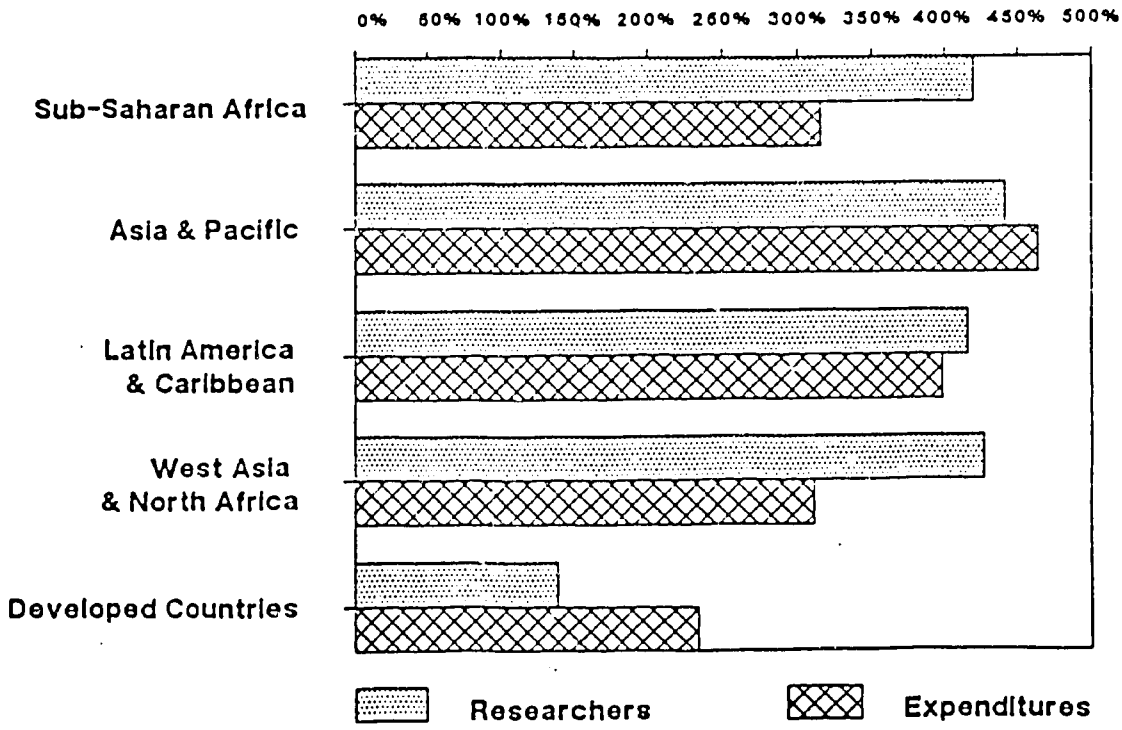


Figure 4.6--Research expenditures per researcher
(thousands of 1980 PPP US dollars per full time equivalent)

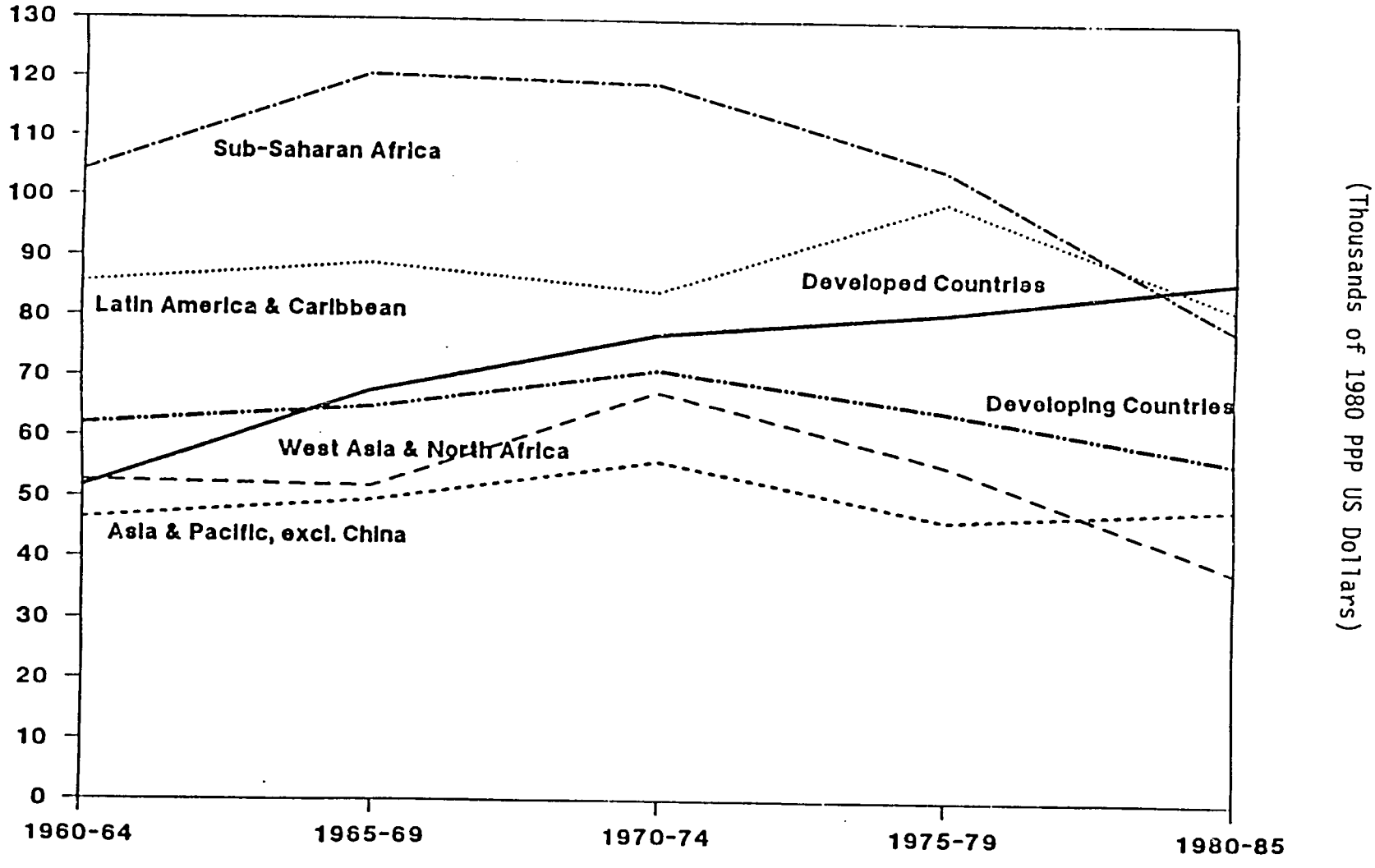
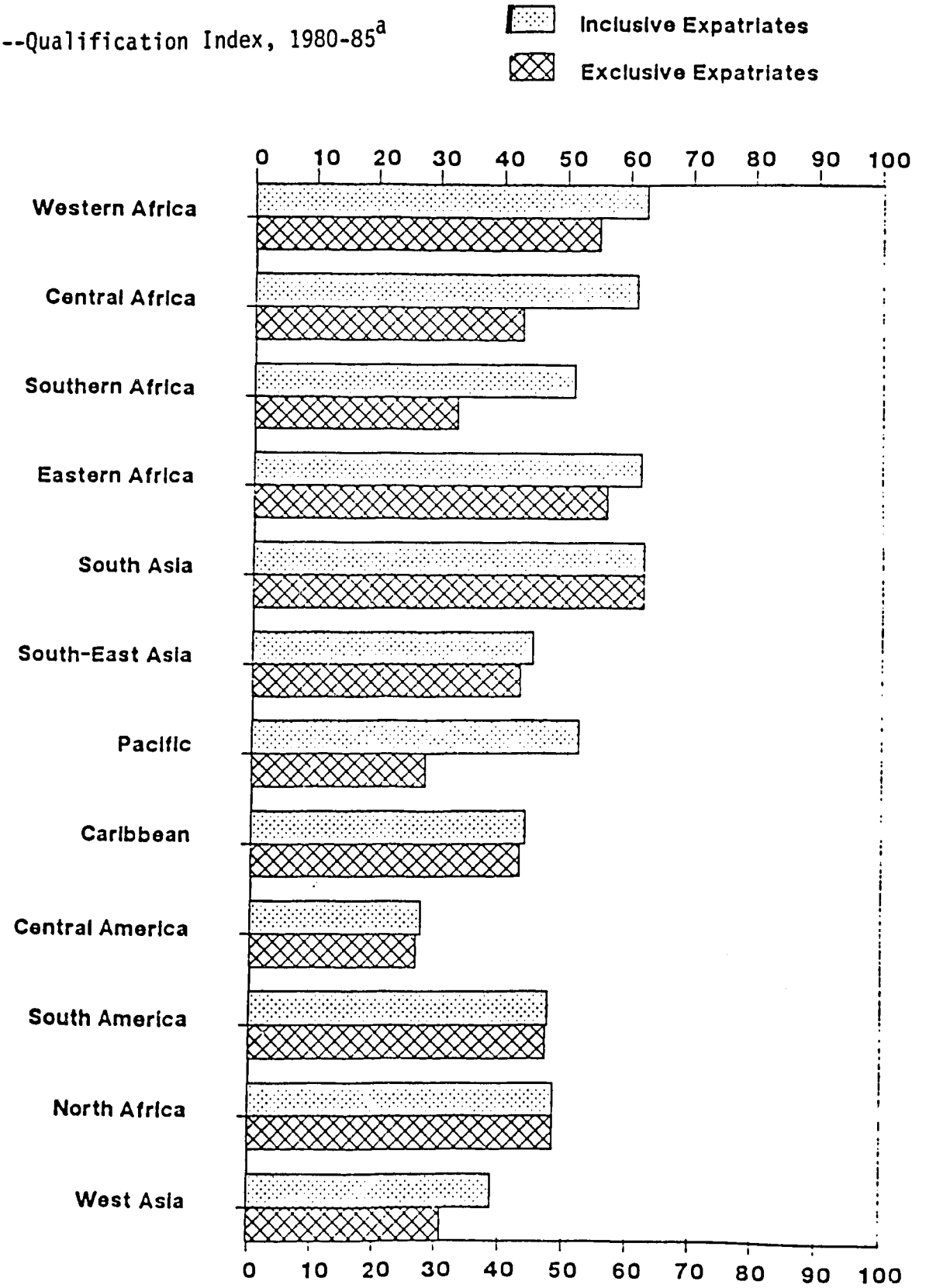


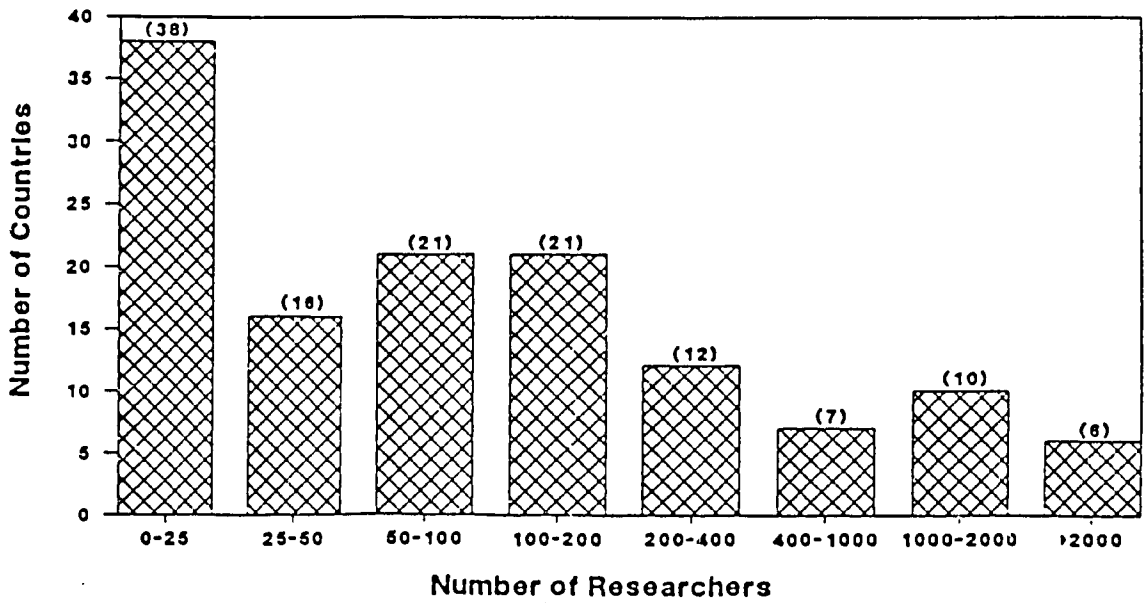
Figure 4.7--Qualification Index, 1980-85[a]



a) Qualification index = (PhD+MSc)/(PhD+MSc+BSc).

Expatriates are assumed to hold a PhD or an MSc degree.

Figure 4.8--Size distribution of 131 developing country NARS by number of researchers (1980-85 average)



are nearly all located in the Caribbean, the Pacific and throughout sub-Saharan Africa (Elliott and Roseboom, 1988).

Data in Table 4.4 indicate that in the 1980-85 period over $7 billion was spent annually for agricultural research by national systems throughout the world. Some 35% of that ($2.5 billion) was being spent in developing countries. It should be noted that developing country expenditures for agricultural research and numbers of scientists have increased significantly over the past two decades, with the developing countries NARS becoming a large and significant part of the global agricultural research system. This means that the division of labor between the NARS, the international agricultural research centers and private sector research is changing significantly.

Changing Relationships

The challenge of trying to help sustain national agricultural programs in the Third World requires continual fine-tuning of relationships with the international centers, developed country institutions and networks. One of the most vexing difficulties for national agricultural research programs in the Third World is providing rewarding career opportunities for scientists as they return home from training abroad. The brightest scientists in developing countries are often tapped for administrative roles in government programs or enticed into the private sector--thereby effectively removing them from the front lines of research. Others may become dissatisfied with poor laboratory and field equipment and seek employment abroad. The effectiveness of national programs thus hinges to a large extent on the political and economic health of the country at large.

It is often remarked that strengthening developing country NARS will prompt a re-thinking of the role of international centers and may even call into question their relevance. However, many national programs, particularly in Africa, will continue to rely heavily on international centers, developed country institutions and international networks for such services as training, germplasm, and information data bases for a long time to come. Many other more developed NARS will also look to the IARCs for assistance in more strategic and basic research areas. It should be noted, however, that NARS have to cope with many commodities and problems not addressed by the IARCs.

As national programs in developing countries strengthen and take on more diverse activities, the more varied and intensive the interactions with other institutions become. In other words, the greater the capacity for research, the greater the demand for basic research, scientific intercourse and technology exchange. A parallel can be drawn here with international trade; the most important trading partners with the United States are other industrialized countries such as Japan and Western Europe, not "developing" countries with limited ability to absorb foreign goods.

Qualitative Concerns

Much of the foregoing section has dealt with quantitative measurements of NARS. Consideration needs to be given, as well to qualitative improvements of national programs. For example, management problems often lead to poor performance of national research programs. Both the IRRCs and CRSPs have training components which can contribute to improving the quality of national research efforts. Moreover, one IARC, ISNAR, has a specific responsibility for

Table 4.4--Estimation of Expenditures per Scientist in Agricultural Research (1960-64 to 1980-85)

Region	Total Number of Scientists 1960-64	1980-85	Ratio 1980-85/ 1960-64
Sub-Saharan Africa	1159	4870	4.2
Asia & Pacific	5123	22625	4.4
Latin Amer. & Caribbean	2095	8720	4.2
West Asia & North Africa	2100	8767	4.3
Developed Countries	39097	54488	1.4
Agricultural Research Expenditures (Millions of 1980 PPP $ US)			
Sub-Saharan Africa	120.879	381.940	3.2
Asia & Pacific	238.337	1105.523	4.6
Latin Amer. & Caribbean	179.386	714.349	4.0
West Asia & North Africa	110.652	344.048	3.1
Developed Countries	2020.762	4717.398	2.3
Expenditure per Scientist (1980 PPP $ US)			
Sub-Saharan Africa	104,257	78,430	0.75
Asia & Pacific	46,526	48,864	1.05
Latin Amer. & Caribbean	85,645	81,917	0.96
West Asia & North Africa	52,687	38,366	0.73
Developed Countries	51,685	86,576	1.68

Source: Elliott and Roseboom, 1988.

helping to strengthen the management and overall performance of national programs.

It should be noted that most of the agricultural research in developing countries is carried out in Ministries of Agriculture--and is usually separated from agriculturally-related university programs. In some countries, universities have substantial research capabilities and their efforts should be effectively integrated into national programs.

The Private Sector in Industrial and Developing Countries

A host of private companies, ranging from small venture capital operations to large, multinational corporations, are pursuing research and development in such fields as biotechnology, pesticides, plant breeding, and fertilizers. All these institutions are, directly and indirectly, improving agricultural productivity in the developing world.

In the 1970s and the 1980s, the private sector has been playing an increasingly important role in producing technologies for farmers in both industrial and developing countries. In the U.S., for example, the expenditures for private research and development in agriculture surpassed the level of public expenditures in 1986 (Furtick, 1988). A similar pattern holds in Canada, Australia, Japan, and Western Europe. The United Kingdom government, for example, recently sold to Unilever one of the country's premier agricultural research centers, the Plant Breeding Institute at Cambridge.

Private companies are leaders in developing pesticide and biotechnology products. Private companies are at the forefront of biotechnology research and development because many of them can commit substantial resources relatively quickly for research, particularly in setting up laboratories. Monsanto, for example, has invested over $150 million in biotechnology laboratories (Fernandez, 1987). One of the more interesting fields of research combines biotechnology and herbicides in the development of crops that withstand applications of certain weed killers. When perfected, such crops will be immune to particular herbicides, increasing the utility of such herbicides.

Biotechnology research is dominated by two main actors in the private sector: multinational firms and private venture companies. In the 1990s, multinational firms are expected to acquire many of the surviving private venture companies engaged in biotechnology research (Dembo et al., 1987). Already, multinational firms are acquiring equity in small biotechnology firms. Multinational firms are also forging research partnerships with universities, particularly in the numerous "science parks" that are developing around research universities. This trend toward the "privatization" of agricultural research will bring benefits, but also poses some potential problems. The extent to which germplasm will be freely exchanged is questioned. The issue of crop variety protection and patents on transgenic plants is being increasingly debated in scientific and government circles. In general, one would expect those countries that recognize such patents will benefit more rapidly from biotechnology research. Some Third World countries are nervous that they will be left behind in the biotechnology race.

The private sector is also gaining grounds in conventional plant breeding, particularly in the production of cereal hybrids. Many companies are increasing their research and development budgets while public sector institutions

are being forced to trim theirs. Many researchers in the agricultural sciences are now opting for careers in the private sector where the pay is often better and facilities are more up to date.

In some developing countries, policy barriers have been erected that effectively shut out investment by private companies. For example, some nations do not respect plant variety rights, which discourages private seed companies from investing in such countries. The global trend, however, is towards recognition of plant variety rights. This trend does not necessarily portend a restriction in the exchange of basic germplasm. Only multiplication of the patented variety for sale is prohibited where plan variety rights are protected. Protected varieties can be used in further breeding, and the genes used in producing a protected variety can usually be found in germplasm collections.

Even in countries that do not recognize plant variety rights, the private sector is encouraged to produce hybrids and other technologies for farmers. Farmers in India, Mexico, and Brazil obtain high-quality seed from a mix of public and private sources. The door is still open for companies producing hybrids in such cases because farmers must return to the company for seed each year if they wish to maintain high yields. The lack of plant variety rights discourages the private sector from working on open pollinated varieties and vegetatively propagated crops.

Innovative ways need to be found to build on the strengths of the private sector for the benefit of more farmers. Evidently, the private sector is doing a good job overall; acceptance in the marketplace is fueling growth. Still, the climate for closer collaboration between the private and public sectors could be improved in many cases. In the United States, agro-industrial corporations are supporting research at some universities, while small "high tech" firms, spun off from universities, are attempting to accelerate the transfer of technology from laboratories to farmers fields.

The private sector is already active in agricultural research development in many Third World countries. Private seed and pesticide companies, for example, have research stations and sales forces at work in numerous developing countries. International centers are increasingly serving as bridges between developed country institutions and clients in the Third World. CIMMYT, for example, is establishing links with biotechnology firms to further its work on maize and wheat; such partnerships are likely, eventually, to benefit farmers and consumers with higher yielding and hardier varieties.

The Public Sector in Industrial Countries

The impressive growth of the private sector in agricultural research and development in industrialized countries also raises questions about the future role of public institutions in developing agricultural technologies. As private companies take on more adaptive research, the public sector will presumably move more towards strategic and basic research--working on problems that usually require a protracted research effort with no assurance of success. The larger mission of universities, however, is to serve the public good, and providing research for private companies to use and sell does benefit society. But working out the specifics of who does what, and where the funds will come from, will require some creative thinking and planning.

In the U.S., public institutions involved in agricultural research include the land-grant colleges and the USDA Agricultural Research Service which maintains a network of research programs across the country. Public universities and non-university research programs have long dominated agricultural research in the U.S., particularly since World War II when state governments and the Congress greatly increased funding for agricultural research. These public institutions have underpinned the impressive growth of the agricultural economy in the United States and need continued support. Their functions are not likely to be assumed by the private sector although the private sector can significantly complement their efforts.

Although the U.S. scientific community, both in the public and private sectors, is clearly involved in the international agricultural research system, there is still room for increasing such ties. The Special Constraints Project in the S&T/Agriculture portfolio allocates $0.5 million to foster linkages between U.S. scientists and international centers. This is a relatively small sum in comparison to the U.K.'s Overseas Development Administration (ODA) C 4 program which has an annual budget of close to $3 million that is set aside specifically to facilitate the collaboration of British scientists with counterparts at international centers. The initiative for collaborative activities in the C 4 program, comes from the international centers rather than political constituencies within the U.K.

For the most part, public research institutions, oriented more to basic research, and the more product-oriented private sector are working well together in industrial countries. Sometimes, a university comes up with a new design such as an agricultural machine, and a private company takes the prototype and develops it further with no direct compensation. In other instances, joint arrangements are worked out with patents or licensing agreements between public institutions and private companies. In either case, both researchers and consumers benefit.

International Agricultural Research Centers

The concept of an international agricultural research center (IARC) as a catalyst for the Third World agricultural research and development grew out of the tangible success of the "green revolution" in rice and wheat. The Ford Foundation was pivotal in launching the International Rice Research Institute (IRRI) in the Philippines in 1959. The experience of the Rockefeller Foundation with wheat research in Mexico, starting in 1943, led to the creation of the International Maize and Wheat Improvement Center (CIMMYT--Centro Internacional de Mejoramiento de Maiz y Trigo) in 1964. CIMMYT and IRRI developed semi-dwarf wheats and rices in the mid-1960s that revolutionized food production in Mexico, South Asia and many parts of Southeast Asia.

The rapid and far-reaching benefits of CIMMYT and IRRI soon prompted the Rockefeller and Ford Foundations to fund two more international centers in 1967. CIAT (Centro Internacional de Agricultura Tropical) was set up in Colombia to work on beans, cassava, pasture and forage species and rice in the American tropics. The International Institute of Tropical Agriculture (IITA) was established in Nigeria to focus on subsistence crops in Africa (Plucknett and Smith, 1982). It soon became apparent that international centers, built around the "Centers of Excellence" idea, was a cost-effective way of supporting research to boost and maintain agricultural productivity in the Third World.

The burden of creating more "Centers of Excellence" in developing countries was too great for the two private foundations to bear alone, however. A trans-national framework for sponsoring international centers was called for. To meet this ambitious task, the Consultative Group on International Agricultural Research (CGIAR) was formed in 1971 by the Food and Agricultural Organization (FOA) of the United Nations, the United Nations Development Program, and the World Bank as co-sponsors.

The CGIAR is a unique organization with a mission to improve food production in developing countries. CGIAR serves as a mechanism to promote interaction among autonomous international centers in a unified mission to improve agricultural production and nutrition for rural and urban people in developing countries. The Group is advised by an independent Technical Advisory Committee (TAC) with a Secretariat headquartered in the United Nations Food and Agricultural Organization in Rome and two Scientific Advisers at the CGIAR Secretariat located in the World Bank in Washington, D.C. Recommendations by TAC and the CGIAR Scientific Advisers are usually considered carefully but are binding on no one (TAC, 1988).

CGIAR Centers are responsible primarily to their Governing Boards, but scientific input from TAC and the CGIAR Secretariat influence policies and research directions within the System.

Under this supportive structure nine more International Centers were brought under the umbrella of the CGIAR System by 1979. These were as follows: the West Africa Rice Development Association (WARDA), the Centro Internacional de la Papa (CIP), the International Board for Plant Genetic Resources (IBPGR), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the International Livestock Center for Africa (ILCA), the International Laboratory for Research on Animal Diseases (ILRAD), the International Food Policy Research Institute (IFPRI), the International Center for Agricultural Research in the Dry Areas (ICARDA), and the International Service for National Agricultural Research (ISNAR). The year each Center was founded and its headquarters location are indicated in Table 4.5.

Table 4.5 also shows the funding levels, both core and non-core for the 13 Centers in 1988. It should be noted that the expenditures by the CGIAR System represent only about 10% of the total expenditures for developing country agricultural research and some 4% of global agricultural research expenditures.

Changes in funding levels for each of the 13 Centers since 1981 are reflected in Table 4.6 along with the percentage of the core funding coming from AID. It should be noted that the level of core funding increased some 63% in nominal terms from 1981 to 1988. In real terms, the increase was, of course, much less due to the relatively high rates of inflation during parts of that period. In fact, in several of the intervening years, funding increases did little more than accommodate inflation.

The success of the Centers associated with the CGIAR has led to the creation of a number of additional Centers since 1971. These include the Asian Vegetable Research and Development Centre (AVRDC), the International Board for Soils Research and Management (IBSRAM), the International Center for Integrated Mountain Development (ICIMOD), the International Centre of Insect Physiology and Ecology (ICIPE), the International Center for Living Aquatic Resources Management, Inc. (INCLARM), the International Council for Research in

Table 4.5--Headquarters Location, Founding Date and 1988 Funding Levels for The International Agricultural Research Centers in the CGIAR System

Center	Year Founded	Headquarters Location	Funding Levels - 1988 ($000,000) Core	Non-Core
CIAT	1968	Colombia	$ 24.14	3.81
CIMMYT	1964	Mexico	26.14	4.93
CIP	1972	Peru	17.60	2.51
IBPGR	1973	Italy	5.70	0.54
ICARDA	1976	Syria	18.33	3.71
ICRISAT	1972	India	24.71	12.63[1]
IFPRI	1975	U.S.A.	8.88	0.10
IITA	1967	Nigeria	21.26	14.3
ILCA	1974	Ethiopia	14.98	1.59
ILRAD	1974	Kenya	12.86	0.52
IRRI	1959	Philippines	26.69	7.72
ISNAR	1979	Netherlands	6.30	1.79
WARDA	1971	Cote d'Ivoire	5.67	
		TOTAL	$213.26	$54.15

1/ $5.39 million of this total is for capital projects.

Source: Secretariat, CGIAR, Washington, D.C., Jan, 1989.

Table 4.6--Percent Core Funding of CGIAR Centers
Provided by AID -- 1981-1984-1988

Center	1981 Funding level $000,000	1981 % from AID	1984 Funding level $000,000	1984 % from AID	1988 Funding level $000,000	1988 % from AID
CIAT	15.88	27.4	23.5	23.8	24.14	20.0
CIMMYT	18.57	30.2	20.7	29.0	26.14	20.0
CIP	9.00	24.4	9.7	23.7	17.60	11.6
IBPGR	2.97	26.9	4.0	22.5	5.70	14.0
ICARDA	13.07	24.9	21.0	25.2	18.33	25.2
ICRISAT	13.03	22.3	21.0	23.1	24.71	16.9
IFPRI	2.75	29.1	4.3	32.6	8.88	17.7
IITA	15.50	30.3	20.9	30.1	21.26	30.2 1/
ILCA	9.11	26.3	12.6	25.4	14.98	26.7 1/
ILRAD	9.36	33.1	9.3	26.9	12.86	16.7
IRR	17.40	24.7	19.7	20.5	26.69	19.7
ISNAR	2.03	29.5	3.3	27.3	6.30	13.9
WARD	1.88	--	2.0	--	5.67	-0-
TOTAL	130.55 2/	26.9%	170.0 2/	26.3%	213.26	19.7 1/

1/ These amounts are higher than normal because of a one-time addition of $1 million to both IITA and ILARD. Without this special allocation, the figures would have been as follows: IITA - 25.6%; ILCA - 20.0%; and the total of the System - 18.8%.

2/ Some of the increase from 1981 to 1984 resulted in the shift of some special project funding to Core.

Sources: CGIAR Secretariat and S&T/Agr., Washington, D.C., January, 1989.

Agroforesty (ICRAF), the International Fertilizer Development Center (IFDC), the International Irrigation Management Institute (IIMI), the International Network for the Improvement of Bananas and Plantains (INIBAP), the International Union of Forestry Research Organization (IUFRO), and the International Trypanotolerance Center (ITC). The dates each of these Centers was founded and the headquarters location are indicated in Table 4.7. Also found in Table 4.7, are the core funding levels for each of the Centers along with the level of funding provided by AID.

It should be noted that the total funding level for these eleven Centers is approximately 16% of the funding level for the thirteen Centers that comprise the CGIAR System. Five of these Centers have been created within the last five years and have not had time to develop a substantial support base. The Center currently receiving most financial support, IFDC, derives about 40% of its resources from AID.

The thirteen Centers in the CGIAR System cover a wide variety of mandates (Table 4.8). Major food crops are the primary rationale for many of the Centers while two deal with livestock, one with policy, one with genetic resources for crops and one with the strengthening of national agricultural research systems.

The mandates for the non-CGIAR Centers are reflected in Table 4.9. Two of these deal with food crops, several others deal with factors of production while others are intended to support research on livestock diseases, aquaculture, forestry and agroforestry.

The CGIAR Centers attempt to obtain as much unrestricted, core funding as possible so that they can exercise more control and flexibility over their research efforts. While funding for international centers has not grown much in real terms in the 1980s, the relationship between special project and core funding has remained relatively stable--with core funds representing 80% or more of the total. Special project funding is invaluable in furthering agricultural research but such support tends to be less stable.

International centers have emerged as lynch pins in global agricultural research system because they excel in a number of research and technical assistance areas. The comparative advantage of international centers is particularly apparent in:

- the assembling, maintaining, and evaluating major crop germplasm collections;
- the development of crop varieties adapted to broad range of environments;
- providing linkages to basic research;
- training at various levels, particularly for adaptive research;
- information dissemination; and
- development and testing of path breaking concepts and methodology.

Overall, the IARCs--especially the older ones in the CGIAR System--have been, by any measure, tremendously successful. Their programs which are

Table 4.7--Headquarters, Founding Dates and Founding Levels for International Agricultural Research Centers Not Affiliated with CGIAR System

Center	Year Founded	Headquarters Location	Funding Level - $000,000 Total - 1987	AID - 1988
AVRDC	1971	Taiwan	$ 5.43	$ 1.0
IBSRAM	1985	Thailand	1.90	0.05
ICIMOD	1983	Nepal	1.74	-0-
ICIPE	1977	Kenya	8.31	0.16 1/
ICLARM	1977	Philippines	2.88	0.1
ICRAF	1978	Kenya	4.20	-0-
IFDC	1974	U.S.A.	8.65	3.46 1/
IMMI	1984	Sri Lanka	4.29	0.3
INIBAP	1984	France	0.71	0.06
ITC	1984	The Gambia	4.90	-0-
IUFRO	1973	Austria	0.54	-0-
	TOTAL		43.55	5.13

1/ Funded as projects in S&T/Agr.

Source: CGIAR Secretariat and S&T/Agr.

Table 4.8--Mandates and Georgraphical Coverage of IARCs in the CGIAR System

Mandate	Center	Geographical Responsibility
Crops		
Barley	CIMMYT	Latin America
	ICARDA	Third World
Cassava	CIAT	Third World
	IITA	sub-Saharan Africa
Chick Pea	ICRISAT	Third World
	ICARDA	North Africa, West Asia
Coco Yam	IITA	Third World
Cowpea	IITA	Third World
Fava Bean	ICARDA	Third World
Ground Nut	ICRISAT	Third World
Lentil	ICARDA	Third World
Maize	CIMMYT	Third World
	IITA	sub-Saharan Africa
Millet	ICRISAT	Third World
Pastures	CIAT	Latin America
	ILCA	sub-Saharan Africa
Pigeonpea	ICRISAT	Third World
Potato	CIP	Third World
Phaseolus Beans	CIAT	Third World
Rice	IRRI	Third World
	CIAT	Latin America
	IITA	Cropping systems in West Africa
	WARDA	West Africa
Soybeans	IITA	sub-Saharan Africa
Sorghum	ICRISAT	Third World
Sweet Potato	IITA	Africa
	CIP	Third World
Triticale	CIMMYT	Third World
Wheat	CIMMYT	Third World
	ICARDA	North Africa, Southwest Asia
Yam	IITA	Third World
Livestock		
Livestock Productivity	ILCA	sub-Saharan Africa
Trypanosomiasis	ILRAD	sub-Saharan Africa
Theileriosis	ILARD	sub-Saharan Africa
Other		
Food Policy	IFPRI	Third World
National Agricultural Research Systems	ISNAR	Third World

Table 4.9--Mandates and Georgraphical Coverage of IARCs Not Associated With the CGIAR System

Mandate	Center	Geographical Responsibility
Agroforestry	ICRAF	Third World
Aquaculture	ICLARM	Third World
Bananas and Plantains	INIBAP	Third World
Fertilizer Technology	IFDC	Third World
Forestry	IUFRO	World
Integrated Pests and Disease Management	ICIPE	Third World (especially Africa)
Trypanosomiasis	ITC	sub-Saharan Africa
Soil Management	IBSRAM	Third World
Sustainable Development of Mountain Environments	ICIMOD	Highland Tropics & Subtropics -- especially Himalayas
Vegetables	AVRDC	
Chinese cabbage		Asia
Mung Bean		Third World
Soybeans		Third World
Sweet Potatoes		East & Southeast Asia
Tomatoes		East & Southeast Asia
Water Management	IIMI	South Asia, Southeast Asia, Africa

reviewed every five years or so, by external teams of international scientists, have almost invariably been given very high marks. Moreover, the Centers, their leaders and scientists, have received an impressive array of citations and awards in recognition of their outstanding contributions. For example, a Center scientist received the Nobel Peace Prize for contributions to the alleviation of global hunger. Center Directors have been the first two recipients of the prestigious General Foods, World Food Prize. Many other significant awards have been made by a wide array of national governments and organizational entities to the Centers and their personnel.

Moreover, the CGIAR in recent years has conducted a very comprehensive study of the impact which the IARCs have made on agriculture in the developing world. The study has emphasized the significant contributions which the Centers have made to the development of improved germplasm and other aspects of agricultural technology, to the improvement of the efficiency of agricultural research, to the training of researchers in national systems, to the improvement in the organization of national research systems, to strengthening national capacities for research and policy analysis, to the development of improved agricultural policies within developing countries, and ultimately, the contribution of all of these efforts to improved agricultural production within developing countries (Anderson, et al., 1988).

Some three years ago, it was estimated that the improved varieties of wheat and rice which grew primarily out of the work of only two of the international centers have provided, annually, about 50 million tons of additional food. This is enough to meet the typical cereal needs of some 500 million people (Baum, 1986).

Initially, the international centers were envisaged as resource centers to backstop national programs. The fundamental role still exists, but the relationship is evolving from a patron-client arrangement to a genuine partnership in research. This more ideal, collaborative mode, as opposed to a top-down approach, is facilitated as national programs strengthen and are able to exercise more leadership in establishing priorities and coordinating programs.

The newer international agricultural research centers focus largely on factors of production, rely heavily on a networking approach, and have relatively small budgets.

While it seems unlikely that major new international centers will be built in the near future, more existing centers may be brought into the CGIAR, just as IFPRI came into the System in 1975. The Technical Advisory Committee (TAC) of the CGIAR is exploring the feasibility of bringing new centers into the System by examining the program areas of centers to see how they might complement, or fill in gaps of, existing CGIAR Centers. TAC's approach is to identify major problems or issues that are likely to remain relevant well into the next century and to see how well the current CGIAR Centers are facing these issues. Sustainability, income generation, food supplies, malnutrition, and poverty have been identified as critical issues for the international agricultural research system. Within this context, many donors have expressed interest in supporting an international research initiative on forestry, and this will likely be given serious consideration.

Multilateral and Bilateral Donor Support

The international donor community has made significant contributions to developing world agricultural research in the form of both bilateral and multilateral financial support. For example, the IARCs have been supported primarily by the governments of industrialized countries, international agencies such as the World Bank, UNDP and FAO, foundations from industrialized countries (primarily the U.S.), and by other organizations such as the regional development banks. In recent years, limited resources have also been contributed by some of the more advanced or "middle income" developing countries.

Support of the IARCs, however, represent only a part of this research assistance. In addition, individual nations and international organizations also provide significant bilateral and multilateral assistance for developing country agriculture research. The extent of this support is summarized in Table 4.10. Further indication of this support by major regions of the world is reflected in Table 4.3.

These data indicate that approximately $800 million is made available by the international donor community for bilateral and multilateral support for agricultural research in developing countries--plus an additional $155 million for the CGIAR System of IARCs. This total amount represents some 37% of all developing country expenditures and 13% of global expenditures for agricultural research.

The data in Table 4.10 indicate that in 1983, the United States provided some 42% of the bilateral support for developing country agricultural research. Substantial additional support was also provided through multilateral agencies. Historically, the U.S. has provided approximately 25% of the funding for many of the multilateral agencies such as the World Bank, the UN organizations, and the CGIAR.

Support for Developing Country Research by AID

The U.S. Agency for International Development (AID) has, historically, been a major supporter of developing country agricultural research. This support has been provided through several channels, including (1) the programs administered by the Bureau of Science and Technology, (2) the programs of the country missions administered through the Regional Bureaus and (3) the programs administered through the Office of the Science Advisor.

Bureau of Science and Technology/Office of Agriculture

Historically, the Bureau of Science and Technology has had two complementary functions: (1) supporting research to benefit developing country agriculture and (2) providing technical assistance to U.S. AID country missions. This report deals primarily with the research mission of the S&T Bureau Office of Agriculture.

A major concern of the S&T Bureau has been the programs of the international agricultural research centers. At one time, the core support of the CGIAR System was provided through the S&T Bureau. In recent years, however, the funding has been provided through the PCC Bureau, but decisions with regard

Table 4.10--External Funding for Agricultural Research by Region, 1983[1/]

(Constant 1980 U.S. $)
(000 U.S. $)

Donor	Africa	Asia	Latin Amer.	West Asia/ North Africa	Total[5/]
Australia	260	21,455	--	460	22,175
Belgium	N	N	N	N	12,500
Canada	N	N	N	N	27,800
Denmark	N	N	N	N	517
Finland	N	N	N	N	8
France	81,000	120	9,900	N	113,020
Japan	N	N	N	N	12,400
Netherlands[2/]	N	N	N	N	13,535
New Zealand	N	N	N	N	315
Norway	N	N	N	N	3,080
Sweden	4,875	2,015	1,795	475	9,160
Switzerland[2,3/]	N	N	N	N	3,550
W. Germany[4/]	N	N	N	N	22,795
United Kingdom[3/]	2,783	2,664	1,590	751	16,010
United States[3/]	60,000	37,000	14,250	19,500	191,960
Total Bilateral	$187,366	$94,934	$44,402	$30,000	$448,825
IFAD	N	N	N	N	17,130
EEC	N	N	N	N	17,555
IBRD	25,780	38,360	78,920	21,970	165,030
IDC	--	--	N	--	30,775
UNDP/FAO[3,5/]	35,000	N	N	N	117,000
Total Multilateral	74,765	74,515	128,165	45,545	347,490
Total Multilateral and Bilateral	262,131	169,449	172,567	76,266	796,315
CGIAR System[3,4/]	45,000	35,650	50,530	15,000	155,000
Overall Total	307,131	205,099	223,097	91,266	951,315

1/ Does not include home base costs of technical assistance operations by donor countries or international agencies. When data not available in 1983, it was assumed that the amount available was the same as for 1980 -- not lower.
2/ Includes contributions of core budgets of CGIAR.
3/ Includes some projects not identified by region.
4/ CGIAR data includes core and special project expenditures.
5/ Includes some projects not identified by regions. Therefore, totals may be higher than the sum of regional figures.
-- No contributions recorded
N No data available

Source: Peter Oram, Unpublished data. IFPRI. Washington, D.C.

to allocations of resources to the individual centers have been, primarily, a function of the S&T Office of Agriculture (S&T/Agr).

Table 4.11 provides a summary of core funding of the CGIAR Centers by AID from 1981 through 1988. In nominal terms, funding increased from $35 million in 1981 to a high of $46.25 million in 1986. During this period, AID was providing approximately 25% of the total funding of the CGIAR Centers. Due to budgetary constraints, however, AID's funding dropped to $40 million in 1987--a level that would have continued in 1988 had there not been a special allocation of $2 million to support an alley cropping program in Africa.

Table 4.6 shows how the levels of funding by AID for the CGIAR Centers has changed since 1981. For example, in 1981, AID provided from 22-33% of the funding of individual centers (except for WARDA which has, historically, received no core funding from AID). In 1988, AID provided from 11.6% to some 25% of the core funding of the individual centers. AID's share of total CGIAR System support dropped from 26.9% in 1981 to 19.7% in 1988. This level of funding is expected to be less than 18% in 1989. (The fact that AID's contribution exceeded the 25% level in some years apparently is related to changes in currency values during the year which affected the amounts contributed by various other donors when expressed in U.S. dollars).

Table 4.11 also shows how AID's special project funding for the CGIAR Centers has changed since 1982. Although S&T/Agriculture has provided some special project funding, most of this has come from Regional Bureaus/Country Missions. For example, the Africa Bureau has supported WARDA for many years through special project funding.

It is noteworthy that the steady increase in special project funding has tended to offset the level off and decline in core funding of the CGIAR System. It must be recognized, however, that despite the increases in special project funding, the overall support for the CGIAR System in recent years has declined in real terms.

S&T/Agriculture has also provided limited support to the non-CGIAR Centers. Table 4.7 reflects allocations of some $5 million in 1988--some two-thirds of which is provided to one Center, IFDC. Funding for the non-CGIAR Centers is provided through the project portfolio of S&T/Agriculture, details of which are discussed in the following paragraphs.

Table 4.12 indicates three major groupings of research activities supported by S&T/Agriculture: (1) the non-CGIAR Centers which receive some $5.3 million; (2) support for seven Collaborative Research Support Programs (CRSPs); and (3) some 20 individual projects funded at a total level of $13.2 million.

Two of the 20 projects warrant special mention since each involves a number of individual small programs or projects. The Special Constraints Research Project involves funds for small contracts with U.S. universities to do research on special problems or constraints of importance to the CGIAR Centers. The Agricultural Technology-R&D Project involves some $2.1 million which is allocated to a range of activities, including the following:

- Grant to the Rodale Research Center	$100,000
- USDA Rhizobium collection	80,000

Table 4.11--AID Funding of CGIAR System (Core and Special Projects)

Center	1981	1982	1983	1984	1985	1986	1987	1988
			Core Funding					
				$000,000				
CIAT	4.350	4.900	5.400	5.600	5.540	5.600	4.820	4.820
CIMMYT	5.600	6.550	6.000	6.000	6.000	6.100	5.250	5.250
CIP	2.200	2.200	2.300	2.300	2.300	2.325	2.000	2.050
IBPGR	0.800	0.850	0.900	0.900	0.900	0.975	0.800	0.800
ICARDA	3.250	3.650	5.000	5.300	5.460	5.600	4.820	4.620
ICRISAT	2.900	3.900	4.350	4.850	4.815	4.850	4.175	4.175
IFPRI	.800	.950	1.100	1.400	1.400	1.500	1.475	1.575
IITA	4.700	5.935	6.200	6.300	6.240	6.300	5.435	6.435 1/
ILCA	2.400	2.550	2.800	3.200	3.175	3.475	3.000	4.000 1/
ILRAD	3.100	2.400	2.500	2.500	2.490	2.525	2.150	2.150
IRRI	4.300	5.900	6.300	6.000	5.940	6.050	5.250	5.250
ISNAR	.600	1.000	.900	.900	.900	.950	0.825	0.875
WARDA	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-
TOTAL CORE	35.000	40.785	43.750	45.250	45.160	46.250	40.000	42.000 2/
TOTAL SPEC. PROJECTS	N.A.	7.95	9.0	9.93	13.10	15.31	17.23	19.60
TOTAL AID FUNDING	N.A.	48.735	52.750	55.18	58.26	61.56	57.23	61.60

1/ Includes a special one-time contribution of $1 million to initiate alley cropping research network in Africa.

2/ Includes special allocation of $2 million as noted in footnote 1 above.

Source: S&T/Agr., January, 1989.

Table 4.12--Level of Funding for S&T/Agriculture Projects
FY 1989

Project No.	Project Title	Funding ($000)	
936-4136	Special Constraints Research	$ 500	
936-4109	Agr'l. Technology - R&D	2,120	
936-4024	Fisheries Dev. Supp. Svcs.	275	
936-4161	Reprod. Studies/Milkfish	1,000	
936-4180	Aquaculture Res. & Support	255	
931-0621	Spring & Winter Wheat	325	
931-1229	Soils Mgmt. Support Svcs.	660	
931-1323	Storage/processing Fruits & Vegetables	360	
936-4021	Technol. of Soil Moisture Mgmt.	800	
936-4054	Int'l. Benchmarks Sites Network	1,080	
936-4084b	Agricultural Policy Analysis	840	
936-4132	Soybean Utilization & Research	550	
936-4137	Biotechnology for Tissue Culture	650	
936-4142	IPM & Environmental Protection	600	
936-4143	R&D of Improved Seed Prod./Utiliz.	255	
931-4144	Postharvest Grain Systems R&D	425	
936-4173	Vertebrate Pest Mgmt. Systems	125	
936-4177	Improved BNF thru Biotechnology	1,200	
936-4178b	Improved Animal Vaccine thru Biotech.	800	
936-4179	Irrig. Mgmt. Support & Research	400	
	Subtotal - Projects		13,230
931-1254	Sorghum/Millet CRSP	2,700	
931-1310	Bean/Cowpea CRSP	2,600	
931-1311	Soil Management CRSP	2,100	
931-1328	Small Ruminants CRSP	2,800	
936-4023	Pond Dynamics CRSP	920	
936-4048	Peanuts CRSP	1,700	
936-4146	Stock Assessment CRSP	700	
	Subtotal - CRSPS		13,520
931-0054	Int'l. Fertilizer Development Center	3,460	
936-4111	Int'l. Ag. Research Centers	1,680	
936-4083	Host Resistance/Integ. Tick Control (ICIPE)	160	
	Subtotal - International Centers		5,300
	TOTAL		$32,050

Source: AID/S&T/Agr., Jan., '89

- USDA plant and seed material	70,000
- Dept. of Commerce/NOAA for fisheries research	240,000
- Support of 1 AAAS Fellow	65,000
- USDA for long-term technical assistance, support of RSSAs	700,000
- Fish aggregating devices project	200,000
- CRSPs feasibility study with cool season legumes	100,000
- Sustainability conference with National Academy of Sciences	250,000

Currently the Office of Agriculture is allocating some $13.5 million annually of its research funds in support of the Collaborative Research Support Program (CRSP). This is a program initiated through Title XII of the Foreign Assistance Act and involves a series of multipurpose networks, linking U.S. institutions with developing country research organizations. The central idea is to match the agricultural research interest of the U.S. universities with similar interest or thrust in developing countries.

At present some 40 U.S. universities are working with 66 institutions in 30 developing countries in various CRSPs programs. Some 900 scientists are involved in different CRSP activities worldwide. Based on recommendations growing out of a special study by the National Academy of Sciences, CRSPs dealing with the following subjects are now in operation: small ruminants, sorghum and millet, beans and cowpeas, tropical soils, groundnuts, aquaculture, and fisheries' stock assessment.

Various assessments of CRSP projects have been very positive, emphasizing the merits of this collaborative approach between scientists in the U.S. and the developing world. This approach has also provided a means to achieve significant leveraging of AID funds in addressing important developing country research needs. Moreover, research activities associated with CRSPs have proven to be of significant value to U.S. agriculture, as well as to developing countries.

A comprehensive review of four of the CRSPs by Hogan, et al. (no date) led the conclusion that:

- the CRSPs appear to be effective in addressing important research problems in less developing countries;
- they are consistent with AID's food and agriculture policy and strategies;
- the research undertaken, with few exceptions, appears to be of excellent quality and quantity;
- CRSPs have made substantial contributions to increasing research capability in developing countries; and
- the costs of CRSPs appear to compare favorably with other international research institutions, including the IARCs. Overhead costs appeared to be somewhat less for the CRSPs and the capital costs were substantially less than for the Centers.

A word of caution was expressed however, by the review team. As AID budgeting resources have declined, so have budgetary allocations to the CRSPs.

The team concluded: "Reductions in budgets and uncertainty with respect to future budget allocations have or soon will reach the point where CRSPs can no longer operate effectively."

A summary of the S&T/Agr project portfolio is presented in Table 4.13. This indicates that approximately one-fourth of the $32 million in funds are allocated to crops (with primary emphasis on production). Soils and fertilizers, together, receive one-fourth of the total funding. Animal and fisheries/aquaculture research receive almost another one-fourth of the funding.

Several points of the summary might be highlighted:

- Seven different projects in fisheries and aquaculture receive about the same level of support given all other animal research (production and disease-related).
- Only 2.6% of the resources are allotted to social science research.
- While soil and fertilizer research receives some 25% of the total funding, water research is allotted only 1.2% of the resources.
- Excluding the funding for the multiple programs associated with the Special Constraints and Agricultural Technology projects, the 18 individual projects in the portfolio are funded at an average level of $590,000 each. With management expenses deducted, the amount remaining to support research or technical assistance is, therefore, relatively limited.

The data in Table 4.13 raise questions concerning the rationale for the apportionment of resources among the various areas of research. Has this apportionment resulted from a careful analysis of priorities within AID? Or is it the product of an evolutionary process over the years, influenced by various internal and external pressures--including those form Congress? We suspect the latter.

Figure 4.9 indicates how the S&T Office of Agriculture budget has changed in both nominal and real terms from 1977 to 1988--not considering the support for the IARCs in the CGIAR system. These data show that while the level of funding for the office increased in nominal terms in the early 1980s, the funding level was slightly lower in 1988 than it was 11 years earlier. In real terms, however, the Office of Agriculture is funded in 1988 at a level approximately one-half the level in 1977. This sharp decline in budgetary support is severely affecting the ability of the S&T Office of Agriculture to respond to the many challenges and needs relating to developing country agricultural research.

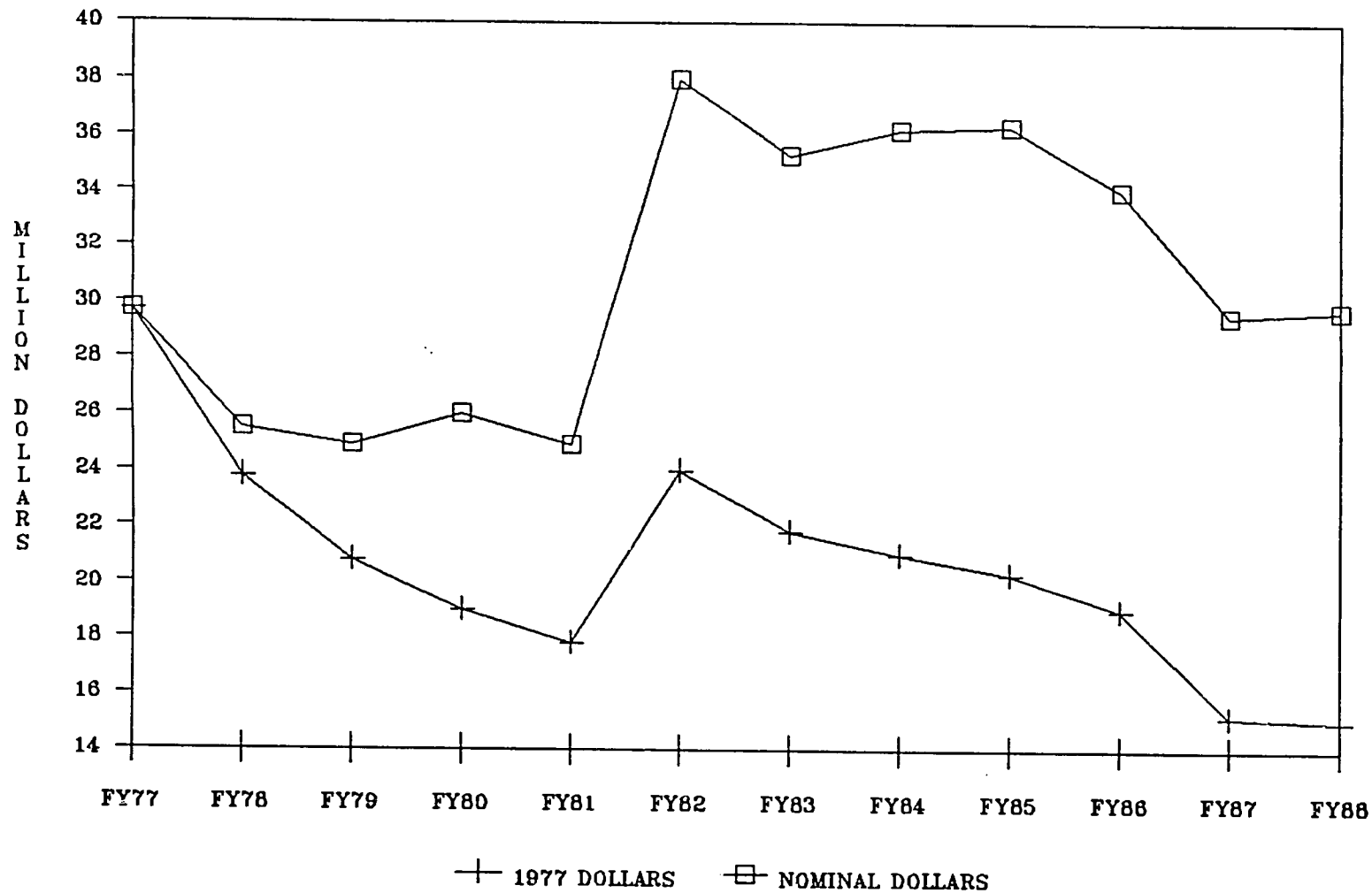
Regional Bureaus/Country Missions

A major portion of total AID funding for research is provided by the country missions, functioning as a part of the three Regional Bureaus. Table 4.10 reflects some measure of the amount of bilateral support being devoted to agricultural research in the respective regions in 1983.

Table 4.13--Funding for S&T/Agricultural Projects

Categories		Proportion of Total Funding (%)
Fisheries and Aquaculture		11.2
Crops (primarily production)		25.2
Animals (primarily production)		8.7
Social Science		2.6
Plant Protection		2.3
Animal Disease		3.0
Post Harvest		4.2
Inputs		31.5
Soils	14.5	
BNF-Rhiz	4.0	
Seeds	1.0	
Fertilizer	10.8	
Water	1.2	
Other		11.3
		100.0

FIGURE 4.9 S&T/AGR NON-IARC BUDGET
FY77 - FY88, with and without inflation



The Asia/Near East Bureau indicates that agricultural research will continue to be given high priority. During the last 20 years country missions under that Bureau have invested much in buildings, laboratories, and training. The programs in Indonesia, Pakistan, Egypt, India and a few other countries reflect these investments. The problem now, according to the leadership of the Bureau, is how to make these institutions "function more effectively." "The systems have a scientific capability but what is lacking, primarily, is management capacity." It was further suggested that while there is some emphasis in the region on diversification, there is a need to give increased emphasis to maintenance research. It was indicated that diversification should come into the picture "further down the road." Leaders in the Bureau further indicate that in the past, the Bureau has focused on research to increase production but that now there is a need to focus more research on income improvement as well (Cobb, 1988).

The Africa Bureau is giving major support to agricultural research through bilateral programs in the country missions and through special project funding of the IARCs. The basis for this emphasis was established through a series of special efforts within the Bureau in the early to mid 1980s--efforts which culminated in the development of "Plan for Supporting Agricultural Research and Faculties of Agriculture in Africa" (Africa Bureau, AID 1985).

The Plan called for substantially strengthening the national agricultural research system in eight core African countries which would be designated as "technology-generating" countries. In addition, the plan involved building of strong applied research capacities in other African countries (referred to as "technology accepting" or "adapting" countries) to enable local scientists to screen and borrow technologies and adapt them to local environments. The plan also called for the use of research networks which would link national agricultural research systems with IARCs, CRSPs, and other research programs. The network would link a critical mass of scientists to work on aspects of problems which transcend national borders. Support is being given to research networks dealing with eight key food crops. In the "technology adapting" countries, major emphasis is placed on training at M.S. and Ph.D. levels. The objective is to develop a critical mass for one or two commodities in these countries in terms of an ongoing research program (Jepsen, Martin, Sherper, 1988).

Currently, the Bureau and/or its country missions are funding several of the International Centers to provide coordinators for each of the commodity networks--CIMMYT, IITA, CIP, CIAT, and ICRISAT. There is also an effort by the Bureau to bring other donors into the network so that the work of the various donors might complement one another more effectively.

The Latin American/Caribbean Bureau, in 1987, published a paper entitled, "Recommendations for Supporting Agricultural Research Institution- Building in Latin America and the Caribbean" (Sarles, 1987). The paper makes a case for agricultural research in the region, and includes a section entitled, "Rethinking Traditional Institution-Building in Agricultural Research." Four recommendations are made which might serve as guidelines for formulating an agricultural research program:

- -- Improve external linkages
- -- Support government research programs
- -- Improve educational programs
- -- Collaborate with the private sector.

The Latin American Bureau, in developing 8 areas of emphasis, did not include such things as biodiversity and biotechnology. They believe the S&T Bureau should be addressing such areas. The LAC Bureau and its country missions are currently focusing more efforts on export crops, realizing that CRSPs and the International Centers are working on food crops. The Bureau and its missions are also focusing on low-cost technology which might help to stabilize eroding hillsides and mountains in the region. The Bureau is not supporting the International Centers directly through special project funding. However, they are supporting regional centers such as CATIA and CARDI (Wingard, 1988).

In summary, AID is providing significant levels of support to national research systems in 12 African countries, 11 countries in Asia/Near East (dropping to 7 in FY 89) and 4 countries in Latin America and the Caribbean. In addition, AID is supporting 8 research networks in Africa, and 2 regional research centers (CATIA and CARDI) in Latin America and the Caribbean. The current total of this bilateral investment is about $95 million, divided as follows: Africa, $31 million; Asia and Near East, $47 million; and Latin America and the Caribbean, $17 million. The total AID investment in agricultural research and training (through its contribution to IARCs and through S&T and the Regional Bureaus/AID missions) is currently approximately $165 million annually (Furtick, 1988).

Office of the Science Advisor

The Office of the Science Advisor in AID administers a portfolio of projects from a budget of some $8.6 million annually. The office supports 6 research areas to which $1 million annually is allocated each of the fund research grants over a span of three years. While this research is not limited to agriculture, each of the six areas offers the possibility of funding research projects related to agriculture. The six areas are as follows:

- Biotechnology/Immunology in human and/or animal systems, including recombinant microbiology, monoclonal antibodies, and related immunological techniques.

- Plant Biotechnology, including tissue culture research, somaclonal variation, and recombinant microbiology to enhance food crops; also improvement of drought tolerance and enhancement of resistance to disease, insecticides and/or herbicides, for example, through studies of gene expression, transfer and regulation.

- Chemistry for World Food Needs particularly biochemical growth regulation in plants and animals, soil chemistry, soil-plant-animal relationships, innovative food chemistry, studies of natural pesticides from plants, biological nitrogen fixation, and the chemistry of integrated aquaculture systems.

- Biomass Resources and Conversion Technology, emphasizing improved, renewable production and efficient use of woody biomass (especially fast-growing trees) and tropical grasses (including cane and bamboo) for fuels, fodder, and highly valued chemicals; newer and simpler methods to identify economically useful biomass products and byproducts.

- Biological Control of (a) mosquito and snail vectors of human pathogens and (b) plant crop pests and pathogens. Emphasis is given to ecologically acceptable interruption of disease transmission based on host-vector relationships, genetics, biochemistry, immunology, natural predation, and pathobiology.

- Diversity of Biological Resources, emphasizes innovative research on terrestrial and aquatic plant/animal microbial species of economic promise for development. This includes: new methods for identifying economically useful species and products, species for the restoration and optimization of habitat, ecosystem maintenance and productivity, and development of new molecular-genetic methods.

For the entire length of the project, grants range from a few thousand dollars up to a maximum of $150,000. These grants are non-renewable except for selected developing country investigators who may compete for funding in a subsequent review cycle.

In addition to the competitive research grant program summarized above, the Office of the Science Advisor has a cooperative agreement with the U.S. National Academy of Sciences (NAS). The NAS Board on Science and Technology for International Development (BOSTID) uses these funds to provide assistance to the recipient of research grants under this program, convene meetings, advise on research topics and projects, and issue study reports on selected research opportunities related to development. Some $2 million is allocated to this function by AID (Minners, 1989).

Research Grants for Historically Black Colleges and Universities

The Office of Research and University Relations within the Bureau for Science and Technology administers a modest grant program for research within historically black colleges and universities. Funds are available for work in four main program areas: agriculture, nutrition, health, and rural development. The total cost to AID of a proposed project may not exceed $100,000 and in most cases should be scheduled for completion within two years after the grant award.

Following is a summary of project funding history under this program in recent years: 1984, 11 projects were funded for a total amount of $383,445. In 1985, 33 projects were funded for a total of $2,497,954. In 1986, 15 projects were funded for a total of $1,295,010. In 1987, 32 projects were approved for a total of $1,862,878 (some of these were approved, contingent upon the availability of funds). Of that total in 1987, $757,939 was committed to projects relating to agriculture. In 1988 projects were funded for a total of $1,569,775 (O'Quinn, 1989).

Research Advisory Committee (RAC)

For the past several years AID has had an official Research Advisory Committee (RAC). Until the early 1980s, the function of RAC was to provide technical examination of individual research projects. However, it was recognized that there was a need for a body to provide broad policy and strategy advice to the Agency on the research programs of AID. In a revised charter for RAC approved by the Administrator in October 1988, the Committee was given the following primary duties: (1) to provide guidance in the

formulation of research policies and strategies and (2) to evaluate, as requested, the progress and future potential of Agency-funded research activities and report its findings and recommendations.

The Committee is composed of not more that 15 members, appointed by the Administrator, as representatives from universities, non-profit institutions, industry, and other private sector institutions, with expertise in LDC research. Members will serve in a representative, not an individual, capacity and, therefore, are not considered government employees for the purpose of the conflict of interest laws. The Committee is expected to meet approximately three times each year (O'Quinn, 1989).

Organization of the S&T Bureau

Within the course of this current study, numerous individuals, both within and outside of the S&T Bureau, have raised questions or expressed concern about the organization of the Bureau. The concerns relate primarily to the separation of vital components of a overall agricultural research effort. This is reflected in the organizational chart, Figure 4.10, which indicates that programs in agriculture, nutrition, forestry, environment and natural resources, and rural development are found in three different directorates and four separate offices. Obviously, the programs in agriculture are separated from several other closely related areas.

The terms of reference for our study did not call for examining this issue. However, in considering the development of effective agriculturally-related research programs within the S&T Bureau, the administrative and programmatic separation of these several components does not appear to be the most desirable arrangement.

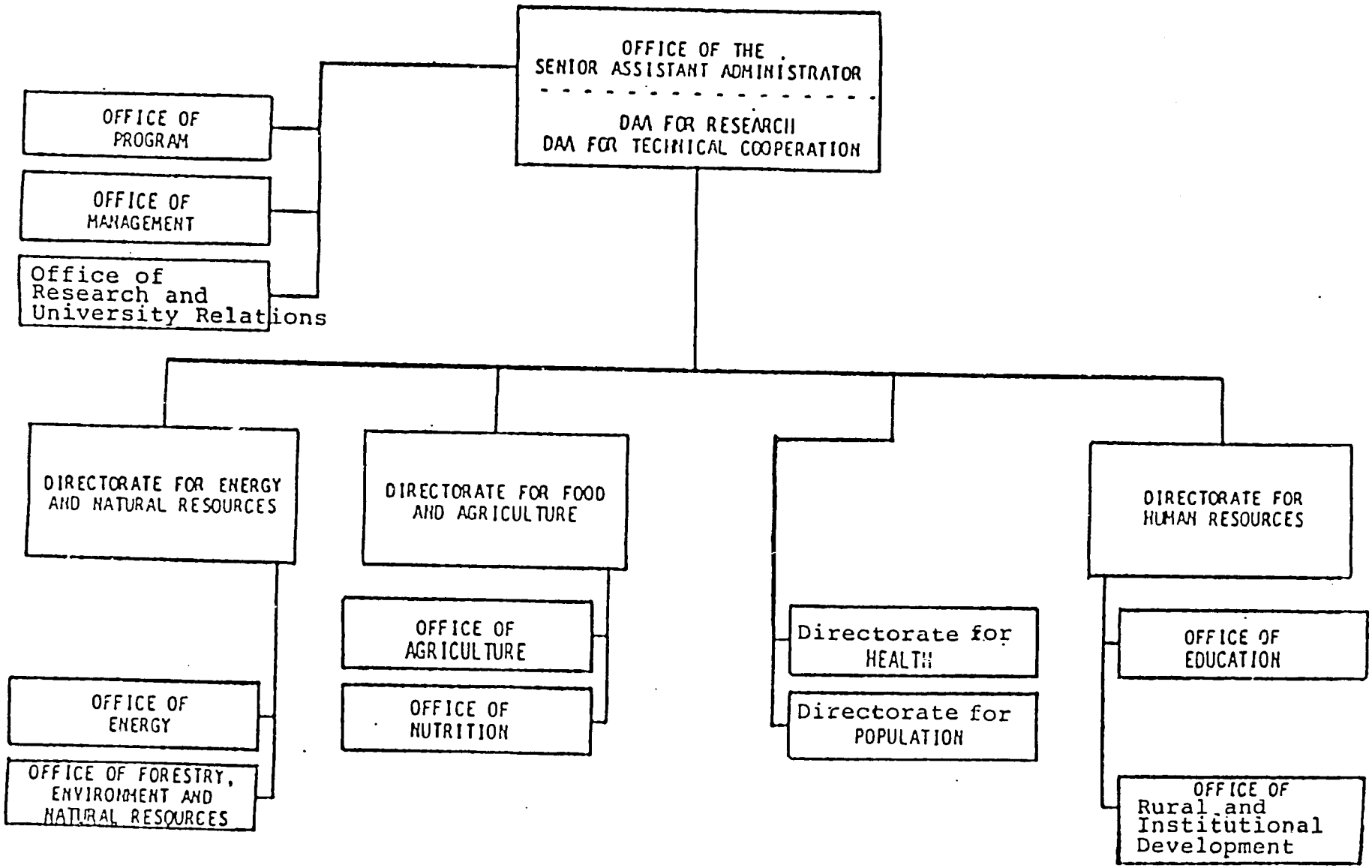
International Research Networks

International networks have emerged as bridges for transferring information and technology from developed country institutions to the Third World, and between agricultural research programs and developing countries (Plucknett and Smith, 1984, 1986, 1987). Networks link individuals and institutions working on widely shared problems by using existing facilities and staff, rather than by setting up new institutions.

Four basic kinds of networks operate to further agricultural research worldwide: information exchange networks, material exchange networks, scientific consultation networks, and collaborative research networks. Information exchange networks are essentially newsletter operations designed to keep interested colleagues abreast of research developments and policy changes. Material exchange networks are set up primarily to exchange crop germplasm or agricultural machinery. International nurseries, where proto-varieties are screened in a wide variety of environments, are the most common form of material exchange networks. Scientific consultation networks link ongoing research efforts with minor adjustments in methodologies and research design. In collaborative research networks, participants jointly plan their research agenda and adhere to a common methodology.

Over 75 international networks currently operate in the agricultural sciences. They range in size from a few dozen individuals on a mailing list,

Figure 4.10 -- BUREAU FOR SCIENCE AND TECHNOLOGY



to multi-million dollar operations involving hundreds of scientists on nearly every continent. The International Rice Testing Program (IRTP), coordinated by IRRI, includes 28 sub-nurseries that are planted in 80 countries. More than half of the entries are contributed by national programs, indicating that IRTP is a successful mechanism for horizontal technology transfer. After a decade of operation, IRTP had launched more than 120 high-yielding rice varieties for a wide range of growing conditions by 1985. Other international networks tackle such diverse topics as farming systems research, livestock diseases, agroforestry, soil fertility and various crops.

The Collaborative Research Support Programs (CRSPs), which match agricultural research needs of certain developing countries with the interests and capabilities of U.S. land-grant colleges, are furthering work in a wide array of agricultural research areas. Each CRSP has a management body, technical committee, board, and external evaluation panel, to provide guidance and quality control. CRSP are exemplary models for networking because they are based on self-interest and generate mutual benefits.

The value of inter-network linkages is increasingly recognized by donors and research institutions. Within S&T/Agr, for example, the proposed Soil and Water Management (SWAN) project will serve as a vehicle to bring together several individual programs and networks concerned with soil and water resources for agriculture. The SWAN program will consolidate the existing soil and water management portfolio within the Office of Agriculture into a single management unit. SWAN will also help coordinate activities between two soil networks--the soil management CSRP and the International Benchmark Sites Network (IBSNAT)--as well as individual soil and water-related projects supported by AID.

Networks have proliferated because they improve efficiency of research, focus scarce resources on widespread problems where payoffs are more likely to reach a sizeable number of farmers and consumers, improve the confidence and morale of scientists in the Third World, and develop scientific leadership skills. Many material exchange, scientific consultation, and collaborative research networks organize monitoring tours that expose often isolated scientists to new environments and approaches to research. Furthermore, some networks operate short training courses to increase the effectiveness of participants.

There are excellent opportunities to expand the use of network concepts in addressing the agricultural research needs of developing countries. However, they should be correctly employed so as not to overburden already thinly stretched NARS staff. There are now at least 50 networks operating in Africa alone (Oram, 1989). There is need for careful consultation by donor agencies, IARCs and UN agencies before launching more networks.

Summary

Chapter 4 provides an overview of the international agricultural research system and indicates some of the contributions by AID to these global efforts.

Attention is focused upon the national systems for agricultural research (NARS) and how they are evolving. There are brief reviews of the contributions of the private sector in both industrial and developing countries and of the public sector in industrial countries.

There is a major treatment of the international agricultural research centers, the support provided by AID and other donors, and how the IARCs are expanding with the creation of a number of centers which are not part of the CGIAR network. There is an analysis of some of the significant contributions made to developing country agriculture by the IARCs and some suggestions of future potentials.

There is also a summary of agricultural research supported by AID, with special emphasis on that carried out under the direction of S&T/Agr. The Office of Agriculture research effort is briefly analyzed and questions raised concerning the apportionment of resources within the project portfolio. Reference is made, as well, to the very positive reviews and appraisals that have been made of the CRSPs. Serious concerns were expressed about the declining levels of financial support for the S&T/Agr research budget.

There is a brief summary of the research efforts being carried out through the three regional bureaus and the Office of Science Advisor along with the research grants to historically black colleges and universities.

A brief description is provided of the research advisory committee and its functions, and questions are raised about the overall organization of S&T Bureau and whether such a structure might pose problems in terms of effective program coordination. Finally, there is a treatment of international research networks and their utility.

The overview of the global research effort, including AID's contribution to this effort, provides some of the rationale for the recommendations set forth in Chapter 6.

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Chapter 5

SOME AGRICULTURAL DEVELOPMENT ISSUES WITH RESEARCH IMPLICATIONS

In considering a 1990s research agenda for S&T/Agriculture, it is appropriate to examine certain development issues that may impact that agenda. This section addresses some of these issues along with implications for research.

Issues

Rapidly expanding global populations have prompted the international donor community to give primary emphasis to research and other efforts aimed at meeting growing food needs of developing countries. In this regard, major attention has been focused on staple food commodities, especially the cereals.

The need for such emphasis on research to increase food production was also made more apparent as a result of the fact that the European colonial governments had been primarily concerned with supporting research on the principal export crops such as coffee, tea, sugar, cotton, and jute. As a result, food crop research was often neglected in the colonial era.

Most of the bilateral research efforts supported by the donor community have, since World War II, been directed toward increasing food production in the developing countries. Moreover, the Consultative Group on International Agricultural Research (CGIAR) was formed with the objective of supporting research aimed at increasing food production in the developing world. The two original centers, IRRI and CIMMYT, which became a part of the CGIAR, were concerned with the three most important cereals--rice, wheat, and maize. Their work is credited with generating the so-called "Green Revolution" in cereal production, making enormous contributions to increasing the supplies of these vital food crops in some parts of the developing world. It should be recognized, however, that this Green Revolution had little impact on food production in Africa (Eicher, 1982).

Need to Generate Means to Purchase Food

There is growing recognition that while it is vital to increase food production or food availability--that, alone, is not enough. People must have the financial means to acquire needed food. Throughout the developing world there are great numbers of people too poor to purchase the food they need. Consequently, there is a growing recognition of the need to place increased emphasis upon efforts aimed at improving incomes of poor people as well as increasing food production.

Food Self-Reliance

Research efforts directed towards increasing food production, per se, might imply that the goal of agriculture in a developing country should be that of achieving food self-sufficiency. It is recognized, however, that this may not be the most efficient or effective way of meeting food needs of such countries. Many countries do not enjoy a comparative advantage in the

production of some food commodities. It may be advantageous, therefore, for them to purchase the commodities from other countries that can produce them more efficiently--while concentrating on the production of those commodities for which they do enjoy a comparative advantage.

These circumstances suggest the need to help developing countries achieve the goal of food self-reliance rather than food self-sufficiency. Food self-reliance might be defined as "the capacity of a nation to provide a sufficient stable food supply to all of its inhabitants either from domestic production or from production of exportable goods to enable commercial imports to cover the domestic deficit" (McCalla, 1988).

Research on Non-Food As Well As Food Commodities

Since World War II, the international donor community has placed primary emphasis on the production of staple food crops. However, with a goal of achieving the capacity for food self-reliance, there is logic for the donor community to support research with other food commodities which have received limited research attention--as well as non-food crops. Many of these commodities have the potential for both domestic consumption and export. These include oilseeds, fruits and vegetables, cotton, fish and tree products.

Strengthening the export crop sector through research should not only improve foreign trade balances, but also should enhance the incomes of poor people so that they can be better able to purchase the food they need. Moreover, foodstuffs produced through such operations can also make significant contributions to improving the diets of indigenous populations.

It should be recognized, as well, that production techniques with many of these commodities are labor intensive, a desirable trait from the standpoint of making productive use of surplus labor in many developing countries. Consequently, such production could contribute to improving the incomes of rural poor as well as to the goal of achieving food self-reliance.

Environmental and Natural Resource Problems

Nothing in recent years has captured the attention and generated the concern of the world community more than the evidence of serious global environmental and natural resource problems. These include the rapid destruction of tropical forests, the increasing concentration of atmospheric carbon dioxide levels and the related global warming trends; the destruction of the ozone layer in the atmosphere; major problems of soil erosion; the contamination of underground aqulfers as well as lakes and streams; acid rain; and myriad other difficulties.

The World Commission on Environment and Development (WCED), chaired by Prime Minister Brundtland of Norway, has recently issued a comprehensive report on this subject entitled, "Our Common Future" (WCED, 1987). This report considers how these environmental and natural resource difficulties may impact future development efforts in poor countries. The report had this to say about the potential implications to global food systems:

> "The next few decades present a greater challenge to the world's food systems than they may ever face again. The effort needed to increase production in pace with an

> unprecedented increase in demand, while retaining the essential ecological integrity of food systems, is colossal both in its magnitude and complexity. Given the obstacles to be overcome, most of them man-made, it can fail more easily than it can succeed" (WCED, 1987).

Agriculture has been viewed as both a contributor to, as well as a victim of, some of these global environmental difficulties. For example, intensification of traditional agricultural systems to meet growing needs can have undesirable environmental or ecological consequences such as greater deforestation, increase soil erosion, and a deterioration of soil structure and fertility. Moreover, the development of more intensive, modern systems may lead to problems of salinity, waterlogging, and the contamination of aquifers with chemicals. These environmental difficulties, in turn, may limit the capacity of agriculture to meet growing food needs. In this regard, it should be noted that if poor countries are not given the opportunities to apply modern agricultural knowledge and inputs, they will be forced to degrade their environment even more for bare subsistence.

These circumstances have led to growing concerns in the global agricultural community over the need to consider ways of meeting current requirements for agricultural products without creating environmental or natural resource problems that might jeopardize this ability to meet future needs. This obviously underscores the necessity for major research efforts to address these complex issues.

Postharvest Losses

Primary emphasis has been focused on research efforts to increase production of crops and animal products. It should be recognized, however, that many of the objectives of increasing food supplies and enhancing incomes of poor people could be served by conserving and utilizing a greater portion of the food which is produced. The potential for this is indicated by the fact that postharvest losses in developing countries may be as high as 40% with cereal crops and 50% with fruits and vegetables (Scrimshaw, 1988).

The fact that such losses are largely prevented in industrialized countries emphasizes the need and opportunity to address this serious problem. More research attention needs to be given to field and harvesting losses as well as to postharvest storage, conservation and distribution.

Research on food preservation, for example, could not only address the problems of spoilage losses, but could otherwise provide opportunities for income generation through the development of small, rural-based processing industries. Furthermore, such efforts would respond to the growing urbanization of developing countries and the challenge of meeting the food needs of expanding urban populations.

Biotechnology

The development of new techniques or tools for research in the biological sciences in recent years has given rise to high hopes for the contributions which these tools might make to meeting the growing demand for food in the developing world. The use of such new techniques, frequently referred to as

biotechnology research, offers some exciting potentials. However, this needs to be put in appropriate perspective.

Such research approaches are, indeed, merely new tools or techniques. They may complement but not replace many existing techniques (in plant breeding, for example). They may, in fact, provide the means to accelerate progress in improving developing world food production. They are not, however, expected to represent a panacea that will revolutionize food production and solve the problems of hungry people overnight.

Many advanced research centers around the world, including universities and private firms, are working feverishly on new biotechnology techniques. These often involve costly equipment, laboratory screening, field testing, public relations, legal, and patent protection procedures. It is questionable whether many developing country institutions or even the international centers supporting the national research programs of developing countries, should attempt to compete in such efforts at the present time. However, the IARCs and the national programs should keep abreast of such efforts and be ready to make use of improved the techniques once they are developed or perfected. Indeed some IARCs and NARS are already using certain biotechniques as a means of speeding up research and transfer of disease-free material. Cohen, et al. (1988) have suggested various models for integrating biotech into crop improvement research programs.

Important areas of biotechnology research and development which should be closely monitored include DNA markers for confirming the incorporation of desirable genes in breeding lines, genome mapping to identify the location of specific genes, recombinant DNA vaccines for livestock, and recombinant DNA technologies for introducing exotic genes into crop plants. Recombinant DNA technologies, such as protoplast fusion and the use of gene vectors, are creating opportunities for transferring genes from unrelated plants. Such breakthroughs underscore the importance of conserving and evaluating genetic resources.

Biotechnology is a particularly fertile area to promote more involvement of the private sector in international agricultural research. At a recent conference on the subject in Washington (April 17-21, 1988), representatives of the private sector indicated a strong interest in collaborative research. The U.S. university community should also offer excellent opportunities for collaborative research in biotechnology with institutions concerned with developing world agriculture.

Other Important Issues

Consideration should be given to a number of other important issues with research implications. These might include, but not be limited to, the following.

- Agricultural Policy. It is increasingly apparent that issues relating to agricultural policy have important implications to agricultural development. For example, the imposition of IMF "guidelines" and their effect on agricultural and trade development are very important emerging questions. Chapter 2 also emphasizes a number of policy-related constraints to development, suggesting the need for research on various policy options.

- Marketing Systems. As urbanization occurs, incomes increase and populations grow, the increase in demand for efficient and effective marketing services will be great. Very little research is being directed to this subject in developing countries.

- Water Use. Given the importance of water to agricultural production, a strong case can be made for more attention being given to research on water quality and efficiency of use. Irrigation is critical in Asia and the Near East. It will undoubtedly become more important in Africa. Moreover, there is need for greater research attention to be given to water conservation and use under rainfed conditions.

Research Responses to Development Issues

There is growing evidence of need for research to address the issues set forth in the proceding section. Following are some of the suggested areas of emphasis.

Sustainable Agriculture

There is a rapidly growing recognition in both industrialized and developing nations of the need to concentrate on developing and maintaining sustainable agricultural systems aimed at meeting food requirements without causing further damage to the environment or the natural resource base on which agriculture must depend. The term "sustainable agriculture" is, therefore, receiving much current attention.

Various definitions of the term have been suggested. The Technical Advisory Committee (TAC) of the CGIAR has suggested that sustainable agriculture should involve the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources. The goal of sustainable agriculture, therefore, should be to maintain production at levels necessary to meet the increasing needs and aspirations of an expanding world population without degrading the environment (TAC, 1988).

It is further suggested that instead of establishing and maintaining a discrete area of activity labeled "sustainability research," concerns with sustainability should be reflected in all aspects of research relating to agricultural production. Research should, therefore, be planned, conducted, and evaluated with a sustainability perspective.

A distinction should be made between sustainability and productivity. While greater productivity will be required to achieve sustainability goals, that productivity must be achieved in such a manner as not to jeopardize the ability of agriculture to meet future needs. More explicitly, productivity goals may often be achieved through short-range approaches which may not be sustainable. Efforts to achieve sustainability goals, however, must take into account long-range implications and needs.

Low-input approaches to agricultural production which are being advocated by some as an integral part of sustainability, should not be considered synonymous with efforts to achieve sustainability goals. While some believe that high input usage threatens sustainability, many others have concluded that

without greater usage of such inputs, increased productivity and related sustainability objectives cannot be achieved. The goal of research should be to develop techniques which might optimize returns from the use of inputs while avoiding, to the extent possible, the undesirable consequences, if any, of such usage. Certainly, low-input approaches, being advocated by some, offer no panaceas for addressing the growing demands for agricultural products in many developing countries.

It is increasingly apparent that if the future agricultural needs of the developing world are to be met, major research attention must be given to the goal of achieving sustainable agricultural systems. Indeed, the achievement of such a goal must be of extremely high priority with international and national agricultural research programs and the international donor community which supports them.

Future research must address many factors which constrain or limit the achievement of sustainability objectives. Many of these constraints are similar to those discussed in Chapter 2 of this report.

Addressing these constraints will require research efforts in such areas as:

- the conservation, evaluation and use of germ plasm in genetic improvement efforts with crops and livestock;
- crop management, including fertilizer use, pest control, and various cultural practices;
- the development of improved and more intensive systems that might evolve from traditional, indigenous systems (e.g., agro-silvi-pastoral systems);
- soil and water management, including erosion control, effective use of irrigation water, etc,;
- the management of animal systems, including animal health and nutrition; and
- an array of socio-economic issues, including such government policies relating to agriculture as taxation and trade, availability of inputs and credit, infrastructure and markets, prices, financial institutions, and land tenure practices.

Research for Less-Endowed Regions

There is a need to give greater attention to research directed towards addressing the problems of less-endowed areas--which frequently involve more fragile ecosystems. It is recognized that progress in such areas will be more difficult and that greater gains will be possible in the more favored areas. While efforts should continue in the better-endowed regions, the needs of people in the poorer regions must also receive more attention.

It should be recognized that some of the marginal areas have the potential to be converted into better endowed regions through investments in infrastructure, drainage and irrigation and other technological innovations. It should also be recognized that increasing the capacities of the more favored

areas may help to relieve the pressures on the less-favored, more fragile ecosystems.

Certain areas of research emphasis should contribute to improvements in less-endowed regions as well as contributing to sustainability objectives, generally. Such research would include, for example, plant breeding work to achieve improved genetic resistance to insects and diseases along with tolerance to stresses such as drought, high and low temperature, acid or alkaline soil conditions, and chemical toxicities in the soil. It also involves research dealing with integrated pest management, including biological control measures; the potentials for mycorrhizal associations that might enhance the plant's ability to absorb phosphorus; and the use of leguminous crops to supply nitrogen to cropping systems. There is need, as well, for more socio-economic research to deal with some of the specific problems people face in these regions--and particularly policies that inhibit or create disincentives to the use of sustainable production technology.

It should be noted that less endowed regions often have large areas more suitable for livestock productions than crops. Research for such less-endowed regions, therefore, should include land use policy work as well as research on animal use including integrated crop-livestock production systems.

Diversification [1/] and Income Generation

As suggested in the introduction to this chapter, there is strong logic for the international donor community, including AID, to provide support for research on a wider array of agricultural commodities than has, historically, been the case. Emphasis was also placed on the need to improve the incomes of poor people in developing countries. In many instances, diversification or the development of a wider array of agricultural enterprises will contribute to income enhancement goals. Therefore, the two are considered simultaneously here.

Several major classes of commodities are being considered by the donor community for increased research emphasis.

- Vegetables and Perennial Tree Crops (for food and feed)

  With steadily rising incomes, consumers in both developing and industrialized countries can be expected to demand more high quality fruit and vegetable products. There are good opportunities throughout the developing world to intensify production of such commodities, both for domestic consumption and for export. There is need for increased research emphasis on such crops to take advantage of this anticipated demand.

  Many fruit and vegetable crops are well known for their high nutrition value, and their greater consumption could enhance the diets of people throughout the developing world. Moreover, many of these crops are high value and labor intensive and provide the potential to increase the incomes of many poor people--both farmers and laborers. Most research has

1/ "Diversification" is used in this context to refer to the development of additional agricultural enterprises in a country or region--not necessarily to diversifying individual farming operations.

concentrated on production technology. However, fruits and vegetables are often perishable, and damage or poor quality greatly reduces their marketability. Research on preservation, transportation, storage, processing, market standards and consumer requirements is, therefore, of particular importance. This is especially true where exports are concerned.

- Non-Food Crops

Because of the primary interest of the donor community in food crops for domestic consumption, the national agricultural research systems generally have not given the research attention to other crops for income generation and export which they might warrant. This would include the traditional plantation crops as well as ornamentals, crops for fiber or feed, and crops which might be grown for energy, and pharmaceuticals. Special attention might be focused upon the growing demand for feed crops (see Chapter 1) and upon biomass production for energy--the potential for which is obviously great.

Special mention should also be made of the need to expand production of oil crop. Deficits of oilseeds are increasing in many developing countries. Were they can be produced and crushed domestically, they provide both oil and cake for livestock feed.

Research with some of these commodities which are of more importance for export is being conducted by private organizations or autonomous government bodies, independent of national research system. Generally, however, many of these crops are not receiving the research attention they need. It does not seem appropriate for the international donor community to continue to ignore the research needs of many of these crops which offer significant development potentials in many poor countries.

These crops provide important sources of foreign exchange to many countries. They can also provide the basis for many countries to achieve a capacity for food self-reliance, and their production offers important opportunities for employment of rural people. Moreover, many of these crops utilize large amounts of labor and can contribute significantly to the enhancement of the incomes of rural people.

In emphasizing the need for research on such crops, however, it should be recognized that traditional food crops produced in excess of domestic demand may also offer important export potential. Moreover, when subsistence farmers begin to produce more of such foodstuffs than their family needs, these commodities become important means for enhancing the incomes of rural people. Such commercialization of the operations of traditional subsistence farmers is a vital step towards the overall economic development of such poor countries.

Emphasizing the need for research on crops other than those commonly grown for food, should not suggest that these traditional food crops be neglected. Indeed, continuing research effort is needed with traditional food crops, such as wheat, rice and maize, merely to maintain the gains in productivity already achieved. Such maintenance research is estimated to require as much as 60-70% of the total research effort of some of the older international agricultural research centers such as CIMMYT.

- Agroforestry

Agroforestry is a collective word used for all land use systems and practices in which woody perennials are deliberately grown on the same land management unit as crops and/or animals. ICRAF suggests that to qualify as agroforestry, a given land use system or practice must permit significant economic and ecological interactions between the woody and non-woody components.

Agroforestry is emerging as an important concept for agricultural systems throughout the developing world. The concept is relatively new in terms of how such systems might contribute to improvement in food production. However, indigenous systems have evolved over centuries in developing countries and the value of these systems have long been recognized by farmers.

Agroforestry concepts and techniques can help to alleviate some of the critical shortages of fuelwood throughout the developing world. Furthermore, such techniques have the potential for making significant contributions to achieving sustainable levels of food production and enhancing the incomes of poor people in developing countries.

Agroforestry systems may make many other significant contributions. For example, clippings from leguminous trees used in alley cropping become fodder for livestock and the manures are used to enrich the soil. Agroforestry systems may provide fence posts, poles for various purposes and construction materials. They may also be used for windbreaks, hedges or living fences to keep livestock enclosed or to prevent them from getting into fields where they might damage crops. The variety of trees used in agroforestry systems may produce a great range of fruits, nuts, and edible leaves, plant materials for dyes and cosmetics, medicinal products and fiber for mats, baskets and ropes. They may also enrich the soil with nitrogen.

The use of shrubbery legumes, and/or tree legumes as fodder banks have made significant contributions to livestock/cropping systems in Africa, especially in dry seasons when forage may be quite scarce.

In view of these circumstances, the potentials for agroforestry need to be thoroughly explored through agricultural research. This presents a rather obvious opportunity for the international donor community. Moreover the U.S. could have a substantial impact in advancing agroforestry efforts in the developing countries (Smuckler, Berg, and Gordon, 1988).

- Animal Agriculture

The international donor community has not devoted the same attention to development efforts involving animals as to crops. The reasons include the poor success rate with animal projects in the past as well as the feeling that the interests of hungry people can better be served when plant products are consumed directly rather than when converted to animal use, given the attendant loss of energy in the conversion.

In a recent symposium on animal agriculture in AID several reasons were advanced to support giving greater emphasis to research on animal agriculture (Animal Agriculture Symposium, 1988):

- Animals make tremendously important contributions to developing country agriculture, accounting for an average of 50% of the gross agricultural product;

- Demand for animal products is increasing very rapidly. In Asia, for example, such demand is reported to be going up at a rate of 12% annually;

- With steadily increasing incomes, demand for animal products is expected to grow even further and faster in the future;

- Animal products can enhance the nutritional levels of many people in developing countries;

- Much has been learned about the reasons for lack of success in earlier animal development projects and it is believed that the potential for future successful efforts is good;

- Animals provide a valuable component in production systems throughout much of the world;

- There is growing interest in the role of animals to provide draft power, especially in Africa;

- Animals also have the capacity to convert low-value feedstuffs to high-value foods;

- Animals often provide important sources of cash income to poor farmers and are an important form of saving and investment in many societies.

- <u>Aquaculture</u>

As in the case of other forms of animal agriculture, there is growing interest in the international donor community in aquaculture. Many reasons have been advanced for this (Nash, 1987):

- Many people in developing countries are in great need of additional animal protein. Fish is often the cheapest source of such protein.

- Fish has the highest feed conversion rate of any of the animal groups.

- Weight for weight, fish requires less units of energy, demands less gross space, and has a higher productivity than all domestic farm animals, including poultry.

- There is a great and continuing demand for fish by people in rural villages. Excess production can also find ready markets in urban areas.

- Aquaculture offers significant potential for enhancing the incomes of rural people.

The CGIAR, in 1986, recommended that aquaculture be explored as a new research initiative in the CGIAR System. Consideration is currently being given to this possibility. The CGIAR is not considering the incorporation of research on marine fisheries into its System. Our review team questions whether this is an area of research which should receive priority attention by S&T/Agr, either. Instead, we have focused primary attention on aquaculture research where there is more of a interface and complementary relationship with agriculture. Indeed, many farmers have the opportunity to develop aquaculture systems in close conjunction with agricultural systems in a complementary manner. We believe, therefore, that the Office of Agriculture should give higher priority to aquaculture research than to research on marine fisheries.

Some impressive examples exist of the amounts of fishery products that can be raised by aquaculture compared to unit production from wild stocks or even compared to some good agriculture systems (Idyll, 1987). Not all of the added productivity cited below by Idyll can be attributed to research since there is still a heavy overlay of art and tradition in fish farming, and without any science some farmers will continue to improve on nature. But in the examples given here, derived from several sources, the influence of research has been substantial.

- In the Philippines production increased from 300-400 kg/ha/yr to 1000-1200 kg/ha/yr in 5 years.

- In Israel intensive culture of carp (with special feeds, aeration of water, genetic selection) has produced 30,000 kg/ha/yr in demonstration ponds.

- In Taiwan production increased 300% from fertilization of ponds; an additional 25% when pest control was used; an additional 100% by manipulating the fish populations; a net increase of 750% over untreated ponds.

- In Norway the National Breeding Program increased the growth rate of Atlantic salmon and rainbow trout 3-4% per year.

- On natural pasture range cattle and sheep raising produces 50-150 kg/ha/yr; on improved rich pasture, 300-700; in inland waters fishing produces 50-150 kg/ha/yr; in the Philippines and Indonesia traditional milkfish farming, 300-500; in Taiwan milkfish farming, 2000-7000; in Asian carp culture in ponds, 700-3500; in Indonesia carp culture in sewage streams, 500,000-750,000; in Japan intensive carp culture, 1,000,000-4,000,000; in Vietnam, carp culture in cages, 2,000,000; in the USA, rainbow trout over 2,000,000 kg/ha/yr.

Summary

Chapter 5 provides a treatment of some important agricultural development issues with research implications.

Recognition is given to the fact that in recent decades, the international donor community has focused primary attention on research to increase food production. It is noted, however, that this alone is not enough. Attention must be focused, as well, on efforts to improve the incomes of poor people to enable them to acquire needed food.

It is also suggested that efforts should be made to help developing countries achieve a goal of food self-reliance rather than food self-sufficiency. And to do this, as well as to contribute to income enhancement, there needs to be greater emphasis on research with non-food commodities and upon a wider array of food commodities.

There is also emphasis on the need to develop means of meeting current requirements for agricultural products without creating environmental or natural resource problems that might jeopardize the ability to meet future needs.

Attention is focused on the need for more research on post harvest losses of agricultural products, the emerging role of biotechnology in agricultural research, and the need to consider, carefully, research relating to such areas as agricultural policy, marketing systems and water use.

A number of suggestions were made about research responses to these development issues, including a discussion of sustainable agriculture, research for less-endowed regions, diversification and income generation involving research on vegetables and perennial tree crops (for food and feed), non-food crops, agroforestry, animal agriculture and aquaculture.

The information in Chapter 5 provides additional rationale for the conclusions and recommendations presented in Chapter 6.

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Chapter 6

CONCLUSIONS AND RECOMMENDATIONS

The information in the foregoing chapters of this report leads to a series of conclusions and recommendations relative to a research strategy for AID/S&T Office of Agriculture for the decade of the 1990s. In addressing a research strategy for this Office, however, we found it imperative to consider research-related issues for the Agency as a whole.

Global Trends and Implications to AID

Future research needs will be influenced greatly by changing global circumstances that impact the demand for agricultural products and the ability to accommodate these demands in developing countries. An examination of evolving trends in world agriculture lead to a number of conclusions and a major recommendation.

During the next decade global population will increase significantly, with 90% of the growth occurring in the developing countries. Numbers of people in developing countries are expected to increase and an average rate of some 85 million annually. The incomes of people in developing countries should also continue to increase at an average per capita growth rate of some 3% annually. With this projected growth in population and income, the demand for food in developing countries should increase at a rate of some 3.5% annually. Moreover, there will likely be a changing pattern in food demand related, primarily to income improvement.

There will be a continued trend towards urbanization during the next decade. Such growth in urbanization will result in a growth in demand for different types of food commodities, especially those that can be easily processed, transported and stored. The trend towards higher incomes should result in a growing demand for livestock products as well as for fruit and vegetables in many parts of the developing world.

Despite global increases in agricultural production, per capita production of food is absolute declining in several areas of the developing world, including countries in the Middle East, North Africa, Sub-Saharan Africa, Central America and parts of Asia. In recent years some countries have experienced actual reductions in levels of food production. These countries are becoming increasingly dependent upon imports. Yet slowed economic growth and balance of trade deficits have reduced the capacity of many developing countries to import food and other agricultural products. Moreover, increases in world prices of agricultural products exacerbates the problem for importing countries and put an additional burden on their domestic agricultural sector to expand production.

The rapidly growing demand for agricultural products must be met, primarily, by more intensive use of existing arable land. This will require that much greater emphasis be given to research to generate the improved technology required to increase agricultural productivity.

While there must obviously be significant increases in production of agricultural commodities to meet growing needs, this alone is not sufficient. The incomes and purchasing power of poor people must also be improved so that the needed food and other products of agriculture can be purchased.

The improvement of the agricultural sector---making it more productive and efficient--is basic to economic growth in developing countries. As the agricultural sector grows and becomes more efficient, surplus resources are generated through higher farm income and lower consumer food costs, thereby stimulating demand for a wide variety of industrial goods and services. Agricultural development, therefore, becomes the primary engine that drives overall economic growth in developing countries. Moreover, cost-reducing, improved technology must provide the primary fuel for this engine.

Given the vital role which agriculture must play in the development of poor countries, it is most disturbing to see the declining support given to agricultural development efforts by AID in recent years. Historically, more than half of AID's total resources have been allocated to agriculture. In 1983, the level was 50% ($730 million); in 1987, it was 39% ($637 million).

Given the vital role which research must play in agricultural development efforts, it is equally disturbing to see that the portion of the AID's agriculturally-related budget devoted to the research also has declined from 30% in 1985 to an estimated 25% in 1990. Moreover, AID's core support for the CGIAR system of research centers has declined in two years from the traditional level of 25% to some 18% of total donor support.

The above circumstances leads us to a major recommendation with Agency-wide implications: that AID take steps to address the declining support for agriculture-- and especially for agricultural research--and seek the means to substantially expand the resources for these efforts which are vital to the achievement of development goals in poor countries.

Agricultural Research Within AID

An examination of the manner in which AID's resources are currently being used to support agricultural research, not only in S&T/Agr but throughout other parts of the Agency, leads us to other conclusions and recommendations that have Agency-wide implications.

The Agency has made significant contributions to the development of research-related institutions in developing countries as well as the human resources needed to staff them. These institutions, in turn, have had a significant impact on developing country agriculture through the generation and introduction of improved agricultural technology.

The Agency has also made wise investments in supporting specific research projects and programs, such as those in the International Agricultural Research Centers. The results of these efforts have contributed substantially to the technology and knowledge needed to improve the agriculture of poor countries.

Despite these significant advances made through AID-supported efforts, there are growing indications that the rate of gains in food production is slowing down in many areas of the world. For example, the rate of growth in

cereal yields in declining in both developing and industrialized countries. Moreover, at least in the short run, production levels are actually declining in some areas.

Such problems are exacerbated in many countries by shortages of arable land, widespread degradation of natural resources, reduced investment in agriculture (for credit, irrigation, inputs, etc.), low levels of investment in agricultural research, inadequate human resources for improving agricultural research and development efforts, economic policies and programs that provide disincentives to producers, and related circumstances. These circumstances suggest the need for major, well-focused efforts within AID to assist developing countries to develop the technology or otherwise obtain the information needed to meet the growing needs for agricultural products.

The goals of AID's Food and Agriculture Program have been stated as follows:

- to increase the income of the poor majority;
- to expand the availability and consumption of food; and
- to maintain and enhance the natural resource base.

The Agency's agricultural research efforts should be oriented towards the achievement of such goals. However, such an objective is not readily apparent in research efforts now supported by AID. Indeed, AID's agricultural research efforts seem to lack an overall strategy or a sense of direction or coordination. There appear to be no clearly targeted Agency-wide priorities or goals for agricultural research. The various Bureaus having responsibility for research, in large measure, go their separate paths with no apparent effective mechanism for achieving Agency-wide coherence. The approaches to agricultural research in the Regional Bureaus have little in common. Some in the Regional Bureaus question the relevance of many of the research projects supported by the S&T/Agr.

These observations and conclusions lead us to the recommendation that the Agency develop an appropriate mechanism and/or structure to achieve a more sharply focused, coherent and better coordinated overall research effort in agriculture--an effort that would be directly supportive of the goals of the Agency. Such a mechanism is not readily apparent, given the present organization of the Agency where research responsibilities are vested in several bureaus and offices (e.g., the Science Advisor).

The Mission of the S&T Office of Agriculture

The Science and Technology Bureau Office of Agriculture has a dual responsibility: (1) providing technical assistance to country missions and (2) supporting research activities to benefit developing country agriculture. Both are important responsibilities and the Bureau is faced with the issue of developing an appropriate balance between the two in the use of available resources. This report deals primarily with the research mission of the Bureau.

The research efforts administered by S&T/Agr have made--and are continuing to make--significant contributions to the improvement of developing country agriculture. Of major significance has been the work of International Centers, both in and outside the CGIAR. The CRSPs are proving to be another very productive channel for AID research funding. The office also supports a group of research projects dealing with developing country agricultural concerns.

The S&T Office of Agriculture is currently engaged in an effort to develop a better defined strategy or direction for its research program. Indeed, this report is a part of such an effort. In the following section, several strategies are suggested for strengthening and improving the research effort supported by the Office. This is followed by recommendations concerning specific areas of research emphasis within the Office.

Strategies for S&T/Agr

In the absence of other Agency-wide mechanisms, the S&T Office of Agriculture should take the initiative in helping to establish an overall agricultural research agenda for AID. This is obviously not something that the Office can do alone but must involve all other parts of the Agency concerned with research. Such an overall Agency-wide strategy should not keep the regional bureaus from focusing on the problems or circumstances unique to their respective regions. It should, however, help to make the various elements for the Agency's research efforts more complementary and allow the Agency to focus needed attention on major issues of global concern (e.g., sustainability of agricultural production).

The Office should formulate a carefully planned strategy for its overall research program--a strategy that will result in a total effort which is more sharply focused on the high priority needs of the Agency. Obviously, other parts of the Agency need to be intimately involved as S&T/Agr considers its research strategies. The development of such a strategic plan is essential if the Office is to exercise effective leadership in helping to formulate a research agenda for the Agency.

In formulating a strategic research plan, the Office of Agriculture should have as an objective that of helping developing countries achieve food self-reliance rather than food self-sufficiency. It should also be oriented towards those activities that can contribute to the goals of the Agency's Food and Agricultural Program, discussed earlier. In this regard, consideration should be given to increasing the incomes and improving the nutritional status of people as well as to meeting the changing patterns of demand for food which are related to increasing incomes and greater urbanization.

The rapidly growing demand for agricultural products, along with the serious degradation of many of the natural resources on which agriculture depends, emphasizes the absolute necessity for giving major research attention to issues of agricultural sustainability. This should be a primary concern of S&T/Agr as well as other parts of AID. Indeed, the Agency should encourage all research efforts with which it is associated to be carried out with a "sustainability perspective." This suggests that sustainability considerations should be well integrated into the planning, execution and evaluation of agricultural research efforts. Research should concentrate on addressing the many problems or constraints that limit the achievement of sustainability

objectives. This should include efforts related to the conservation, evaluation and use of germ plasm; crop and livestock management soil and water management; and many socio-economic problems and policy needs.

There is a need to give greater emphasis to research directed towards addressing the problems of less-endowed areas--areas which frequently involve more fragile ecosystems. At the same time the better-endowed regions must not be neglected because they provide opportunities for more significant gains in food production. This suggests that research efforts with various commodities should involve components relating to both better-endowed and less-endowed regions.

In formulating a research agenda for S&T/Agr, it should be recognized that the natural enemies of plants and animals continue to evolve; pathogens to which cultivars may have been resistant, mutate; and insects adapt to formerly resistant varieties and develop resistance to pesticides. These circumstances call for "maintenance" research to protect the productivity gains already realized with many commodities. The needs for such maintenance research must be given adequate recognition in establishing research priorities.

Similar recognition must be given to the need for research addressing post-harvest losses of food. These losses in developing countries are estimated to be quite high in comparison with those in industrialized countries. More research attention needs to be given to field and harvesting losses as well as to post-harvest storage, conservation, distribution, and marketing.

A strategic research plan for the S&T/Agr should take fully into account the programs supported by other parts of the S&T Bureau, the regional bureaus/country missions and the Science Advisor's Office in AID as well as that of other donors. Special consideration shall be given to the activities and potentials of the international agricultural research centers--both in and outside the CGIAR System. Special consideration should be given, as well, to the potentials for an expansion in the CRSPs as a means of addressing future research priorities of the Agency.

Given the major commitment by AID to the international centers--a commitment which we believe should be continued--there is an opportunity, if not a need, for AID to play a more active role in helping to influence the research agendas of the IARCs. This is not to suggest that AID should attempt to dictate what the Centers should do or that there should be a move away from core funding of the Centers by AID. However, S&T/Agr should maintain close, continuing, informal relations with each of the Centers receiving financial support from the Agency in an effort to keep better abreast of what the Centers are doing and to be able to reflect to the Centers the nature of AID's priority research concerns. By doing this, the international centers should effectively address a significant segment of the S&T/Agr research agenda.

Some have considered the emergence of the newer techniques in modern biology as a panacea that will provide the basis to solve future global food problems. While these techniques may offer opportunities for accelerating progress, they will not revolutionize developing country agriculture. It is not recommended that AID mount a major biotechnology research thrust, per se. Instead, research institutions supported by AID should assess, on a continuing basis, the potentials for incorporating such techniques into their research

programs. Institutions involved in productivity research, such as the IARCs, should have the capability to monitor advances in biotechnology and, when appropriate, develop the in-house capacity to use such techniques that will assist their research programs in a cost-effective manner.

AID should be concerned with research efforts that offer the potential for major, long term advances or breakthroughs in developing country agricultural production. Many such approaches, commonly suggested, include efforts to increase biomass production by altering photosynthetic efficiency, improving the harvest index, incorporating the capacity to fix nitrogen in non-leguminous plants, and improving resistance/tolerance to various stresses. New biotechnology techniques may facilitate more rapid advances in these areas. However, many of the desired characteristics that might be sought through such research involves a complex array of genes, and knowledge of how to manipulate those genes to achieve desired results is generally quite limited. Consequently, AID should be very selective in the type of research of this nature it supports, leaving much of the more basic work to other, more appropriate, organizations. However, AID should maintain a "watching brief" on such efforts by others and be in a position to exploit any breakthroughs which might occur and help to make certain that such advances are quickly utilized in work related to developing country agriculture. The research portfolio of the Science Advisor's Office might also be used to support work of this nature. Efforts should also be made to enlist the support of such organizations as the National Science Foundation and U.S.D.A. in supporting more basic research activities.

It is recognized that many of the problems which limit agricultural development relate to economic, social, political and institutional considerations. Although these problems do not have technological solutions, they lend themselves to social science research aimed at identifying those options most likely to create the circumstances favorable for development. Social science research oriented towards addressing some of these critical issues has an important role to play in the AID research agenda and should be given priority attention. The Social Science Agricultural Agenda Project has identified several important research areas that merit consideration in the AID research agenda.

There are needs and opportunities to forge linkages or networks among research institutions, both public and private, in industrialized as well as developing countries. There is a special need for AID to help facilitate the involvement of the U.S. scientific community in helping to accelerate agricultural development in the Third World. There are also potentials for AID to enlist the participation of other donors, both multilateral and bilateral, in supporting high priority research programs of relevance to developing countries. By so doing, it should be possible to leverage AID research funds and achieve greater results than would be possible through unilateral action. Moreover, a more unified approach to agricultural research within the Agency should facilitate closer collaboration and more joint financing of research efforts by S&T and the Regional Bureaus.

Recognizing the dual research and technical assistance role of S&T/Agr, consideration should be given to the appropriate balance between the two and the extent to which country missions might support both the research and technical support functions through "buy-ins." Special effort might be made to have a major part of the costs of the technical support functions borne by the

country missions making use of such functions, thereby allowing a large proportion of S&T/Agr funds to be used for research and related training.

Many have questioned the current organizational structure within S&T--especially the manner in which forestry and natural resources, and rural development are separated from agricultural production and policy work. Consideration needs to be given to a structure or to working relations within the S&T Bureau that could facilitate a more closely integrated approach to meeting agricultural research needs. For example, sustainability concerns embrace many interlocking production, natural resource, environmental, and policy issues which should be reflected in agricultural research approaches.

A matter of serious concern is the extent to which Congress continues to earmark research funds in S&T/Agr for projects of relatively low priority. This has prevented AID from using its resources in the most productive manner. The absence of a well-defined research strategy for the Office and AID may well have contributed to this tendency by Congress. The development of a well-defined strategic plan for research should help make it easier for the Agency to avoid such earmarking if it can be shown that the projects which individual Congressmen may have interest in supporting do not fit within such a plan.

We believe that the implementation of the foregoing strategies should contribute to a more viable, coherent and relevant research agenda for the S&T/Agr and, indeed, for the Agency as a whole.

Research Agenda for S&T/Agr

The goals and strategies set forth in the foregoing section provide the framework for a specific research agenda for S&T/Agr. Following are recommended areas of research emphasis.

Improvement of Major Classes of Commodities

The significant breakthroughs in food production in developing countries during the past two decades (e.g., the "green revolution") have resulted from concerted interdisciplinary efforts aimed at improving targeted crops through plant breeding and related crop management research. We believe that this type of commodity-oriented research emphasis and focus (similar to that employed by the IARCs and CRSPs) continues to offer great potential with a wide array of commodities and agricultural enterprises.

Since World War II, developing country agricultural research has focused primary attention on staple food crops, some of which are also important sources of feed. Such crops must obviously continue to receive research attention from AID and others in the international donor community. However, the Agency's goal of increasing the incomes of the poor and expanding availability and consumption of food suggests the need for more research directed towards other classes of commodities or agricultural enterprises as well. This would include:

- vegetable and perennial tree crops (for food and feed);
- animal-based agricultural enterprises, including aquaculture; and

- non-food commodities such as ornamentals, feedstuffs, crops for industrial purposes, including those for fiber, energy, pharmaceuticals, oil, and other specialty purposes--as well as for fuelwood.

It is recognized that in a given country or region some of the above enterprises might receive greater attention than others--depending upon the circumstances and needs. While staple food crops should continue to receive major attention, other commodities or enterprises might be targets for research support where circumstances dictate this to be desirable. None of the above should be arbitrary excluded.

As a general rule, S&T/Agriculture should give priority attention to those commodities or enterprises which have broad general adaptation or applicability. However, this should not preclude work with other enterprises offering significant potential--even though they might be more limited in scope or applicability.

Economic and Policy Research

Commodity oriented research should normally involve interdisciplinary efforts to address the physical and biological constraints such as those set forth in Chapter 2 of this report. It is recognized, however, that the development or improvement of enterprises involving such commodities is often seriously limited not only by biological and physical constraints but also by major institutional, economic and policy constraints. Accordingly, the S&T/ Agriculture agenda should give attention to efforts aimed at identifying those economic and policy options that are most favorable to agricultural development or to improving a given part of the agricultural sector.

Relevant social science research on topics such as macroeconomics and trade policies, marketing, and food security will potentially impact consumers and other segments of society. Such research can have important positive impacts on income generation and food consumption and complements the economic and policy research on technical changes in agriculture.

Soil, Water, and Pest Management Research

While focusing on the constraints--both technical and policy-related--which limit the development and utility of the classes of commodities or enterprises set forth above, consideration should be given, as well, to research in soil, water and pest management. Commodity-related interdisciplinary research will, of course, include work on such matters. However, there are significant research needs in these areas that are not commodity-specific. Some of these are extremely important to future progress.

Such research is not only important in commodity-improvement efforts, it can also make significant contributions to the achievement of sustainability objectives, as well.

Sustainability--A Basic Concern in All Research

The third major goal of the Agency--that of maintaining and enhancing the natural resource base--should be addressed by making sustainable agriculture a primary, over-arching priority and goal of the Agency's research efforts. The very definition of sustainable agriculture, as set forth in Chapter 5, refers

to "the successful management of resources for agriculture to meet changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources." Given its significance and importance, it is recommended that concern with sustainability should permeate and be reflected in all aspects of research relating to agricultural production--as suggested in the "Strategies" section of this chapter.

In considering future needs for sustainability-related research, it should be recognized that some feel that both the NARS and the IARCs are "overweight" on the plant sciences--in terms of relative emphasis--and "underweight" on environmental sciences, animal management and forestry.

Addressing Research Priorities

In addressing the research priorities set forth above, S&T/Agr should be guided by the following considerations and recommendations:

- High priority should be given to supporting the work of the international centers and CRSPs that can contribute to research priorities of AID. These are programs of proven effectiveness and they also provide opportunities to leverage AID resources or generate other sources of funding to help achieve AID objectives.

  While giving high priority to the support of IARCs and CRSPs, AID should be discriminating in making decisions with respect to resource allocations to specific programs in these two classes of efforts. Resources should be used in support of those research activities which can contribute most to the achievement of Agency research objectives. Moreover, as suggested earlier, AID should not be reluctant to use its influence, as a major donor, to help shape the research agendas of the international centers to better address its own priorities and goals.

- It should be recognized that consideration is now being given to the inclusion of other international centers in the CGIAR System. These include centers for soil, water, insects, vegetables, fisheries and aquaculture, fertilizers, and agroforestry. If this occurs, it may be expected that the programs of these centers may be further strengthened and offer opportunity for more meaningful research in areas of priority concern to AID. Where feasible, AID should attempt to use the international centers as vehicles for supporting developing country research activities--in view of their demonstrated effectiveness.

- S&T/Agr should use its own portfolio of research projects to complement or supplement the programs of the IARCs and CRSPs. In doing this, there should be a careful review of the research projects currently in the S&T/Agr portfolio to determine if these projects continue to represent programs of highest priority for the Agency--given the evolving circumstances and needs as set forth herein.

- Most of the basic or staple food crops are receiving significant research attention through the CRSPs and the CGIAR system of international centers. S&T/Agr should carefully review these efforts to determine if there are significant gaps (from a AID prospective) or if there is a need to reorient such efforts.

- S&T Agr is also allocating resources to animal-based research programs, including aquaculture. This involves support for CRSPs, international centers and for several specific projects in the S&T portfolio. As in the case of staple food crops, the Office should carefully review the programs currently being supported to determine if there is need for additional effort or if some of the current efforts need to be terminated or reoriented.

  For example, one might question the relative level of resources already being devoted to fisheries and aquaculture (some 11% of the total S&T/Agr project budget). The two CRSPs dealing with aquaculture and fisheries appear to represent productive efforts. To what extent can S&T/Agr justify additional efforts in this area? If an international center on aquaculture should be added to the CGIAR System, the Office should consider the merits of providing support to such a center as compared to maintaining several separate projects, in addition to the CRSPs in the S&T/Agr portfolio. If such a center is developed, and if it promises to have quality programs on par with other IARCs, we believe there would be merit in the Office of Agriculture providing financial support to such a center rather than maintaining several of the current projects in its portfolio.

- Several vegetables are included in the mandates of the CGIAR Centers and are thus receiving research attention through this source. However, many of the common vegetables are not included in the concerns of the CG Centers. On the other hand, the Asian Vegetable Research and Development Center (AVRDC)--a non-CGIAR Center--is concerned with the research on a number of vegetables of importance to developing countries. Moreover, consideration is now being given to the addition of a vegetable research center to the network of centers supported by the CGIAR. If this occurs, such a center should provide an excellent vehicle for AID to support developing country research on vegetables.

- The international research system is currently devoting little attention to perennial tree crops for food. Some consideration has been given by the CGIAR to initiating work on coconuts. There is a limited international effort on bananas. IITA and ICRAF (a non-CGIAR Center) are doing work in agroforestry. However, the trees grown in many of the current systems are used primary for firewood and livestock feed--rather than for food. It should be recognized, however, that many mixed cropping systems that could be classified as agroforestry include species that produce food for human consumption.

  Given the nature of the crops involved and the fact that many of these crops vary greatly in importance from one country to another, AID missions may find it desirable to give increased attention through support of NARS to such crops. Selective strengthening of NARS in countries having good tree-crop research institutes (Malaysia, Brazil, India, Sri Lanka, Colombia, Nigeria, etc.) may be needed. We suggest that the role of S&T/Agr should be one, primarily, of stimulating interest in such research--perhaps supporting networks of research programs dealing with such commodities and in encouraging the participation of other donors and the AID regional bureaus/country missions in such networks. Certainly, S&T/Agr should be willing to commit resource to this important area.

- A wide array of non-food crops offer excellent opportunities for research support by AID. Very little is currently being done in this area except for work in agroforestry. Agroforestry research, such as that carried out by ICRAF and IITA, fully merits the support of S&T/Agr. Indeed, sustainability considerations as well as the growing fuelwood crisis in much of the developing world suggest an urgent need for greater research attention to agroforestry. Moreover, it is likely that at some point increasing research attention must be given to forestry (other than agro-forestry). The global implications of third world deforestation, its effort on environmental problems, and sustainability issues emphasize such a need.

  The array of other crops considered in this category are in about the same status as the perennial tree crops discussed in the previous section. Little research is being done, and the interest in these various crops varies from one country to another. This suggests a similar approach by AID to that proposed for the perennial tree crops: (1) attention by USAID missions and (2) efforts by S&T/Agr to promote the creation of networks of research activities devoted to these crops and to stimulate other donors to support such efforts.

- Although AID is a substantial contributor of IFPRI, and the S&T/Agr portfolio includes efforts in the economic and policy area, we question whether the current emphasis on such work is commensurate with the importance of the problems which such research needs to address. S&T/Agr should be giving higher priority to the allocation of its available resources to research in this important area. It is important that the policy work supported by S&T/Agr complement that conducted by IFPRI, the World Bank, USDA, and others. Moreover, the economic analyses of agricultural technologies, should be conducted in conjunction with physical and biological scientists.

- The commodity-related CGIAR Centers and CRSPs deal in some measure with soil and water management. Moreover, several of the non-CGIAR Centers and one CRSP are primarily concerned with work in this important area. In addition, the S&T research portfolio includes several research projects oriented towards soil and water management. A careful analysis of what is being done through the international centers and CRSPs should be weighed against needed emphasis in this area in determining the extent to which additional work might be required through support of specific S&T projects.

- As in the case of soil and water management, most of the commodity-related CGIAR Centers and CRSPs are concerned with research dealing with pest management. One non-CGIAR Center and several S&T research projects also deal, specifically, with this issue. Consideration should be given to needs for research in this area not currently being served by the international centers to determine what additional emphasis might be provided through S&T research projects.

- While recognizing its importance, research on postharvest losses of food has not been singled out as an area of priority research concern. We suggest that research on postharvest losses should be made an integral part of other research with the various commodities discussed earlier. To the extent that this is not done, and significant problems are not being

addressed, S&T/Agr should consider specific research projects to deal with such needs. The development of a CRSP might provide an effective way to address this problem.

- The need for emphasis on research relating to sustainable agriculture has been emphasized throughout this report. However, this need should be addressed by making sustainability a priority concern in the planning and conduct of all research supported by AID. Therefore, we do no envisage the need for specific research projects which deal with sustainability as such. Thus, support for sustainability research, per se, does not enter into our consideration of resource allocations.

Allocating Resources to Address Priority Concerns

There should be a careful assessment of the manner in which S&T/Agr resources are currently being used in support of research. If AID accepts the areas of research priorities recommended, resources should be allocated or reallocated to address these priority concerns.

This would mean that S&T/Agr should examine the program and potentials of the international centers and the CRSPs, to determine the extent to which they address priority concerns. Resources should be allocated accordingly. Similarly a careful review should be made of the projects now included in the S&T/Agr research portfolio.

The current study does not provide an opportunity to make the needed in-depth review or analysis of specific programs. However, an even cursory review might result in questions raised about the level of priority that might need to be given to some projects or programs in the S&T/Agr portfolio. It is widely recognized that strong political pressures from Congress have been significant factors in allocating resources to some of these projects by AID.

The key issue, however, is not whether some of the current projects are doing useful work or not. The concern, is one of priority and whether there may be other research activities that could be more relevant in terms of addressing critical developing country research needs. For example, one might question the relatively large amount of resources allocated to fisheries and aquaculture or the relatively low priority accorded policy research or research relating to water resources.

There are also other areas that would appear to merit greater attention. For example, we are recommending that the international centers play an extremely important role in addressing AID's research priorities. We believe, however, that the effectiveness of the programs of the international centers could be enhanced by developing closer collaboration with the U.S. university community in supporting the work of the centers. We believe this could be done through an expansion of efforts such as those in the "Special Constraints Research" project in the S&T/Agr portfolio.

Through such approaches it should be possible to involve some of the "best and brightest" in the U.S. university community in research on developing country agricultural problems. Many universities, for example, have relatively advanced programs in biotechnology which the IARCs could find extremely beneficial and complementary.

We would encourage AID to consider means of strengthening or expanding programs which might facilitate such linkages between the university community and the international centers. Increased involvement of the university community has the additional advantage of raising the probability that the training of international students in the U.S. will be relevant and that the reverse flow of technology be facilitated.

S&T/Agr should also consider how it can better communicate information about its programs to others, including other AID Bureaus, country missions and LDC institutions. We found that key people in other AID Bureaus were not familiar with the S&T/Agr program.

Charting a Future Course

We believe that the types of efforts proposed herein can contribute to a more meaningful research program for the Bureau and the Agency. A part of what is being proposed can be accommodated by taking fully into account the existing (or redirected) programs of the IARCs and CRSPs and not duplicating these efforts. Other objectives can be achieved by closing out lower priority research programs in the current portfolio and reallocating these resources to activities of higher priority. Greater leverage of AID resources can be achieved through the development of appropriate linkages with other donor agencies as well as with public and private research organizations to support high priority research needs. S&T/Agr should also be able to help influence how research funds are being spent by other parts of the Agency.

We further believe that the recommended courses of action set forth in this report will be desirable, irrespective of the level of resources available to carry out these tasks. However, we must emphasize the inadequacy of current financial resources to support these activities.

For example, in real terms expressed in constant 1977 dollars, the funds available to support the S&T/Agr project portfolio are approximately 40% of the level of just five years ago (1984). In nominal terms, the AID core funding for the CGIAR System has dropped more than 10% in the last two years. In real terms, the drop is, of course, greater. This reduction in support for research comes at a time when there is a well-documented need and justification for a substantial expansion in research efforts supported by AID.

The funding issue might be put in further perspective. With current budgets and levels of funding for the IARCs and CRSPs, there is only $13.2 million to support the S&T/Agr project portfolio. This is a woefully inadequate amount to meet the priority research needs which are not being addressed by the IARCs and the CRSPs. Moreover, reductions already made in the financial support accorded the CRSPs and IARCs limit the effectiveness with which these programs may carry out needed levels of activity in their respective area. In addition, several other IARCs not associated with the CGIAR System and currently receiving little support from AID/S&T, could make significant contributions towards addressing the research objectives of the Agency.

All of these circumstances make a compelling case for substantially increasing the budgetary effort for research in S&T/Agr (including the CGIAR Centers which are funded through the PPC Bureau). This is a matter which warrants attention at the highest policy levels in AID.

In the event, however, that such funding increases are not forthcoming, serious consideration should be given to how the $13.2 million currently allocated to the S&T/Agr project portfolio could be most effectively used.

Should these resources continue to be used to support an array of projects as currently is the case? Or could some of the resources currently allocated to projects be more effectively used in one or more of the following ways:

- Supporting additional CRSPs which are oriented towards addressing some of the priority research concerns of the Agency;

- Providing more support to some of the non-CGIAR Centers which are concerned with issues of high priority to AID. These might include IBSRAM, IIMI, ICIPI, and ICRAF, all of whose work has significant implications to sustainability concerns. This might include as well some of the commodity-related programs such as ICLARM and AVRDC (or other entities dealing with these commodities that might result from the current study now underway within the CGIAR System).

- Expanding the concept embodied in the Special Constraints Research project to support linkages between the IARCs and the U.S scientific community, both public and private.

- The development of additional linkages or networks which could focus attention on some of the priority research needs of the Agency--especially those not addressed by the IARCs and CRSPs--including perennial tree crops for food and non-food crops.

Time constraints associated with the current study do not permit a thorough exploration of these alternative courses of action. However, we believe these are issues the Office of Agriculture needs to address further as it develops its agenda for the 1990s.

Several criteria might be used in making such an assessment of how resources might be most effectively used by S&T/Agr to support research activities. This might include the following:

- The degree to which a given research activity might contribute to the food and agriculture goals of the Agency;

- The potential for achieving useful results, including a consideration of risks and pay-offs;

- The type of research (adaptive, applied, strategic or basic) and how it fits in with other research activities supported by AID and the donor community;

- The degree to which the problem area is being addressed by other institutions;

- The extent to which the research might have broad global application;

- The extent to which the U.S. (or AID as donor) might have a comparative advantage in supporting a given research activity;

- The extent to which S&T/Agr funds might be leveraged through support by others;

- The extent to which to which there may be mutual benefits--to developing countries and to the U.S. While developing country needs must be the primary concern of AID-supported research, it is recognized that such research often makes significant contributions to the U.S. agriculture as well.

It should be noted that S&T/Agr in its 1988 Agricultural Program Guidance Paper has set forth some excellent criteria for establishing its research priorities. What is now apparently needed is a thorough, objective process for applying such criteria.

In considering the possible allocation of S&T resources for research, it must be recognized that the Bureau has a technical assistance function as well, and that some of the current projects in the S&T portfolio have a significant technical assistance component. Many of these programs have proved to be of significant value to the country missions. Is it feasible for the country missions to bear the full cost of such technical assistance, thereby allowing the S&T Bureau's resources to focus primarily on research? Or is it necessary for the Bureau to continue to provide a significant technical assistance dimension to its total effort? If the latter is the case, there would be even fewer resources available to carry out vital research activity with current levels of funding.

Summary

Following are the major proposals and/or recommendations incorporated in Chapter 6:

- AID should take steps to address the declining financial support within the Agency for agriculture, generally, and for agricultural research, specifically. Efforts should be made to substantially expand the support for these efforts which are vital to the achievement of development goals in poor countries.

- AID should develop an appropriate mechanism and/or structure to achieve a more sharply focused, coherent and better-coordinated research effort in agriculture.

- In the absence of other Agency-wide mechanisms, the S&T Office of Agriculture should take the initiative in helping to establish an overall agricultural research agenda for AID.

- The objective for such a strategic plan should be to help developing countries achieve a state of food self-reliance rather than food self-sufficiency.

- The rapidly growing demand for agricultural products, along with the serious degradation of many of the natural resources on which agriculture depends, emphasizes the necessity for giving high priority to research relating to agricultural sustainability.

- There is a need, as well, for greater research attention to the problems of less-endowed regions--while not neglecting the better-endowed areas on which many countries must depend for much of their agricultural output.

- The need for maintenance research to protect production gains already realized must be recognized and supported.

- There is a need, as well, for research aimed at reducing significant post-harvest losses of food.

- In formulating a strategic research plan, S&T/Agr needs to take fully into account the programs of other parts of the Bureau, the regional bureaus/ country missions, and the Science Advisor's office in AID--as well as that of the other donors.

- The potential for applying modern biotechnology techniques to research supported by S&T/Agr should be carefully monitored and evaluated on a continuing basis without launching a major effort in this area with AID funds.

- Recognizing that there are many non-technical constraints to development in poor countries, greater emphasis should be given to the support of social science research, including that related to agricultural policy.

- Efforts should be made to forge linkages or networks among research institutions, both public and private, in industrial as well as developing countries. There should be a special effort by AID to help facilitate the greater involvement of the U.S. scientific community in helping to accelerate agricultural development in the Third World.

- Recognizing the dual research and technical assistance roles of S&T/Agr, special efforts should be made to have a major part of the cost of technical assistance functions borne by the USAID country missions making use of such functions.

- Consideration should be given to an organizational structure and/or working relationship within the S&T Bureau that could facilitate a more closely integrated approach to meeting agricultural research needs of the Agency.

- Efforts should be made by the Agency--at the highest levels--to avoid Congressional earmarking of research funds in the S&T/Agr for projects of relatively low priority. The development of a well-defined research strategy should help in this regard.

A number of additional recommendations are made to implement or facilitate the foregoing proposals. Included are the following:

- High priority should be given to interdisciplinary research efforts aimed at improving targeted commodities or enterprises. (Good examples of this type of research are the interdisciplinary plant breeding and related crop management research carried out by the commodity-oriented international centers--research that has contributed so significantly to the Green Revolution and other improvements in developing country agriculture). In addition to staple food crops which should continue to receive high

priority, it is recommended that certain other commodities also receive priority attention where appropriate. This includes vegetables and perennial tree crops (for food and feed), animal-based agricultural enterprises, including aquaculture, and a range of non-food commodities.

- High priority should be given to soil, water and pest management research which is not commodity-specific. (Commodity-specific research in these areas will be conducted as a part of the interdisciplinary approaches referred to above).

- Highest priority should be given to supporting the work of the international centers and the CRSPs that can contribute to the goals of AID. These are programs of proven effectiveness and they also provide opportunities to leverage AID resources to help achieve Agency objectives.

- S&T/Agr should use its portfolio of research projects to complement the programs of the IARCs and CRSPs where appropriate.

- There should be a careful assessment of the manner in which S&T/Agr resources are being used in support of research. If the areas of research emphasis recommended herein are accepted, resources should be allocated or reallocated to address these priority concerns.

- The sharp drop in support for S&T/Agr research during the past decades makes a compelling case for substantially increasing such funding to enable the office to address critical research needs. If such expanded funding is not forthcoming, however, it is recommended that priority be given to maintaining at least the current levels of funding for the IARCs and CRSPs. (For example, the review of the CRSPs programs referred to herein has already emphasized that reduction in CRSP funding have already reached critically low levels and serious questions concerning their viability might be raised with further reductions.) Consideration should then be given to alternative uses of at least some of the resources being allocated to individual projects in the S&T/Agr portfolio. Several possibilities for such alternative uses are suggested. Moreover, several criteria are suggested for determining how S&T/Agr resources might be most effectively used.