THE CRUCIAL ROLE OF INTERNATIONAL AGRICULTURAL RESEARCH:

IMPROVING GLOBAL FOOD PRODUCTION, BENEFITING U.S. AGRICULTURE, ENHANCING THE ECONOMIES OF DEVELOPING COUNTRIES AND STIMULATING U.S. TRADE

A Report of the

Working Group on International Agricultural Research
to the
Commission on International Trade, Development and Cooperation

February 1997

National Center for Food and Agricultural Policy
1616 P Street, N. W.
Washington, DC 20036

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Report of the Working Group on International Agricultural Research

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National Center for Food and Agricultural Policy

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PREFACE

This is one of three reports issued by the National Center for Food and Agricultural Policy in connection with the Commission on International Trade, Development and Cooperation. Another report comes from the Working Group on International Trade and Development and another reports the Conclusions and Recommendations of the Commission.

This Working Group on International Agricultural Research was formed to assist the Commission by identifying the key policy issues and offering background information and policy options. The Commission's report draws heavily on this report and adopts its major recommendations.

The idea for this Commission grew out of the debate that led up to the 1996 Farm Bill. A number of participants lamented that the debate centered around a rather narrow set of policy issues, ignoring some that were extremely critical to the long-term economic health of the U.S. food and agricultural sector. Those neglected issues related to the stake U.S. agriculture has in this country's international affairs, and particularly our economic interests in developing countries and emerging market economies.

This country's leadership and support has been important in international agricultural research. The U.S. was instrumental in forming the Consultative Group on International Agricultural Research, which now oversees a network of 16 agricultural research centers. The direct benefits of these centers to U.S. agriculture has not been fully appreciated nor has the potential from collaboration with them been realized. The Working Group on International Agricultural Research has offered several suggestions for realizing that potential.

On behalf of the National Center for Food and Agricultural Policy and the Commission, I wish to thank the members and alternates who served on this working group. Special thanks are due Dr. E. T. York, chair of the working group, for his leadership and to Dr. Don Plucknett for producing a draft of this report.

Recognition and thanks are also due those whose financial contributions made this all possible. They include: The Economic Research Service; the Foreign Agricultural Service and the Agricultural Research Service; USDA; USAID; Cargill, Inc.; DowElanco; Farmland Industries; Pioneer Hi-Bred International; and Harvest States Cooperatives. They deserve our thanks but bear no responsibility for the content of the three reports and do not necessarily agree with their conclusions and recommendations.

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Foreword

This report was prepared by the Working Group on International Agricultural Research, and its efforts were supported and expedited by the National Center for Food and Agricultural Policy, Washington, DC.

This report is prepared as a part of the effort of the Commission on International Trade, Development and Cooperation for use in the preparation of its report which will be presented in a national meeting scheduled to be held in Washington, DC, on February 25, 1997.

The Research Working Group is greatly appreciative of the excellent support and direction it has received from Dr. John Stovall of the Center for Food and Agricultural Policy and expresses to him its deep gratitude for his efforts. We are also indebted to Dr. Don Plucknett who was primarily responsible for developing a draft of the Working Group's report on International Agricultural Research. Excellent inputs to the report were made by all members of the Working Group.

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The Crucial Role of International Agricultural Research: Improving Global Food Production, Benefiting U.S. Agriculture, Enhancing the Economies of Developing Countries and Stimulating U.S. Trade

A Report of the
Working Group on International Agricultural Research
Commission on International Trade, Development and Cooperation

Summary

The world faces tremendous challenges in the next quarter century, including feeding and improving the diets of a burgeoning world population, increasing employment for the poor, protecting and enhancing natural resources, and ensuring global peace and security—as well as one increasingly committed to global trade involving greater national and regional competitiveness. Most of these challenges focus upon the poorest countries in the developing world.

Since agriculture is the foundation of the economies of most developing countries, there is widespread evidence and agreement that the best way to address these challenges is through effective programs of international agricultural research which can provide the means to increase food production, protect natural resources, enhance economic growth and reduce poverty. Such research is essential to help transform the agricultural sectors of developing world countries, which, incidentally, also represent the largest market for U.S. agricultural commodities, goods and services. Such research also contributes to improving U.S. agricultural productivity and competitiveness, thereby enhancing our own economies as well as those of developing countries.

It is in the national interest of the United States to participate fully and take leadership in a broadened global agricultural research system that supports economic cooperation, growth, and global trade. This proposal represents a considerable shift in emphasis for the United States, from a present foreign aid approach to support global agricultural research, to a new paradigm of international partnerships in agricultural research conducted within a framework of economic cooperation. To make the new paradigm work, changed thinking and different modes of operation will be required in many parts of the Federal government, as well as in universities and private firms, especially since the U.S. domestic research system is somewhat compartmentalized and inward-looking. Only a strong national commitment will bring needed changes, but the result would be the emergence of a more robust and agile research system, to handle both

domestic and international problems that hamper U.S. agriculture today and tomorrow as well as helping to expand trade.

Our Working Group makes one overarching recommendation:

> ***"As a matter of high national interest, that the United States support and participate actively in international agricultural research as part of a new paradigm of global economic cooperation based on trade rather than foreign aid."***

Given the contributions of international agricultural research to the economies of developing nations, as well as to the U.S., and the deterioration in support of U.S. international agricultural research over the last decade, there should be a major increase in U.S. financial support for such research.

Such financial support should come from two sources: (1) traditional USDA appropriations, and (2) the International Affairs budget (the 150 account) of the U.S. Congress. The Commission on International Development, Trade and Cooperation is proposing a 3 percent increase in real terms annually for five years in the total International Affairs budget, suggesting that at least half of this increase should go to a revitalized economic growth package which includes international agricultural research as a major, if not primary, component.

There must be active U.S. participation and leadership, involving federal, state and private entities, to conduct global agricultural research to deal with problems and opportunities, both current and future. This is a goal which cannot be achieved any other way—and, indeed, may depend on unprecedented research efforts and partnerships.

Planning, advocacy, and administration of federal support for international agricultural research should be a national responsibility to ensure broad involvement of agencies and departments whose efforts might be enhanced by international agricultural research, including USAID, USDA, EPA, Interior, Treasury, Commerce, U.S. Trade Representatives, National Science Foundation, and others.

Primary leadership for such an effort should be given, perhaps through a Presidential executive order and/or legislation, to a reformed USAID, which should be an independent agency reporting directly to the President and responsible primarily for international economic development. The name of this agency should be changed to reflect the new emphasis of the agency on cooperation in development rather than "aid." The *Agency for Development Cooperation* or *International Economic Cooperation Agency* are possible new names.

The agency would have humanitarian objectives and goals such as a response to famine, natural disasters and other emergencies around the world. However, the justification for its programs of international agricultural research could readily be based on how such programs directly benefit the U.S. through enhanced trade and improved domestic economies rather than on an altruistically-based aid rationale. It should be recognized, as well, that these programs benefit the U.S. by contributing to increased political stability in developing countries.

Currently there are a number of independent initiatives strongly advocating substantial increases in U.S. support for international agricultural research. These include the following: The Collaborative Research Support Programs (CRSPs), the Global Research on Environmental and Agricultural Nexus (GREAN) initiative, the program for Globalizing Agricultural Science and Education Programs for America (GASEPA), the efforts of the U.S.-based Trustees of the International Agricultural Research Centers, the International Food Policy Research Institute, the U.S. Department of Agriculture and others. Implementation of the recommendations of the Commission on International Trade, Development and Cooperation, along with its Working Group on International Agricultural Research, would provide the means to achieve the objectives of these various independent initiatives. Accordingly, we urge all of these groups to provide active, cohesive support to implement the proposals of the Commission and its Research Working Group.

The Global Challenge and Need

"We must engage the international community in the demanding and unremitting task of meeting the challenge of feeding a world where a billion people go hungry today and to whose population will be added another billion over the next decade."

Ismail Serageldin, Chairman of the CGIAR, 1996.

" ...poverty reduction, widely-shared growth, food security, and sustainable natural resources management, cannot be met unless rural development in general, and a thriving agricultural economy in particular, are nurtured and improved."

Rural Development: From Vision to Action. The World Bank, 1996.

The Challenge

The world faces tremendous challenges in the next quarter century, including feeding and improving the diets of a burgeoning world population, increasing employment for the poor, protecting and enhancing natural resources, and ensuring global peace and security—as well as one increasingly committed to global trade involving greater national and regional competitiveness. Leading experts from many backgrounds and countries have conferred on how best to meet the challenges and opportunities and to improve peoples' lives; there is essential agreement on the imperative to increase food production and economic opportunity and to increase access to food and improve peoples' lives by reducing poverty.

There is also agreement that the most powerful way to achieve increased agricultural production, protect natural resources, achieve economic growth and reduce poverty in poor countries is the modernization of the agriculture sector brought about by effective global agricultural research and supporting services. These basic services are essential to help transform the agricultural sectors of the world's poorest countries, which incidentally also represent the largest potential markets for U.S. commodities, goods and services. Such programs therefore not only improve U.S. productivity and competitiveness, but also are essential for improving our own levels of economic growth.

Globalization

"...worldwide globalization issues have been in the forefront of every discussion. Globalization means moving away from well-known, traditional structures, organizational forms, and hierarchies and entering the unknown; it means **change.**"

Christian Bonte-Friedheim and Kathleen Sheridan, The Globalization of Science: The Place of Agricultural Research. ISNAR, The Hague. 1996.

Many studies support the propositions presented above, most of them concluding that: *business as usual will just not do as globalization becomes a way of daily economic life.* What is needed are changed institutions and modes of operation in a rapidly-changing, free-trading world struggling to cope with rapid population growth and mounting pressures on natural resources, while at the same time trying to raise incomes, improve nutrition and provide individual opportunities. In an increasingly competitive world, hundreds of millions of poorly equipped farmers with limited supporting services will be forced either to become competitive or leave their farms. Unless handled well, major social and political disruptions will increasingly occur which could upset global political and economic well-being. Such circumstances lead us to conclude that economic cooperation, not foreign aid, is needed as nations work together to overcome problems that limit agriculture and its improvement. Unless such problems are overcome, overall economic growth and security will also be limited.

The Global Food Situation

It is obvious that global food production must increase greatly to meet rapidly growing demands. Food needs are estimated to more than double by 2025, with further increases of 50 percent needed by 2050. The **need** for food will be influenced primarily by population growth. However, **demand** for food will be affected also by the ability of consumers to purchase food and by changing dietary patterns and urbanization.

It is also obvious that accelerated economic growth is needed in most countries, and for most developing countries, such growth will only occur if agriculture and related industries are improved. Today, with more favorable economic policies and trade liberalization, agriculture becomes even more important as a primary sector for economic growth, and agricultural products, including commodities, inputs, machinery and new technologies become centerpieces in international trade.

Although world population growth rates have been declining steadily since about 1970, about 90-100 million people will be added annually for the next several years; at this rate a new India would be added every decade. Some 95 percent of the growth will occur in developing regions where food deficits are already severe, and where alternative employment opportunities and economic growth are limited.

World Bank studies suggest that global population should grow from some 5.7 billion in 1996 to 8 billion in 2025 and 10 billion in 2050. More conservative estimates suggest a maximum population of about 8.5 billion may be reached around 2035. Regardless of whether one accepts a higher or lower projection, numbers of people and the related demand for food will increase substantially over the next several decades.

Response to Increasing Global Needs—And Future Prospects

Significant Developing World Progress

As a result of new technology from agricultural research, coupled with policies that encouraged agriculture and agricultural development, remarkable gains have been made in food production in some developing countries, particularly in India, China, parts of South and Southeast Asia and Latin America. India has increased its wheat production more than five-fold since the late 1960s, with almost all of the gains being made through higher yields on about the same area of cultivated land. China has achieved similar successes in meeting its food needs by applying science to agricultural production; using improved seeds, irrigation and fertilizer; and diversifying its agriculture in response to export market opportunities. As a result of these developments, China has transformed its economic and support structures that serve agriculture and the rural economies.

While improved technologies and policies are essential to achieve successes such as those listed in the preceding paragraph, appropriate institutions and services are also needed to help support agricultural development and transformation. With the exception of the gains made in China, most of the success stories listed above can be related to considerable U.S. investments in improving agricultural institutions and agricultural research capacity that were made more than a decade ago, some of them more than two decades ago.

Future Prospects for Improving Food Production

There is considerable debate about the outlook for agricultural productivity in the future. Some believe that crop yields have reached a plateau or that they are beginning to decline. Others point to continuing yield improvements in many countries throughout the world and urge a continuing search for scientific advances and new technology to boost yields even further.

Yield levels in most countries are well below theoretical potential yields, which for high potential lands have been calculated as high as an annual yield of 25,000 kg/ha grain yield equivalent. Also, theoretical yields have been calculated for the continents: South America leads in highest potential yields (18 metric tons/ha), followed by Africa (14.2 mt/ha), Asia (13.1 mt/ha), North and Central America (11.2 mt/ha), Europe (10.4 mt/ha) and Australia (10.4 mt/ha).

Throughout history, yearly crop yield gains have mostly been small and marginal, about 2-15 kg/ha/yr (1 percent or less). The question for agriculturists has always been, how to attain higher yields? Scientific agriculture has proved to be the answer, especially since World War II when most yield takeoffs occurred, beginning after the

war in industrialized countries and since the late 1960s in some developing countries. Yield takeoff can be defined as a point where, after years of very slow or stagnant yield gains, usually well under one percent per year, there is a clear transitional point where yields move well beyond rates of gain of one percent (or less) to two percent or more. These higher rates signal a shift toward modern agriculture, and, in most cases, these rates of gain can be sustained over the years.

Both the United Kingdom and the United States reached yield takeoff in wheat just after World War II when yields began to climb with the advent of new varieties and improved practices. Yield takeoff in corn in the United States began in the 1930s with the advent of hybrid corn and has averaged about 125 kg/ha/yr since. Average corn yields in 1900 were about 25 bu/ac (1.4 mt/ha), while in 1994 the average yield was 153 bu/ac (8.6 mt/ha).

What does yield analysis tell us about present trends? The picture in wheat is very interesting. China achieved yield takeoff in wheat about 1960 and over 30 years has had an average gain of 91 kg/ha. India achieved takeoff in 1967, with an average 54 kg/ha/yr gain since, enabling it to more than triple wheat production while reducing the amount of land sown to wheat. Ireland has achieved yield growth of 285 kg/ha/yr over the past decade and now enjoys yields of more than 8 mt/ha. Parenthetically, a yield improvement of 285 kg/ha/yr would provide a new (metric) ton of wheat every 3.5 years. Egypt achieved yield takeoff in wheat in 1969, and has had two distinct periods of yield growth; 1969-1980 gains averaged 64 kg/ha/yr, and 1980-1990 gains averaged 200 kg/ha/yr, giving an averaged 128 kg/ha/yr since yield takeoff, a figure that compares with corn yield gains in the U.S. since takeoff in the late 1930s.

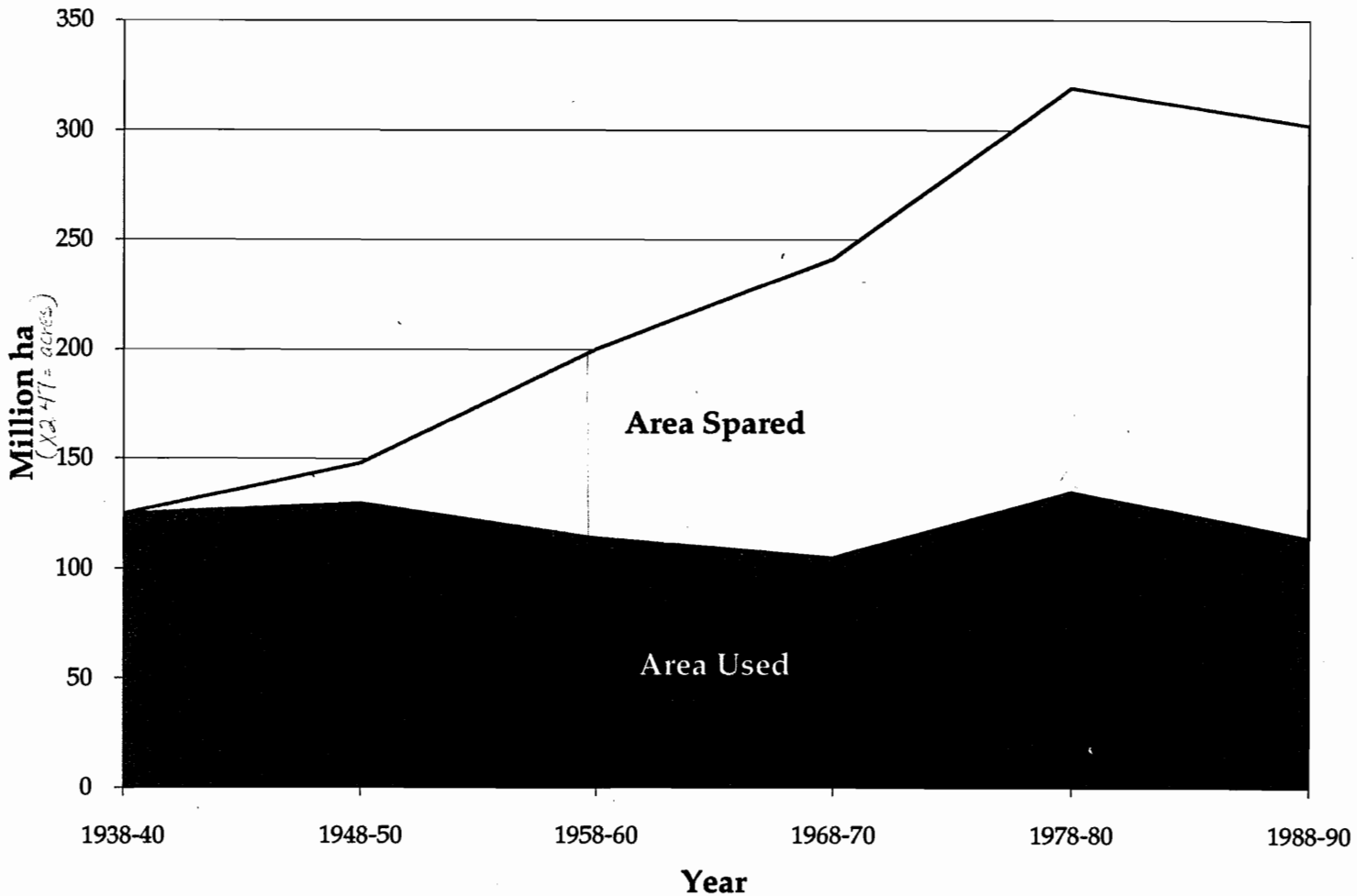
Rice presents another example. Once thought to be a dead-end crop for many tropical countries because of intractably low yields, rice has experienced tremendous yield growth since the late 1960s. New semi-dwarf rice varieties developed at IRRI and CIAT have dramatized the high yield potential of rice in developing countries, particularly in Asia, Latin America and Egypt. Rates of gain after takeoff have been: China--125 kg/ha/yr; Philippines--takeoff in 1968, averaged 68 kg/ha/yr for more than 20 years during which yields more than doubled; Indonesia--takeoff in 1968, averaged more than 110 kg/ha/yr as yields more than doubled; Colombia--takeoff in late 1960s, yields jumped from 2 mt/ha to 5 mt/ha in 23 years, at a rate of 95 kg/ha/yr.

In corn, the world average gain during the 1980s was about 30 kg/ha/yr. Twenty-four countries, 15 of them developing countries, had yield gains above the world average. Highest gains were achieved by Chile, with an astounding rate of 300 kg/ha/yr over the decade of the '80s, using U.S. hybrids as the genetic base. Corn yields in Chile now average over 8 mt/ha (more than 140 bu/ac), more than double the yields of 1979-81. Takeoff in corn in Europe apparently occurred about 1963, and yields more than doubled over the next 20 years, at a rate of 160 kg/ha/yr.

More examples could be given, but space does not allow. The following are some conclusions that can be drawn from yield studies:

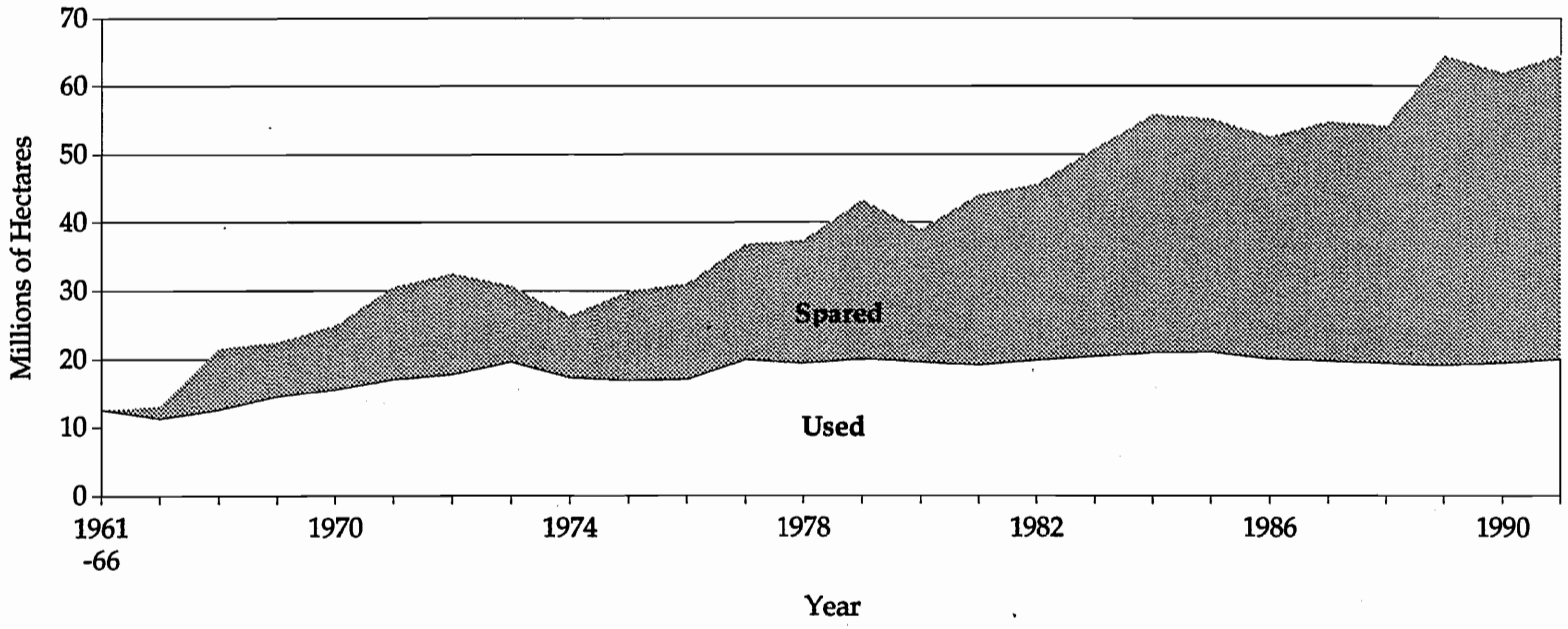
- Most countries are well below their attainable, practical yields.
- Average annual rates of yield gains for most countries indicate we are still well below the maximum yield of most crops. The high rates of gain being achieved by some countries indicate there is still room yet for further yield improvement, but this will not be easy. Excellence in agriculture requires much hard work, knowledge, and keen attention to detail - not only in the laboratory and research stations of both public and private parties, but also on millions of farms.
- Yield performance in terms of annual gains as well as average yields attained does not indicate significant environmental degradation that might affect yields. The general trend for most crops and countries is sustained growth, often at high and even accelerating rates of gain. A significant environmental benefit of improved productivity is that less land is required to obtain the necessary productivity. Figure 1 shows the amount of land spared from production for all crops in the U.S. from 1961 to 1990 as a result of higher yields. Figure 2 provides comparable data for India as a result of improvements in productivity of wheat from 1961 to 1991. It should be recognized that the figures in Figures 1 and 2 of "land spared" are very conservative since the land "spared" for agricultural production is usually less productive than the land currently responsible for the higher yield.
- High rates of yield gain today indicate that research begun in the 1960s, 1970s, and 1980s is paying off in greater productivity. Continued investments in research will allow continued gains in productivity.
- Yield takeoff is not restricted to developed countries; indeed, it appears that almost any country that wishes to improve its yields can do so, provided it imports or develops the necessary technology and develops a more favorable policy environment for agriculture;
- At least in the cereals and most food crops, yields do not appear to be leveling off or declining; where yield gains are falling or even negative, very often civil strife, war, or droughts have been involved.
- When developing countries achieve yield takeoff, their rates of yield gain often exceed those achieved earlier in developed countries; this can be attributed at least in part to the increased knowledge base and improved plant materials and techniques developed through international research.
- Continued support for agricultural research, both at national and international levels, will pay big dividends in providing a strong base for continuing productivity gains into the foreseeable future.

Figure 1. The Land U.S. Farmers Saved by Raising Yields of All Crops, 1938 to 1988-90



1938-40 Production: 252 million tons
1988-90 Production: 596 million tons
Source: Unknown

Figure 2. The Land Indian Farmers Saved as a Result of Increased Improvements in the Yield of Wheat



In addition to yield studies which indicate potentials to achieve desired production goals, it should be recognized that there are other means to enhance food production and availability. For example, research to improve resistance to both biotic and abiotic stress is a means to enhance food production. Reducing total cost of production by reducing chemical inputs through genetic research has both production and environmental implications. Further changes in national policies in developing countries may also provide a major stimulus to agricultural production. Moreover, research to reduce significant levels of post harvest losses of crops can result in significant increases in the amount of usable agricultural production.

The Vital Role of Agricultural Research in Meeting Global Challenges

We begin our consideration of the vital role of agricultural research with three propositions and six basic assumptions—as follows:

Proposition 1. The aim of international agricultural research should be the transformation of agriculture:

- to attain productive, profitable enterprises for farmers,
- to not only enhance agricultural productions, but also to respond to changing market requirements and reduce significant post-harvest losses,
- to protect and enhance the natural resource base and address agriculturally related problems of environmental degradation,
- to address and resolve policy and social problems which may impede agricultural development,
- to deliver healthy, quality products to markets,
- to generate research products, technologies, and information systems,
- to attain lower food prices for consumers,
- to generate increased on-farm and related off-farm employment and expand economic growth in the poorer, generally agrarian-based economies; and
- to achieve an increased contribution of agriculture and related industries to global trade and overall economic development.

Proposition 2. Based on a goal of agricultural transformation, there is a critical need for strengthened United States involvement in a dynamic global agricultural research system:

- **to bring about agricultural transformation in poorer countries** by boosting agricultural production and reducing poverty, thereby providing improved global security and new trading partners and markets for U.S. products, and
- **to continue agricultural transformation in the U.S. itself** by ensuring a more robust and agile domestic agricultural technology generation capacity, both public and private, to deal with problems facing U.S. agriculture in a trade-driven, free market global economy.

Proposition 3. A new paradigm for global agricultural research must be developed with creative, forward-thinking U.S. leadership that will:

- create a collaborative system for agricultural research to suit the goal of international economic cooperation, in which trade and free markets will be guiding principles,
- build on past experiences in international agricultural research such as the work of the Consultative Group on International Agricultural Research (CGIAR) and its partners—as well as by others,
- through strategic partnerships, involve more fully the leadership and scientific prowess of United States public and private research with scientists from industrialized countries and developing countries,
- mobilize appropriate support and strategies for poor countries to participate in the rapidly changing, market-led development agenda of global trade,
- link institutional scientific capability and national self interest with global productivity, trade, economic development and sustainability needs and, thereby,
- significantly improve the well being of billions of people.

Six basic assumptions underlie the propositions stated above, as well as for planning for future agricultural improvement to meet national and global needs:

- continued intensification of agriculture is essential if we are to meet the needs of the growing world population,
- environmental concerns which must receive appropriate research attention can be partly addressed by enhancing and sustaining productivity on the best lands, thereby reducing mounting pressures on marginal lands,
- problems of public policy which impede agricultural growth in many countries must be addressed and resolved in order to achieve needed agricultural development,
- research to find new pathways for productivity gains is essential, as well as research to reduce large post-harvest losses which often occur,
- global trade will expand and, within that expansion, agricultural trade between the U.S. and developing countries will expand, and
- new strategies and approaches are needed to generate relevant technologies and develop knowledge systems that are responsive to changing comparative advantages and improved competitiveness for both the United States and the poorer countries.

Scientific Revolution and Agricultural Transformation

The previous section illustrates the power of science to help transform agriculture, especially in industrialized countries, and it should be clear that what is wanted in all countries is agricultural transformation. However, as recently as 60 years ago, few persons held even a dim vision of what the potential for agricultural improvement might be. Still, there was a glimmer of understanding, for in 1930, the eminent economist, John Maynard Keynes, wrote:

"From the sixteenth century, with a cumulative crescendo after the eighteenth, the great age of science and the technical inventions began, which since the beginning of the nineteenth century has been in full flood--coals, steam, rubber, cotton, the chemical industries, automatic machinery and the methods of mass production, wireless, printing, Newton, Darwin, and Einstein, and thousands of other things and men too famous and familiar to catalogue....

"There is evidence that the revolutionary technical changes, which have so far chiefly affected industry, may soon be attacking agriculture. We may be on the eve of improvements in the efficiency of food production as great as those which have already taken place in mining, manufacture, and transport. In quite a few years--in our own lifetimes I mean -- we may be able to perform all operations of agriculture, mining and manufacture with a quarter of the human effort to which we have been accustomed." (Keynes, 1931)

Keynes ended his article as follows:

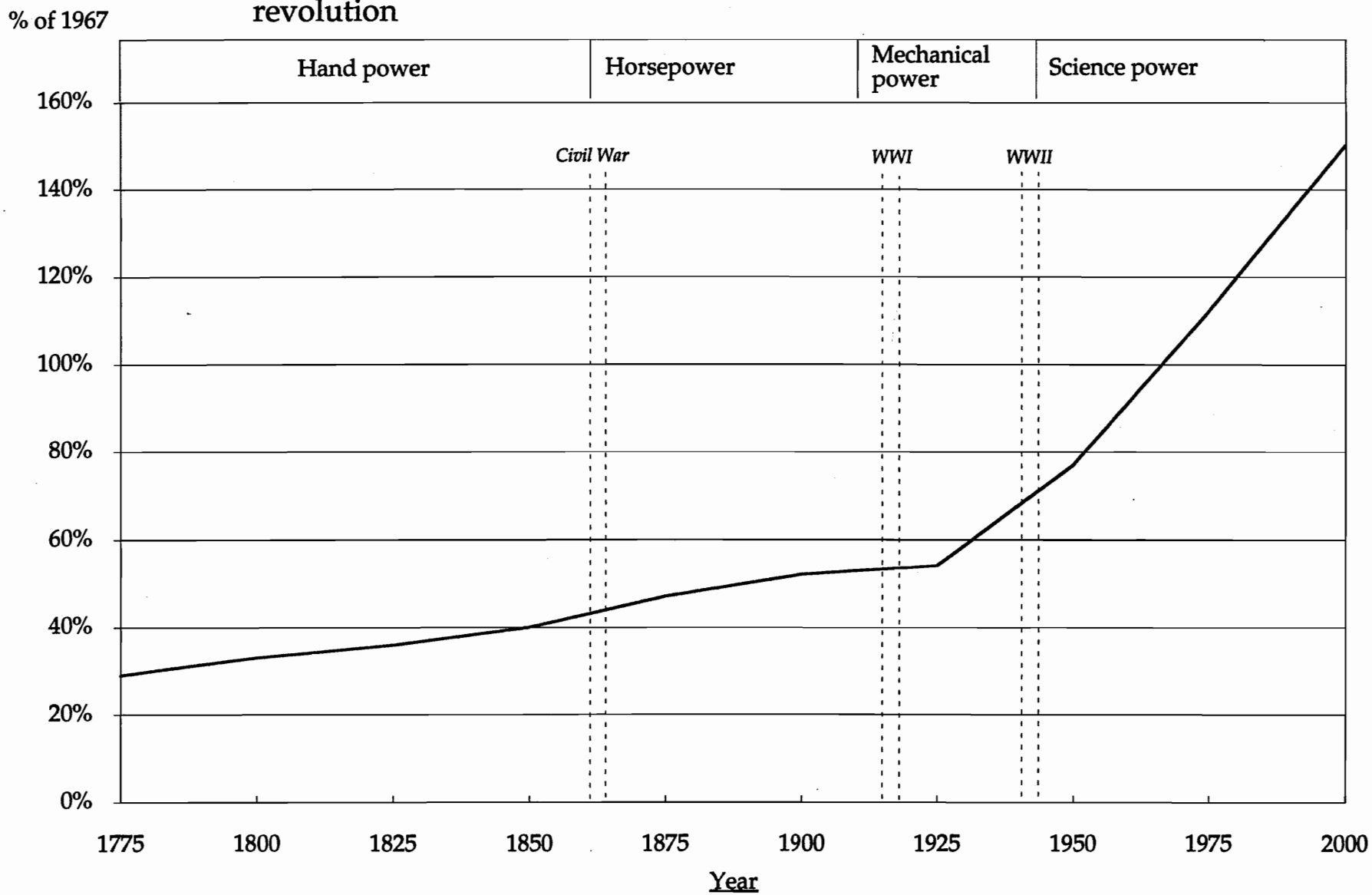
"Assuming no important wars and no important increase in population, the economic problem may be solved, or be at least within sight of solution, within a hundred years."

Keynes was referring, of course, to agricultural transformation so profound that he foresaw dramatic change in agricultural productivity, with drastic reductions in the amount of human effort required to achieve significant production. We know he was right in general terms, but even his prescient gifts did not allow him to understand just how efficient agricultural production would become, nor how powerful agricultural transformation could be in driving and transforming economies. Today, in the United States, one farmer feeds 77 persons, at a cost of just over 7 percent of total family income. Similar, but less dramatic, improvements are happening in other countries, including some that only a decade or two ago were considered less developed and with little hope of improvement.

Figure 3 illustrates how U.S. farm productivity has changed in various periods since 1775, highlighting the contributions of "science power" since World War II. Agricultural transformation has been a major factor in the United States which, within a century, changed from a third-tier country to superpower status. Figure 4 illustrates the transformation in U.S. corn productivity from the Civil War to the present.

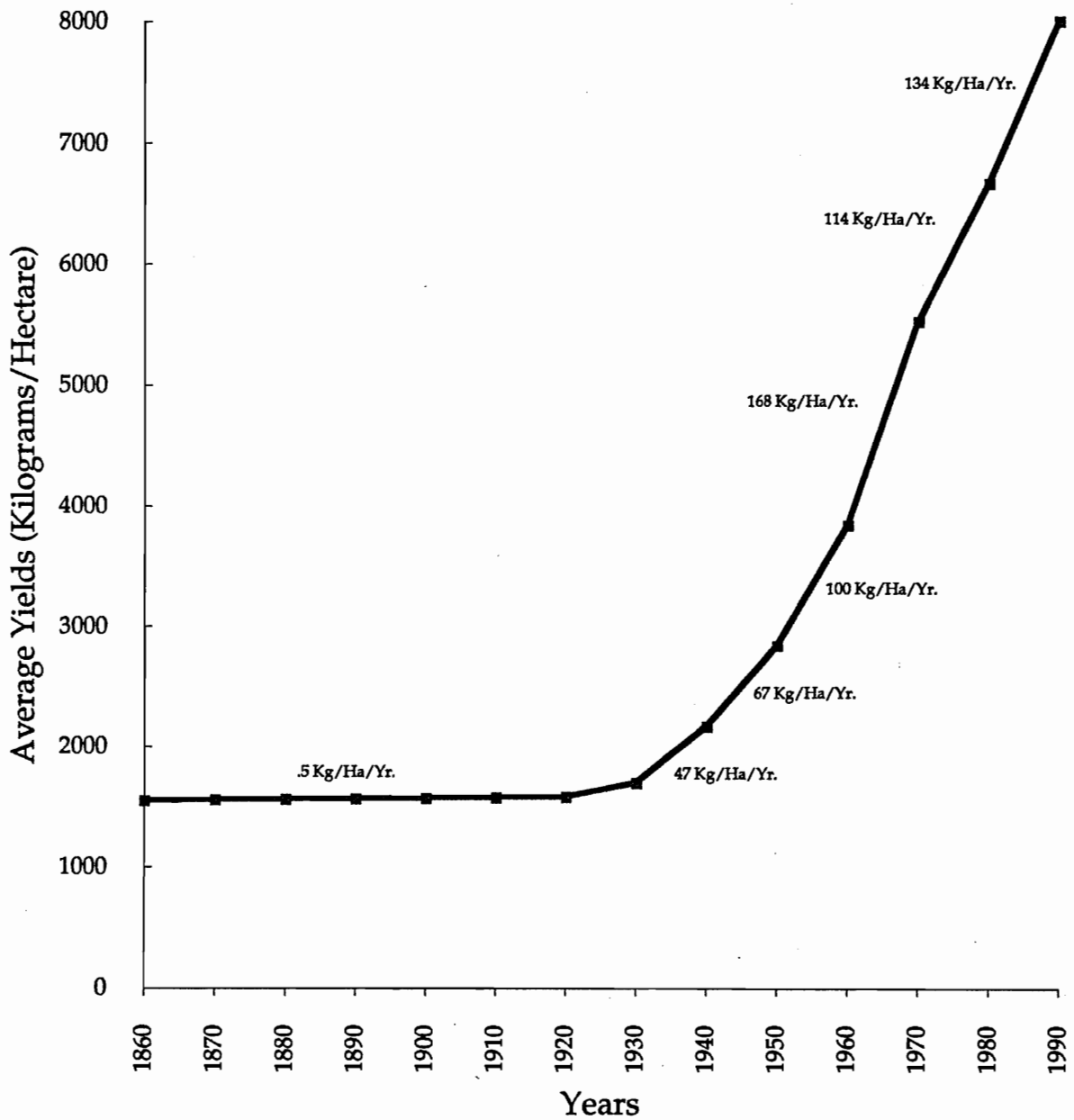
We now know that science-driven agricultural transformation can occur in countries that develop effective agricultural research capacities. This success was achieved first in industrialized countries, but in the late 1960s and early 1970s the dramatic success of the Green Revolution in wheat and rice in Asia and Latin America brought the realization that agricultural transformation could also occur in developing countries and that agricultural research was a wise and high-return investment.

Figure 3. US farm productivity rose dramatically because of scientific revolution



Source: After the Office of Technology Assessment, 1981.

Figure 4. U.S. Maize Yields, 1860-1990



The Agricultural Research Continuum

Research can be carried out in several levels or phases, recognizing, however, that research is really a continuum of activity, from the search for fundamental knowledge, through applied research to solve problems, the consequent development and testing of technology, and its eventual use (Figure 5).

• **Basic Research** (Level V).
Fundamental research aimed at understanding basic biological and physical laws and processes while advancing the state of knowledge. Basic research produces a feedstock of new ideas and concepts from which many fields of endeavor, including agriculture, draw and derive benefit.

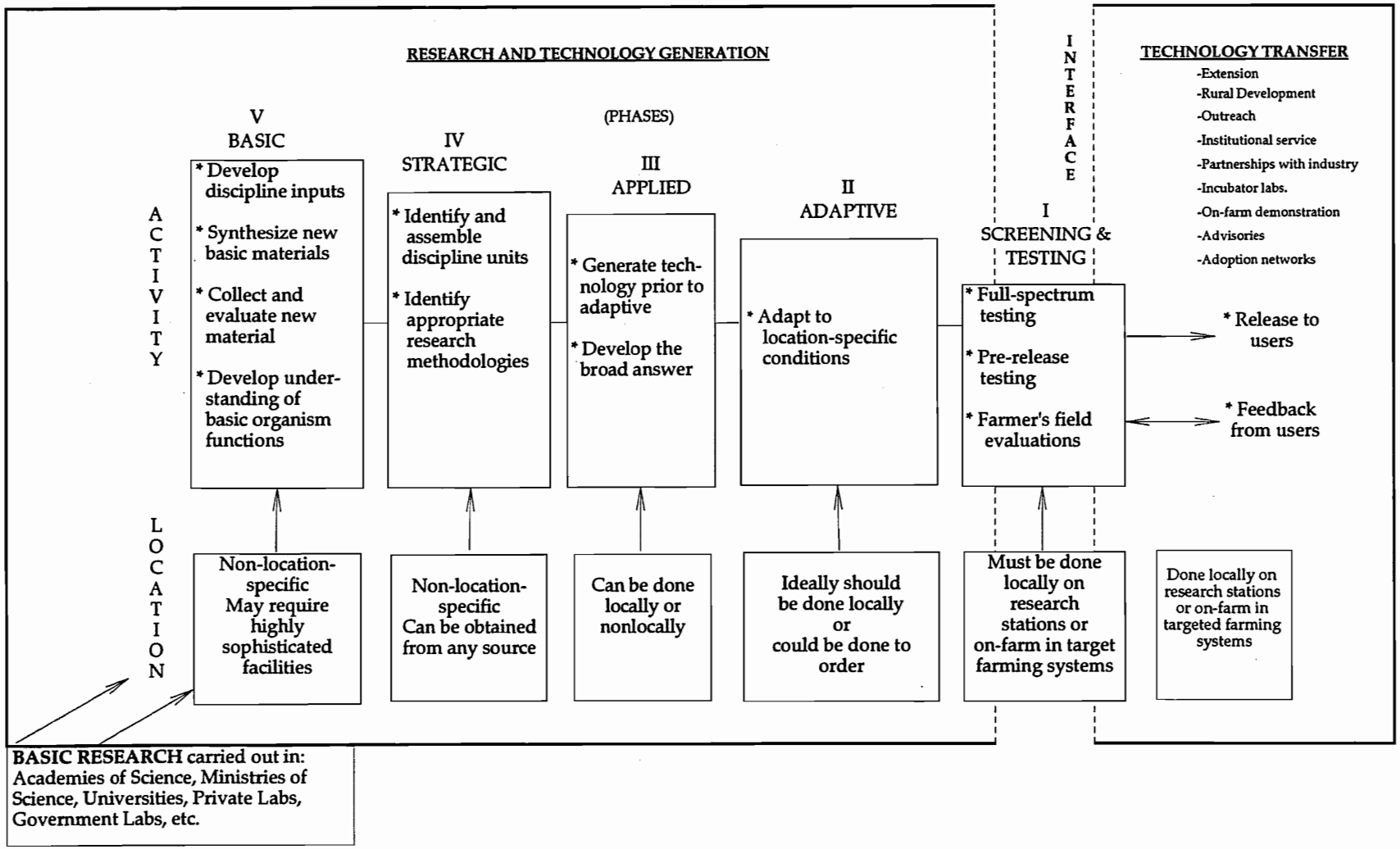
• **Strategic Research** (Level IV).
Strategic research is essentially fundamental research that is aimed at overcoming specific problems, and differs from basic research in that it does not aim solely to gain knowledge, but aims at a particular problem. For that reason, fundamental research in agriculture is best classified as strategic research, because although the reason for the research is problem solution, new understanding concerning biological and physical processes and principles necessary to overcome major problems. In private laboratories Level IV would be considered as **pre-technology research.**

• **Applied Research** (Level III).
Applied research aims to find a use for knowledge and ideas coming from strategic or basic research and to apply them to improve agriculture. Level III probably can be considered as **technology invention.**

• **Adaptive Research** (Level II).
Adaptive research aims to modify research products and new technologies for use in production, and is especially useful in extending the range of adoption of new technologies by fine-tuning products or management practices required to make the technology work in specific locations. Level II can be considered as **technology production and early testing.**

• **Screening and Testing** (Level I).
Screening and Testing aims to test new technologies under local conditions for possible direct use. Good research techniques and analytical skills are required to ensure its validity, but usually Level I does not require sophisticated equipment or laboratories. Level I could be considered as **technology diffusion/extension.**

Figure 5. Agricultural Research and Technology Generation and Diffusion Continuum: Phases of Agricultural Research



Source: Adapted from ISNAR (1981).

National Agricultural Research Systems (NARS)

Major partners in the global agricultural research system are the NARS, both in developing and developed countries.

A National Agricultural Research System can be defined as: All elements of a country's agricultural research establishment and capability, including; institutions run by government ministries, universities, specialized commodity or problem-oriented institutes, and private sector research institutions, including non-governmental research organizations supported by voluntary development or philanthropic bodies.

There have been attempts to categorize NARSs according to their capacity to carry out research and the resulting role(s) they might play within their borders and in partnerships. In 1985 the Agency for International Development classed countries as technology-producing and technology-adapting. Plucknett (1996) fashioned a related typology, using plant breeding capability as a proxy for relative state of development of scientific capacity:

• **Category I.** Technology-importing countries that do essentially no experimentation and whose only capacity may be to serve as a generalist contact with outside organizations. In Category I countries, only rudimentary Screening and Testing (Level I) is usually possible.

• **Category II.** Technology-importing NARSs that do limited experimentation restricted mostly to Adaptive Research (Level II) and Screening and Testing (Level I), and with no plant breeding capability.

• **Category III.** NARSs that import technology but also produce technology by conducting Screening and Testing (Level I), Adaptive Research (Level II) and some Applied Research (Level III). Some selection of improved crop plants but no plant breeding.

• **Category IV.** Technology-producing NARSs that are linked effectively into the global technology generation system, that have plant breeding capability, and can carry out research in Levels I, II, and III with relative ease.

• **Category V.** Technology-producing NARSs that enjoy peer or near-peer relationships with IARCs and advanced research organizations in selected areas of research, and can carry out Strategic Research (Level IV) in selected areas when necessary. Effective plant breeding capability, including the ability to handle and utilize basic germplasm and advanced techniques. Category V NARSs can be full partners in helping to solve certain pressing global or continental research problems.

Expanding the Agricultural Research Agenda

Increasing environmental concerns, along with a greater awareness of the need to protect and conserve our natural resource base for future generations, is becoming a vital part of our agricultural research agenda. Consequently, in addition to our emphasis on enhancing productivity, agricultural research institutions must realize the need for research on management and conservation of natural resources. Furthermore, policy, social and cultural perspectives are being incorporated into agricultural research programs. Moreover, there is a greater realization of the critical role of women in agriculture. Therefore, a new paradigm for agricultural research is developing in which these environmental and social issues are receiving needed attention as research agendas are developed.

Agricultural Research and Economic Cooperation

The world economic system has changed dramatically. In the midst of such change agriculture is becoming recognized again as an engine of economic growth, particularly in poor countries. The goal is agricultural transformation which involves dynamic agricultural change that moves a country from traditional agriculture with low yields, generally poor performance, and little hope for improvement toward modern agriculture that exploits comparative advantages to achieve higher yields, greater farm profitability, more off-farm employment, greater economic growth in rural areas, and improvement of rural life and communities.

A few models have been developed -- including needed institutional capacity -- to respond effectively to the new global competitive trade agenda. Examples are Chile and Indonesia where U.S. institutions have helped to generate the capacities, institutions and technologies to achieve remarkable agricultural transformation. These countries and other fast-growing economies started their dynamic economic growth rates by first expanding their agricultural sector at growth rates of 5-6 percent per year. Such dramatic growth was accomplished by focusing on policies and targeted programs, and agricultural technology development was always a key element of effective national efforts.

In the future, as national comparative advantage becomes the new driving emphasis, agriculture will be even more important, both domestically and abroad. International agreements -- GATT, NAFTA and its look-alikes-- and the development of other trade-related regional or international bodies are causing changes in markets and patterns of international trade. For example, agricultural commodities -- especially cereals-- have been traded internationally for years, but increasingly, high-value products such as fruits and vegetables are traded between continents, in both fresh and value-added form. To support such change there is need for a research system that works beyond national borders and that helps link public and private science to agricultural innovation, development and markets.

We are concerned, however, that at the same time new developments in trade are stimulating interest in a wider global agricultural research effort, funding for such research has declined. For example, the CGIAR--despite high praise for its work that sparked agricultural revolution in Asia and Latin America with dramatic increases in food production and reduced food costs--by 1994 had experienced a significant downturn in funding. Donor "aid fatigue" was cited as one reason for the decline, but even traditional supporters of agricultural research, including USDA and USAID, were reducing their support for agriculture and agricultural research. For example, since 1985 USAID has reduced its support to international agricultural research by 66 percent, its support to national agricultural research systems by 71 percent, while USAID technical staff numbers were being reduced by 66 percent. USAID, once the largest donor to the CGIAR, provided more than 25 percent of the CGIAR budget for almost 20 years, but in 1996 provided only about half that. Also the United States, once an intellectual leader in the CGIAR, based largely on the eminence of its integrated Federal/State agricultural research system, has seen its influence decline as it appears to be backing away from one of its "prize offspring" and as support for domestic agricultural research also has waned. However, support for agriculture and agricultural research was also waning elsewhere.

A matter of great concern is the state of the national agricultural research systems (NARS) in developing countries, many of which have declined in capacity over the past decade or two. The U.S. was once a leader, through USAID, in helping to strengthen NARS and to make them more effective, but since 1985 this support has dwindled by 71 percent and appears poised to disappear entirely. This declining support comes at a time when developing countries are facing problems of competition, trade and economic restructuring. The United States has made significant, effective investments in developing country NARS in the past, and continued linkages with these programs are essential. Such linkages must be revitalized in order to recoup elements of past investments and to utilize established capacity not now used effectively.

The continuing decline in support for agricultural research by the Agency for International Development, both in amounts and rates of decline, is alarming. Gary Alex (1996) recently completed a study of USAID Support for Agricultural Research in which he showed significant rates of decline for support for NARS, university development and IARC support. If one looks at the highest year of support for each category and compares it with 1996, both the patterns and rates of decline can be readily seen. Regarding support to NARS, the highest year was 1987, when $108.5 million was allocated, while the figure for 1996 was $27.8 million, with a 50 percent drop from 1995 alone. Support for university development reached a high of $24.9 million in 1991 but was only $3 million in 1996. Support for the IARCs reached a high of $48.3 million in 1986 while $22.4 million was provided in 1996. Finally, AID agricultural staff levels from 1977 to 1996 reached a high of 248 in 1985, but totaled only 84 in June, 1996.

We believe it is in the national interest for the United States in its economic cooperation activities to be involved more in the global agricultural research system--as an advocate, financial supporter, and policy formulator--building on our extensive prior experiences and investments and taking advantage of the clear link such activities have to our economic well-being. Such involvement would not only engage what is the world's largest national agricultural research capacity, but also the great educational establishment represented in the land-grant university system. Research and scientific cooperation for economic development, especially in agriculture, should become a keystone of U.S. foreign policy.

A Research/Agricultural Development/Economic Development/Trade Continuum.

The new paradigm for a global agricultural research system must lead to a system to deal with a continuum of *research, agricultural development , economic development and trade*. The new paradigm will build on previous experience in international agricultural research to boost food production, enhance natural resources and reduce poverty, but would move beyond to build strong linkages with partners in agricultural development, the private sector and international trade. Such a system has been proposed for Latin America and the Caribbean (LAC): TIAFTA (Technology Institutions for Agricultural Free Trade in the Americas) was designed to deal more effectively with economic opportunities brought about by trade liberalization (Bathrick *et al.*, 1996). To move agricultural research away from the former LAC agricultural development objective of import substitution, TIAFTA would develop a system to support agricultural competitiveness, diversification, and responsiveness to markets. Market-driven research underlies the TIAFTA concept, which aims to assure timely access to appropriate information and technology from both public and private research, as well as to enhance skills in management and marketing. In this increasingly trade-driven global economy, the TIAFTA approach has global implications.

Public Support for Agricultural Research

> *"Given the demonstrated success of agricultural research in bringing science and technology-based solutions to agricultural production constraints, it is paradoxical that agricultural research is now facing a crisis of a global nature.*
>
> *"In spite of the demonstrated effectiveness of agricultural research, policy makers are not convinced that further investments are necessary or that they can accomplish the seemingly overwhelming task of assuring food security to millions of the poorest of the poor and protecting the environment at the same time."*
>
> Petit, Michel J., et al., 1996.

Dr. Nyle Brady in a recent article (Brady, 1996) aptly stated the current situation concerning public funding of agricultural research:

> *"One last constraint that must be overcome is the decline in public support for agricultural research. Such decline is noted in both the North and South. The relative abundance of food supplies in industrialized countries, coupled with increased private-sector funding in some sectors, is used to justify relative declines in funding for agricultural research. But in most developing countries, where drastic reductions in public support for agricultural research has taken place, there are no compensating increases in private-sector support for scientific activities. Furthermore, decreases in foreign aid by some donor nations, particularly the United States, have compounded the budget problems of research institutions serving the developing countries. The overall decline in support for agricultural research must be reversed if the food needs of the future are to be met."*

Partnerships

> *"... the message cannot be ignored: without more--and more effective and efficient--agricultural research at all levels, and without global partnerships, we will never meet the challenges of feeding the hungry, providing a living for the poor, sustaining and protecting our natural heritage, and providing the basis for all of us to live in comfort and security."*
> Christian Bonte-Friedheim and Kathleen Sheridan, The Globalization of Science: The Place of Agricultural Research. ISNAR, The Hague. 1996.

A key concept of the new paradigm is partnership in global agricultural research, and different means are being explored to identify partners and build necessary working relationships. As an example, the International Rice Research Institute has organized a Council for Partnership on Rice Research in Asia (IRRI, 1996) to enhance mechanisms for rice research partnerships, promote interdependence, and reduce barriers hampering effective research.

There are very few market-focused institutional and operational models in research which systematically are trying to change from past strategies of supporting demand and import substitution economies. Clearly, new approaches are needed to develop new technologies and services to support market-driven economic growth. Here, small and medium-sized countries will be especially vulnerable in the face of new market and trade realities.

Partners in the global system will include public and private advanced research organizations (AROs), national agricultural research systems of developing countries (NARSs) and international agricultural research centers (IARCs), plus private and voluntary organizations (PVOs). These partners will operate in many ways including:

research networks, research consortia, global initiatives aimed at a particular problem or topic, bilateral or multilateral collaboration and scientist-to-scientist collaboration.

Partnership was a major theme of International Centers Week in October, 1996, during which the CGIAR convened a *Global Forum on Agricultural Research* to explore needs and opportunities, the scope for collaboration, and ways to strengthen partnerships. Four major related themes -- biotechnology; genetic resources conservation and utilization; ecoregional research; and public policy and institutional strengthening -- were considered in plenary sessions. A NARS Global Steering Committee presented a proposed *Plan of Action for Strengthening Global Agricultural Research* to improve NARS participation in global research and to strengthen NARS/NARS and NARS/ARO/IARC partnerships. The Global Forum culminated by adopting a *Declaration of Global Partnership in Agricultural Research.*

Partnerships are sought not only with other research institutions but also with stakeholders, including producer associations and agribusiness. A successful organizational model should include linkages to enlist private sector participation in establishing, financing and implementing the agricultural research agenda, and evaluation of the global system's response to technology needs and challenges.

While the U.S. itself has established capacities and relevant international connections to make partnerships work, there is an urgent need to create programmatic, institutional, operational and support structures to nurture needed changes and to identify opportunities in poor countries that should be supported.

What kind of partners does the global system require? It should be obvious that a given NARS or IARC cannot collaborate with a large number of AROs or other partners at the same time, partly because staff numbers alone would preclude that. What is needed is a meshing of the work of those involved in basic science with agricultural scientists who are knowledgeable about particular international problems and to find research sites that suit the needs of the global collaborative research effort. To obtain the talent and basic science capability needed, institutions with depth and excellence in particular fields will be sought.

An Emerging Strong Consensus Concerning the Need for Major Commitments to International Agricultural Research.

Despite the tremendous progress made in food production since World War II, many responsible organizations in the U.S. and worldwide are calling for major research efforts to improve agricultural output over the next half-century. In the U.S. food and sustainability concerns plus advances in trade, science and free markets have led to new ways of thinking. Some of the ideas and findings that are emerging include:

In the months of preparation for the World Food Summit held in November 1996, USDA, the U.S. State Department, the Agency for International Development and the U.S. Treasury Department came together to emphasize the need for the United States to endorse a major agricultural research initiative to help achieve the goal of global food security. This coalescing of support for international agricultural research by major U.S. government agencies recognizes the fact that the U.S. has much to contribute to such efforts and that the U.S. must reassert its leadership role in this area--a leadership role which has deteriorated greatly in recent years.

As a follow-up to the World Food Summit, the Association for International Agriculture and Rural Development (AIARD) convened a forum in Washington, DC, on January 23, 1997 to address the implications of the Summit for the United States.

A recent study by the Center for Strategic and International Studies for the Task Force on U.S. and the Multilateral Development Banks (MDBs) Working Group on Poverty Reduction concluded that it is in the U.S. interest for MDBs to place strong emphasis on helping countries to transform their agriculture sector. Without such assistance, there could well be "backsliding" on global trade liberalization, with detrimental effects on U.S. economic growth. Agricultural research and complementary market-driven services have increasingly become an important role for the MDBs. As an added benefit, the U.S. itself has considerable expertise to support such important multilateral investments in poor countries.

The International Food Policy Research Institute (IFPRI) in recent years has published a very impressive series of analytical papers emphasizing the need to intensify global agricultural research efforts. IFPRI considers these efforts essential in addressing major emerging economic and humanitarian problems related to food production and developing-country economic development needs--as well as to advance U.S. trade interests.

A recent USDA study (Fuglie *et al.* 1996) presented three general conclusions: ... that agricultural research (1) continues to be a solid public investment, and (2) continues to require involvement by the Federal Government, and that (3) the most compelling case for Federal funding is for more basic research, development of technologies where private incentives are weak, and research that informs public and private decision-making. Specific conclusions included: (1) the lack of growth in federal research expenditures and support for maintenance research limits the ability of public research to respond to new demands; (2) some 40 percent of private R&D investments goes to product development, as compared to 7 percent in public research; and (3) investments in public research can lead to increased private research, because of new market opportunities created by scientific and technological advances.

The GREAN Initiative (Global Research on Environmental and Agricultural Nexus), which has the active backing of 20 major land-grant universities, the IARCs and a

half-dozen leading U.S. professional associations of agricultural and natural resource scientists, proposes a major expansion in research by U.S. universities in collaboration with the IARCs and NARS to improve agricultural productivity in an environmentally sustainable manner (Lele and Coffman, 1995). Funding limitations prevent the implementation of this very promising initiative.

In the late 1970s and early-to mid-1980s the Board for International Food and Agricultural Development, working with and through USAID, provided leadership and direction to the development of a number of research programs involving collaboration, primarily among U.S. universities and NARS—with some participation by IARCs. These programs, collectively referred to as CRSPs (Collaborative Research Support Programs), supported partially by USAID, earlier faced major reductions in financial support from AID, despite their widespread success and acclaim. We applaud the fact that the CRSPs appear to be benefiting from recent increased support within the Agency for International Development. This support must be sustained because of the promise that the CRSPs demonstrate as a model for the new paradigm being suggested by the Working Group.

The U.S.-based Trustees of the IARCs have launched an effort to encourage greater support for international agricultural research--with emphasis on better collaboration between the IARCs, U.S. universities, and the U.S. private sector. Emphasis is being placed upon the concept of "complementarity" rather than "competition" among research organizations.

The U.S. National Association of State Universities and Land-Grant Colleges (NASULGC) in its new Action Plan for Agriculture and Natural Resources stressed the importance of: (1) an agricultural system that is highly competitive globally, (2) a safe and secure food and fiber system, (3) a healthy, well-nourished population, (4) greater harmony between agriculture and the environment, (5) economic development and improved quality of life, and (6) society-ready graduates (NASULGC, Nov. 1996). This study pointed out that, "Improving food security in developing countries through agricultural research and education provides a major opportunity to both meet humanitarian needs and to increase global stability," concluding that it is in the self interest of the United States to improve agriculture in poor countries and thereby increase trade with those countries. To enhance their involvement and effectiveness in global agriculture, many of the land-grant universities have integrated an international dimension as a cross-cutting theme to the tripartite missions of teaching, research and extension/outreach. This is a significant departure from their past international involvement which was characterized largely by roles in development assistance and institution building. The new paradigm for international activities that is emerging on the land-grant campuses recognized that a global dimension is essential in this period of history, and that it greatly enriches the on-campus experience of members of the academic community.

An important new initiative of the Board on Agriculture of NASULGC is GASEPA (Globalizing Agricultural Science and Education Programs for America). GASEPA aims at "assuring a critical mass of ingenious and creative scientists and professionals... attuned to global agricultural and environmental issues,...and...solve the problems of the future," by making "our colleges and universities...windows to the world, through collaborative partnerships with overseas institutions that are mutually beneficial to us and our partners." Although focused primarily on human resource development, GASEPA priorities reflect a need for research and extension/outreach and refer specifically to international education, economic and research partnerships and joint ventures.

To follow the NASULGC plans a little further, we would point to the example of the plans of Washington State University to develop as a "global land-grant university." The concept is based on development of mutually beneficial products or ideas that result from sharing information, technology and resources within global partnerships. Funds from public, foundation and private sources are used to develop "strategic alliances" with institutions around the world (Bathrick *et al.* 1996). One such alliance is with the *Universidad de Chile* in several fields, including integrated pest management, food sciences, agriculture, natural resources, nutrition and international trade. Planning workshops are held between the two universities to help find common interests and identify research responsibilities.

These and other essentially independent efforts all emphasize the same basic point--namely, the need for a greatly expanded emphasis on international agricultural research to meet emerging new problems, the solutions for which demand a renewed emphasis on research. So, despite the great progress through past research efforts, the task is continuing and, in many respects, is more complex and difficult because:

- Many believe that easy gains in food production have in many instances already been realized, and that greater research efforts will be needed to achieve the continued rate of gain necessary to meet steadily growing demands for food and other agricultural products.

- Some attribute the slowing down in the rate of increase in food production in recent years to natural resource and environmental degradation problems associated with agricultural production, while others believe different factors are responsible for such slowing. There is a strong consensus within the agricultural science community that needed agricultural production increases can be achieved without damage to the environment or the natural resource base on which agriculture depends. Where environmental or natural resource degradation problems do result from agricultural practices, it is widely believed such problems can be addressed satisfactorily through research so that needed agricultural productivity gains can be realized without damage to the environment. Increasingly, agricultural research is being conducted with such a "sustainability perspective."

- It is recognized that as yields or productivity levels increase, there must be an ever greater emphasis on "maintenance" research to maintain the gains in production already achieved. Global agricultural research in its international trials and search for genetic resistance or tolerance to pressing agricultural problems has an important role to play in productivity maintenance research. Estimates are that half or more of genetic improvement research at IARCs such as CIMMYT and IRRI must be devoted to maintain production gains already attained.

- Basically, the global agricultural research system was developed to help meet world food needs, and while that goal still exists and, indeed, must be intensified to meet the needs of the next two or three decades, other factors have also come to the fore. In today's trade-driven economic setting, management of farm enterprises must reflect complex issues embracing local, regional, and international competitiveness, including rapid changes in commodity prices and consumer preferences. Such new realities have tremendous impact on the usually under-serviced small- and medium-sized producers.

Agricultural Research as an Investment

Peterson(1976) effectively stated the case for agricultural research:

> *"Agricultural research is best viewed as an investment. Real resources such as scientific personnel, laboratories and equipment, buildings, etc. are employed to produce a product or output. This output is new knowledge. New knowledge has value because it enables society to increase its total output of goods and services. In the case of agricultural research, the knowledge produced is utilized in two ways. First, it makes possible the production of new or improved inputs for agriculture. These inputs include new higher yielding varieties of crops, more productive breeds of livestock and poultry, more efficient machines and power, and yield-increasing herbicides and insecticides. Second, the knowledge can be used directly by farmers enabling them to produce more efficiently, thereby increasing output for a given level of production cost.*
>
> *"The value of agricultural research can be measured by the value of additional output that results from greater productivity in agricultural production. This additional output can be food and fiber, or it can be a greater output of nonagricultural products made possible by the release of conventional inputs from agriculture, mainly land and labor."*

In the second paragraph, Peterson points to the positive effects of agricultural growth on nonagricultural enterprises, which, of course, helps lead to industrialization. This message should be heeded by policy makers in all countries, including the U.S.

Benefits to the United States from International Agricultural Research

"The bottom line is that our assistance programs foster an environment in which American trade and investment can prosper in developing nations."
George Ferris, Chairman and CEO, Ferris, Baker, Watts.

"After the Korean War, we provided Korea with a lot of wheat, corn and soybean oil. As a poor country, they needed that to survive, but as they got richer, they became good customers,"
Roy Smith, Nebraska Farmer

Returns from Investments in International Agricultural Research through Greater Trade

Simply put, it is good business to help developing countries to improve agricultural research and thereby speed agricultural development and achieve agricultural transformation. Research at the International Food Policy Research Institute (IFPRI) shows that "...each dollar invested in agricultural research [in developing countries] generates $4.39 of additional imports by those countries" (Pinstrup-Andersen *et al.* 1995) . Why would this be so? In the words of the authors, the answer lies in the fact that,

> *"...agricultural assistance in the form of agricultural research expands developing-country imports from the world market. . .because agricultural research does more than increase agricultural production. The rise in agricultural production boosts incomes within and outside agriculture, which increases demand for other goods and services. This increases economic growth, and more growth leads to more imports. Ultimately, the value of the additional imports actually exceeds the initial investment to research."*

Finally, the authors conclude:

> *"Donor investments in productivity-enhancing agricultural research will yield positive returns for donor countries in the form of new exports."*

So research-induced change in developing countries can help improve United States trade, and agricultural research constitutes an essential investment for the U.S. which can generate considerable benefits and returns. These benefits are evident in terms of increased export of agricultural commodities. In fact, more than 50 percent of all U.S. agricultural exports are purchased by lower income developing countries. As the agriculture of developing countries is improved through research, the U.S. also exports many production items including fertilizers, chemicals, farm machinery, processing equipment, etc. Thus, as the agriculture of developing countries improves, the opportunities for exporting both agricultural products and agricultural inputs to developing countries is greatly enhanced. Indeed, agricultural research-induced

change is essential to improve U.S. trade, which is so closely linked to domestic economic growth and job expansion. But, further, let us explore direct benefits to the United States from international research.

Direct Benefits to U.S. Agriculture

A recent IFPRI study (Pardey *et al,* 1996a, 1996b) shows that United States assistance to the CGIAR, in this case to CIMMYT and IRRI, has paid off handsomely in improvements to domestic wheat and rice production. Cost-benefit analyses indicate that from 1970 to 1993 the United States gained at least $3.4 billion and up to $13.7 billion from the use of improved wheat varieties developed by CIMMYT, at an investment cost of less than 2 cents for every $100 of U.S. wheat production. The benefit-cost ratio for U.S. support of CIMMYT is as high as 190 to 1. In the same period the U.S. economy realized at least $30 million and up to $1 billion through the use of improved rice varieties developed by IRRI, at an investment cost of about 9 cents per $100 of U.S. rice production. The above benefits were gained through international research aimed at developing countries, but such research also produced gains in U.S. production because of genetic improvements to wheat and rice. (Figure 6.)

Experts agree on a number of other benefits to the United States of international agricultural research, including the following:

- access to new ideas and technologies;
- access to global germplasm collections;
- helping overcome threats of import of exotic diseases of crops and animals;
- a way to perform "preemptive research" on problems not yet found in the United States, especially incorporating resistance to pests and diseases;
- research linkages for studies of global change;
- participating in specialized global research initiatives in which there is a clear national interest and potential payoff; and
- access to crucial research sites in locations outside the U.S.

Beyond the direct and indirect effects listed above, especially as both USDA and state research budgets are declining and as the new farm bill reduces further the subsidy system, the U.S. needs strong growth in export markets. Agricultural commodities and processed products form a real growth pole of our country's total exports. Most of these shipments go to poorer countries, and this trend is expected to increase.

Figure 6. U.S. Benefits and Costs from CGIAR Wheat and Rice Research

Benefits and Costs	Wheat	Rice
	(millions of 1993 U.S. dollars)	
Present value of benefits	**13,653**	**1,042**
Present value of costs	**71**	**63**
Benefit-to-cost ratio	**190:1**	**17:1**

Source: Pardy, 1996.

Note: Benefits from varietal improvement research are expressed in present value terms for the 1970-93 period; costs represented U.S. government support to international wheat and rice research and cover the 1960-93 period.

The United States Stake in a Greater Global Agricultural Research System

Present U.S. National Capacity and Institutions

Despite declining public financial support for domestic agricultural research, U.S. agricultural research capacity is still the greatest of any country. However, future U.S. capacity is threatened as salary costs often comprise the largest share of institutional budgets, while operating funds for research drop to woefully low levels. Despite such problems, U.S. participation in the global system is not only desirable but essential, because the U.S. is still a leader in basic and strategic research, a major provider of advanced education in the agricultural sciences, and has much to gain from active participation in the global system.

The U.S. land-grant universities (LGUs) are natural participants in the global research system. Their interests are fueled by involvement in solving major international problems, in educating the next generations of agricultural scientists, and in assisting in global agricultural development to help meet national trade and economic goals. In this regard it is fortunate that partnerships with IARCs and NARSs are also highly desirable for the LGUs which represent an immense scientific and educational resource, both domestically and internationally. However, we cannot leave this topic without pointing out how vulnerable and weakened these LGUs can become, if adequate support is not provided to keep them creative, innovative and scientifically strong. At present, not all LGUs are as capable as they once were, and their continuing contributions should not be taken for granted.

Unfortunately, the U.S. lacks effective devices to support continuity of effective participation by the land-grant universities (and USDA) in the global agricultural research system. The Collaborative Research Support Programs (CRSPs) of USAID have provided one means of support for selected institutions to take part in research with NARSs and IARCs in partnerships in which human capital development (education) is linked to strategic and applied research. Despite their success, and their promise as a successful model for the new paradigm being suggested, the CRSPs face increasing financial pressures and their future appears uncertain. Also, at one time USAID had a competitive grant program to link U.S. scientists with the IARCs on important "bottleneck problems," and, while successful, the program was allowed to lapse.

The U.S. agribusiness community and producer organizations can play an important role in the greater global R&D system, especially in helping to generate new markets for products, providing the capital base for increased and sustainable growth, and in providing technical assistance and training. New public/private sector linkages are essential in this demand-driven era.

In the past USAID was a major supporter for international agricultural research but recently that support, too, has lagged. However, even at the height of USAID funding for international agricultural research, the U.S., of all the major countries, was most inadequate in systems to ensure that U.S. institutions and scientists could become involved effectively in international research. As a result, scientists have struggled on, sometimes with individual grants, sometimes on a case-by-case basis with USAID country mission support, sometimes with support from other donors, sometimes with personal funds, or sometimes with help from IARCs or NARSs themselves. Such arrangements have been less than satisfactory, with some good work being done, but always with the looming threat of funding shortfalls or outright halting of support.

The IARCs and NARSs want and need research collaboration with U.S. institutions. For problems that can only be solved on an international basis, most require close linkages with basic research laboratories. Some examples are: the successful collaboration of IRRI and CIAT with two Purdue University scientists, one skilled in biotechnology and the other who worked out the genetic relationships of the fungus that causes rice blast disease and its destructive disease patterns; the work of Cornell University and University of Wisconsin scientists with the International Potato Center (CIP) in enlarging the genetic pool of the potato by incorporating genes from wild *Solanum* relatives; the work of the Peanut CRSP, the Universities of Georgia, North Carolina State, Florida and Texas A&M with ICRISAT in using wild relatives of *Arachis* to widen the genetic pool of peanuts; and the success of the Sorghum and Millet CRSP (INTSORMIL) and its partner NARSs and ICRISAT in developing resistance in sorghum to the parasitic weed *Striga*.

In the cases listed above, the work of all institutions was enhanced by the depth of scientific talent and capacity for basic research at the universities, the wide pool of genetic resources held in collections of the IARCs, and participation of institutions in developing countries with their many valuable research sites. In such work, everyone brings some strength or expertise to the table to the benefit of all. This makes for exciting, dynamic research, and the results can have powerful effects on production agriculture. In the case of the *Striga*-resistant sorghum, an added dimension has been provided in that resistant materials are now being distributed and tested in some Sub-Saharan countries through World Vision, an NGO, with funding from USAID.

Making the U.S. Agricultural Research System More Effective in a Global Research System

The U.S. stands to gain tremendously from increased collaboration in a global agricultural research system. However, to do so more effectively, it must:

- understand that future U.S. development cooperation to support development in poor countries will depend on effective agricultural R&D to support market-led

economic development, and that this is not just the business of USAID or USDA. Indeed, it should be part of the total U.S. economic cooperation effort including, for example, the Departments of Commerce, State, Treasury and the Office of the U.S. Trade Representative, as well as agencies dealing with matters concerning the environment,

- make a firm commitment, provide public resources and develop an improved operational model to ensure broad, effective participation of the LGUs and USDA in international research efforts within the global agricultural research system,

- regain its strong level of support of the CGIAR and the IARCs as a national interest, not just as a responsibility of AID when support has greatly deteriorated,

- urgently begin collaboration to help develop the new capacities for the national agricultural research systems (NARS) in both developing and developed countries,

- invest in domestic strengthening of both LGUs and USDA research to reduce the erosion of public support that threatens the longer range viability of the integrated U.S. Federal/State/private research complex,

- be prepared to invest more in domestic productivity maintenance research, to sustain the gains already made; incidentally, the increased knowledge base that comes from productivity maintenance research has the benefit of adding to the store of knowledge and advancing agricultural development,

- involve the private sector (e. g., U.S. commodity organizations, agribusiness, PVOs) more fully in the total effort, and

- make a more effective global agricultural research system a matter of U.S. policy in our country's linkages with multilateral development banks, FAO, and other international agencies dealing with development.

Our Potential Roles and Benefits

It is clear the United States can benefit from a broadened, more effective role in global agricultural research that is driven by considerations of productivity, sustainability and trade. However, to achieve this will require a changed mindset on the part of policy makers and leaders so they will understand that U.S. involvement in agricultural research is essential to meet needs related to global food production, competitiveness and trade. The mindset change may be more difficult for U.S. institutions that see their role solely as supporting domestic agriculture, without fully understanding that participation in international research can improve their effectiveness in strengthening and developing new opportunities for U.S. agriculture as well as the broader national economy.

The USDA has laboratories located overseas which work mostly on crop and animal protection problems that are not yet present in the United States but pose potential threats to U.S. agriculture. These laboratories should be seen as assets in a global system and should be used strategically in that context, seeking and working with partners to gain crucial biological information concerning the organisms and their threats and, where possible, performing "preemptive research" to lessen the threats to U.S. agriculture.

The U.S. has much to contribute and to gain from global research on genetic resource conservation and utilization. The Biodiversity Convention has made global collaboration more complex, but we must continue to help work through the problems. The result should be continued access to germplasm, a widened gene pool for crops and animals, and a greatly improved knowledge base for both conservation and utilization of genetic resources.

Global Research for Global Trade: Benefits, Potential Impacts

More than ever before, the U. S, is a part of a global economy. We are, more than ever, selling and buying products that are a part of such a global economy. U.S. agricultural research efforts must reflect our role in the global economy and address issues to enhance our competitive position.

It is clearly in the self-interest of the United States to provide strong support for improving developing-country economies by strengthening their agricultural sectors.

Some recommendations from the TIAFTA proposal for LAC (Bathrick, *et al*, 1996), discussed earlier, appear to be relevant as the United States re-thinks its role in the greater global research system:

- a bold new institutional paradigm is needed based on the primacy of "institutional comparative advantage," to provide a basis for establishment of dynamic institutional linkages, operational processes, and working relationship with a broad spectrum of technology-related institutions. Driving concepts for the paradigm would include; "market-driven," "mutual benefit," "operational agility," "responsiveness to local resource constraints," and "responsiveness to market demands."

- differences in national comparative advantages will lead to customized institutions for each country, with new approaches that could be shared across borders.

- new "mindsets" must be created at all institutional levels, e.g., it is good business to work globally to overcome agricultural problems, and working in international research has clear domestic benefits, both in domestic production and in global trade.

- there is need to move quickly on development of new directions and approaches, and to involve essential institutions in the greater global research system.

- the concept of "strategic alliances" needs to be explored to encourage mutual benefits and to gain linkages between real beneficiaries of newly developed technologies.

Recommendations

It is in the national interest of the United States to participate fully and take leadership in a broadened global agricultural research system that supports economic cooperation, growth, and global trade. This proposal represents a considerable shift in emphasis for the United States, from a present foreign aid approach to support global agricultural research, to a new paradigm of international partnerships in agricultural research conducted within a framework of economic cooperation. To make the new paradigm work, changed thinking and different modes of operation will be required in many parts of the Federal government, as well as in universities and private firms, especially since the U.S. domestic research system is somewhat compartmentalized and inward-looking. Only a strong national commitment will bring needed changes, but the result would be the emergence of a more robust and agile research system, to handle both domestic and international problems that hamper U.S. agriculture today and tomorrow as well as helping to expand trade.

We make essentially one overarching recommendation:

> **"As a matter of high national interest, that the United States support and participate actively in international agricultural research, as part of a new paradigm of global economic cooperation based on trade rather than foreign aid."**

Following are strategies for the implementation of this recommendation:

- There must be active U.S. participation and leadership, involving federal, state and private entities, to conduct global agricultural research to deal with today's problems and opportunities as well as those of tomorrow. This is a goal which cannot be achieved in any other way--and indeed may depend on unprecedented research methods and partnerships.

- Strong national priority must be placed on broad-based effective participation in such a comprehensive global agricultural research system with adequate appropriations to undergird it.

- The Administration must reassert U.S. leadership and advocacy for international agricultural research systems to achieve the goal of a comprehensive global agricultural research system.

- Programs should be established to ensure U.S. participation in collaborative global agricultural research between U.S. advanced research organizations, both public and private, the national agricultural research systems in developing countries as well as more advanced countries (NARS), and international agricultural research

centers (IARCs). The program should be administered in the national interest within the context of global economic cooperation.

- Planning, advocacy, and administration of federal support for international agricultural research should be a national responsibility to ensure broad involvement of agencies and departments whose efforts might be enhanced by international agricultural research, including USAID, USDA, EPA, Interior, Commerce, Office of the U.S. Trade Representative, National Science Foundation, and others.

- In USDA and federal research institutions there should be a broader research agenda that includes global research collaboration; the new agenda should include research to bring good science to support trade objectives and international agreements, as for example, international harmonization of science-based food safety regulations.

- Part of the program related to basic and strategic research could be carried out using a competitive grant mechanism. This program should include a requirement for cost sharing with NARS partners and an invitation for private sector participation in the research.

- Given the potential contributions of international agricultural research to the economies of developing nations as well as to the U.S., and the deterioration in support for U.S. agriculture over the last decade, there should be a major increase in U.S. financial support for such research.

- Such financial support should come from two sources: (1) traditional USDA appropriations, and (2) the International Affairs budget (the 150 account) of the U.S. Congress. The Commission on International Development, Trade and Cooperation is proposing a 3 percent increase in real terms annually for five years in the total International Affairs budget, suggesting that at least half of this increase should go to a revitalized economic growth package which includes international agricultural research as a major, if not primary, component.

- Primary leadership for such an effort should be given, perhaps through a Presidential executive order and/or legislation, to a reformed USAID, which should be an independent agency reporting directly to the President and responsible primarily for international economic development. The name of this agency should be changed to reflect the new emphasis of the agency on cooperation in development rather than "aid." The *Agency for Development Cooperation* or *International Economic Cooperation Agency* are possible new names.

Reference was made earlier in this report to a number of independent initiatives strongly advocating substantial increases in U.S. support for international agricultural research (GREAN, CRSPs, GASEPA, the group of U.S. Trustees of IARCs, IFPRI, USDA and others). The implementation of the recommendations of the Commission on International Trade, Development and Cooperation, along with its Working Group on International Agricultural Research, would provide the means to achieve the objectives of these various independent initiatives. Accordingly, we urge all these groups to provide active, cohesive support to implement the proposals of the Commission and its Research Working Group.

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