INVESTING IN AGRICULTURAL RESEARCH

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It is a pleasure to participate in the inaugural meeting of the National Coalition for Food and Agricultural Research. I am now in my 57th year of continuous involvement in agricultural research and production, working primarily in the low-income, food-deficit developing countries. I have worked with many colleagues, political leaders, and farmers to transform food production systems. Despite the successes of the Green Revolution, the battle to ensure food security for hundreds of millions of miserably poor people is far from won.

Mushrooming populations, changing demographics and inadequate poverty intervention programs have eaten up many of the gains of the Green Revolution. This is not to say that the Green Revolution is over. Increases in crop management productivity can be made all along the line—in tillage, water use, fertilization, weed and pest control, and harvesting. However, for food crop production to continue at a pace sufficient to meet the needs of the 8.3 billion people projected by 2025 continuing research breakthroughs will be needed.

Meeting Global Food Demand

By the year 2025, global demand for maize will approach one billion tons, wheat 900 million tons, and milled rice 600 million tons. To meet this future food and feed demand, annual production of the three cereal grains—which account for more than 60 percent of the world food supply—will have to increase collectively by more than 600 million tons over the next 25 years. Over the next 25 years, it is likely that demand poultry and livestock products—with their consequent feed requirements—fruits and vegetables, and oilseed crops will also increase rapidly, perhaps more rapidly than the cereals, if income levels in the developing world improve in real terms.

The United States today is the largest producer of food surpluses, with agricultural exports in excess of $53 billion annually. This pre-eminent position is not accidental, nor is it exclusively due to natural resource endowments. Rather, it is the result of investments in agricultural education, research, and extension; mechanization and transport; fertilizers; irrigation; energy; credit; stimulatory agricultural policies; and lastly, but certainly not least, extremely productive farmers and ranchers. The demand for U.S. agricultural products is likely to be very strong in the coming two decades.

To meet projected food, feed, and fiber demands will require breakthroughs in both conventional and transgenic breeding to raise the maximum genetic yield potential of the major food crop species. Without increased investments in agricultural research and technology development it is unlikely that we will achieve adequate growth in agricultural production, and certainly not in environmentally sustainable ways.

Benefits of Agricultural Research and Technology

The success of American agriculture, the envy of farmers worldwide, owes much to the agricultural institutions and policies first established nearly one century and a half ago. In 1862 President Lincoln signed into law three bills that played a vital role in raising the U.S. to its preeminent position: The Homestead Act, which made relatively large (at the time) tracts of land on the frontier available to persons who committed themselves to living on the property and developing it; a law establishing the U.S. Department of Agriculture; and the Morrill Act, which established publicly supported land-grant colleges of agriculture and mechanical arts in every state. These laws later were supplemented in 1887 by the Hatch Act, which provided for the establishment of agricultural experiment stations, as well as closer collaboration between the agricultural colleges and USDA, by the Smith-Lever Act in 1914, which established the cooperative extension service, charged with introducing new technology to farm and ranch families; and by the Smith-Hughes Action in 1917, which established vocational agriculture programs in high schools.

The significance of these institutional developments cannot be over-emphasized. They truly revolutionized agricultural production in the United States, and had many positive spillover effects around the world. Indeed, few industries have been as productive and innovative as agriculture during the 20th Century. The quantity, quality, and availability of food have increased many-fold, and real food prices have steadily declined. Today, less than 2 percent of the U.S. population is directly engaged in primary agricultural production, yet American farmers are able to provide consumers with the lowest-cost food supplies in the world, plus produce ever-growing surpluses for export to food-deficit nations abroad.

American farmers and ranchers not only have been able to increase agricultural production many-fold through the application of science and technology, I contend that they have also been able to achieve these production feats in ways that have helped conserve the environment, not destroy it. For example, had the U.S. agricultural technology of 1940—when relatively little chemical fertilizer and agricultural chemicals were used—still persisted today we would have needed an additional 575 million acres of agricultural lands—of the same quality—to equal the 1996-97 of 700 million tons for the 17 main food and fiber crops produced in the United States (Figure 1).

Put another way, thanks to the agricultural productivity increases made possible through research and new technology development, an area slightly greater than all the land in 25 states east of the Mississippi River has been spared for other uses. Imagine the environmental disaster that would have occurred if hundreds of millions of environmentally fragile lands, not suited to farming, had been ploughed up and brought into production. Think of the soil erosion, loss of forests and grasslands, and biodiversity, and extinction of wildlife species that would have ensued!

Luckily, thanks to continuing advances in agricultural research and technology, the productivity of American agriculture has continued to increase, and I content, in environmentally sustainable ways. Continuing streams of high-yielding varieties and hybrids have allowed farmers to take maximum advantage of water, light, and soil nutrients. Integrated pest management, conservation tillage, and precision farming have permitted farmers to become more selective in their use of crop protection chemicals, reduce tillage operations of the soil, achieve more targeted and efficient and targeted use of plant nutrients. The use of non-renewable resources—and consequent real production costs—per unit of output has declined.

Recent Trends in Agricultural Research Funding

During the past two decades, public U.S. agricultural research funding, in percentage and real terms, has slowly declined. The decline in international agricultural research support is especially disastrous. At the same time, private sector agricultural research funding has increased.

The concern that if these trends continue, we risk losing the broad continuum of agricultural research, from the more basic to the more applied and practical, needed to keep agriculture moving forward. In an earlier day, public sector institutions—mainly the U.S. Land Grant Universities and the USDA's Agricultural Research Service, were concerned with this full gamut. But with the advent of hybrids and modern varieties, and crop protection chemicals, private companies became more and more involved in applied research activities in which the marketplace will enable them to capture a return on their investments. As the scope and quantity of private sector agricultural research has expanded, publicly funded research has tended to shift more towards fundamental basic research, with longer payback periods to society, and where the private sector cannot easily capture directly the benefits from the investments.

Private sector research, which tends to be more narrow and short term, and public sector research, which can be broader and longer term, complement each other, and should not be seen as competitive. It is important to maintain a healthy balance between the two.

One important characteristic of public sector research is that the information and products that it produces have tended historically to be quite freely available, not only to U.S. scientists but also to the international scientific community. Permit me to use the example of the dwarf spring wheat, which I have been personally involved. In 1996, economists at the University of California-Davis and the International Food Policy Research Institute (IFPRI), in Washington, published a report on U.S. benefits from international research aid. According to their statistics, between 1960 and 1993, U.S. government support to wheat improvement to CIMMYT and its predecessor institution amounted to $71 million (in 1993 U.S. dollars) and the present value of the benefits of this investment to U.S. wheat production was $13.7 billion. That's a 190:1 benefit-to-cost ratio!

But the benefits of international cooperation between publicly-funded research organizations are much greater than even these statistics suggest. The advent of international germplasm exchange and testing began in the early 1950s in wheat, as a response to a devastating stem rust epidemics in North America. In search of resistant germplasm, the USDA, the Mexican Government-Rockefeller Cooperative Agricultural Program and selected national agricultural research programs in South America agreed to exchange and screen a broad range of early and advanced breeding materials. Out of this initial effort, sources of resistance to stem rust were identified and that have held up to this day. Indeed, no stem rust epidemics have occurred in nearly 50 years.

In addition, a new institutional innovation—international germplasm exchange and testing—was developed that continues to bear fruit even today. International testing broke down the barriers that previously isolated individual breeders from each other, and led to the introduction of enormous quantities of new and useful genetic diversity. It became accepted policy that individual breeders could use any line from these international nurseries, either for further crossing or for direct commercial release, as long as the original source of the germplasm was recognized. This led to the accelerated development around the world of new high-yielding cultivars, with much higher levels of disease and insect resistance.

Strong public sector research programs are also needed to provide dynamic research environments to train new generations of scientists for the private sector as well. They also have a role to play, I believe, as "honest brokers" so that farmers and consumers do not become hostages to private sector research monopolies. The current case of biotechnology research is a good example to make my point.

The majority of agricultural scientists, including myself, anticipate great benefits from biotechnology in the coming decades to help meet future needs for food and fiber. Despite efforts to stop the spread of transgenic crops, commercial adoption by farmers has been one of the most rapid cases of technology diffusion in the history of agriculture. The area planted commercially to transgenic crops has increased from less than 2 million in 1996 to roughly 40 million hectares in 2000.

Since much of the biotechnology research underway is in the private sector, intellectual property rights must be addressed and accorded adequate safeguards by national governments. On the other hand, while I can certainly understand the need for private companies to be assured a return from their research investments, government policymakers must face up to several potentially serious problems. First, deals with the nature of the patenting process, itself. How long, and under what conditions, should patents be granted for bio-engineered products?

Further, it appears that the high cost of biotechnology research is leading to a rapid consolidation in the ownership of agricultural life science companies. Thus, is there a danger that a few companies could end up owning most of the world's food crop genetic resources? And if so, is this desirable? Finally, how will resource-poor farmers of the developing world gain access to the products of biotechnology research? These are matters for serious consideration by national, regional and global governmental organizations.

Research Entrepreneurship

Agricultural research has become a substantial enterprise in both the public and private sectors over the past century, so extensive that no research director can keep abreast of the many advances in science nor can any scientist stay on top of all the changing conditions in agricultural production.

I agree with the late Nobel Economist T. W. Shultz, that most working scientists are research entrepreneurs and that centralized control is an anathema to progress.

> **"In the quest for appropriations and research grants all too little attention is given to that scarce talent which is the source of research entrepreneurship. The convenient assumption is that a highly organized research institution firmly controlled by an administrator will perform this important function. But in fact a large organization that is tightly controlled is the death of creative research. No research director…can know the array of research options that the state of scientific knowledge and its frontier afford.**
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> **Organization is necessary. It too requires entrepreneurs…But there is an ever-present danger of over-organization, of directing research from the top, of requiring working scientists to devote ever more time to preparing reports to 'justify' the work they are doing, and to treat research as if it was some routine activity."**

Certainly, there are many management problems that must be addressed to improve the efficiency of agricultural research. But what needs to be done is far from clear, at least to me. Perhaps National C-FAR stakeholders will be able to contribute constructively to this debate and challenge.

Educating Urbanites about Agriculture

The current backlash against agricultural science and technology evident in some industrialized countries is hard for me to comprehend. How quickly humankind becomes detached from the soil and agricultural production! Less than 4 percent of the population in the industrialized countries, and only 2 percent in the United States, is directly engaged in agriculture. Thus, it no longer possible for urban children to spend summer vacations on their grandparents or uncles' farms.

With a low-cost food supplies and urban bias, is it any wonder that consumers take for granted the world food supply each year in its entirely, and expanding it further for the nearly 85 million new mouths that are born into this world each year?

I believe we can help address this "educational gap" in industrialized urban nations by making it compulsory in secondary schools and universities for students to take courses on biology and science and technology policy.

As the pace of technological change has accelerated the past 50 years, the fear of science has grown. Certainly, the breaking of the atom and the prospects of a nuclear holocaust added to people's fear, and drove a bigger wedge between the scientist and the layman.

Rachel Carson's book ***Silent Spring***, published in 1962, which reported that poisons were everywhere, struck a very sensitive nerve. Of course, this perception was not totally unfounded. By the mid 20th century air and water quality had been seriously damaged through wasteful industrial production systems that pushed effluents often literally into "our own backyards."

Moreover, our capacity to measure minute quantities of toxins also contributed to the growing fear that land and water resources were being destroyed by high-yield, chemicals-based agriculture. When I was a graduate student, it was pretty good analytical chemistry to be able to measure 1 part per 20,000. Today 1 part per quad-trillion is routinely done. This growing capacity to for minute measurement has been used to scare people that we are being poisoned out of existence, even though age longevity has nearly double over the past Century.

We all owe a debt of gratitude to environmental movement in the industrialized nations, which has led to legislation over the past 30 years to improve air and water quality, protect wildlife, control the disposal of toxic wastes, protect the soils, and reduce the loss of biodiversity. However, I agree also with environmental writer Gregg Easterbrook, who argues in his book, ***A Moment on the Earth***, that "In the Western world the Age of Pollution is nearly over…Aside from weapons, technology is not growing more dangerous and wasteful but cleaner and more resource-efficient. Clean technology will be the successor to high technology."

However, Easterbrook goes on to warn that, "As positive as trends are in the First World, they are negative in the Third World. One reason why the West must shake off its instant-doomsday thinking about the United States and Western Europe is so that resources can be diverted to ecological protection in the developing world."

In his writings, U.S. Professor Robert Paarlberg, who teaches at Wellesley College and Harvard University, sounded the alarm about the deadlock between agriculturalists and environmentalists over what constitutes "sustainable agriculture." This debate has confused—if not paralyzed—many consumers and political leaders who, afraid of antagonizing powerful environmental lobbying groups, have turned away from supporting sciencebased agricultural modernization projects still needed in much of smallholder Asia, sub-Saharan Africa, and Latin America.

This deadlock must be broken. We cannot lose sight of the enormous job before us to feed 9-10 billion people projected to be living on the planet Earth by 2050, 90 percent of whom will begin life in a developing country and, sadly, probably in poverty. The only hope to alleviate poverty and improve human health and productivity and reducing political instability in the world is through dynamic agricultural research and development systems. Technological development is not the problem; rather it is the solution.

World Cereal* Production—Areas Saved Through Improved Technology, 1950-1999

*Uses milled rice equivalents

Source: FAO Production Yearbooks and AGROSTAT

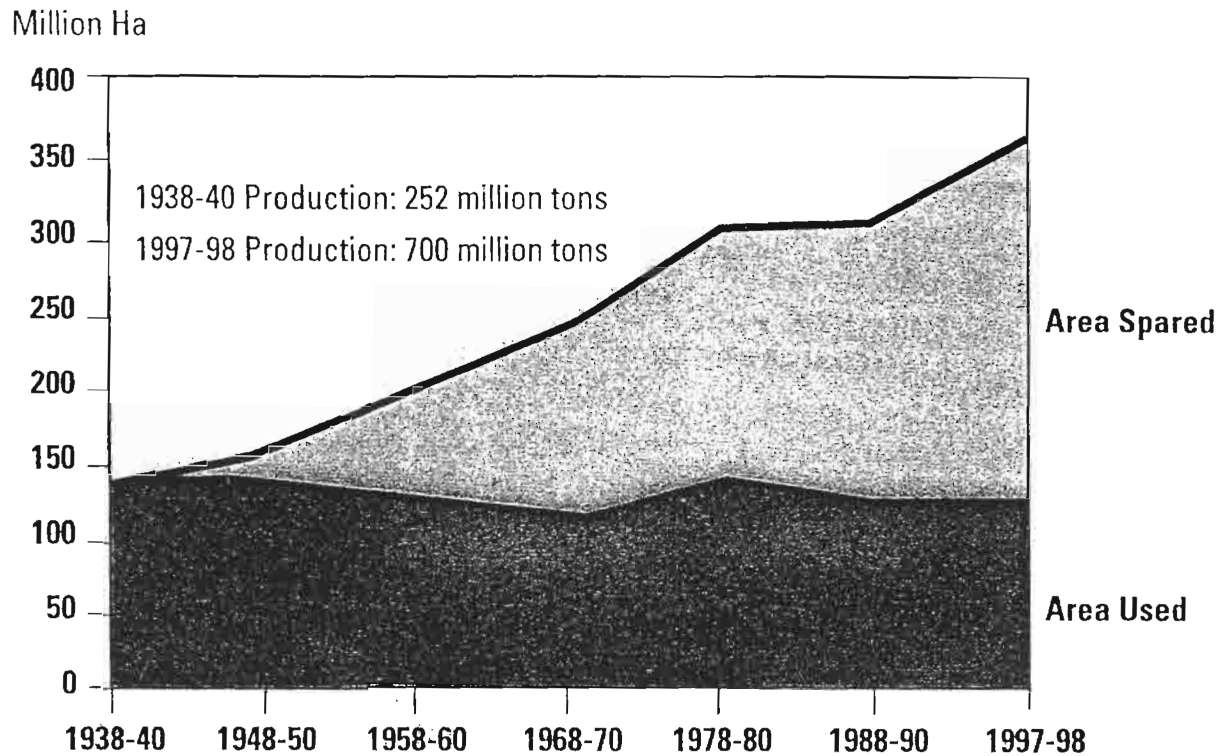

Figure 2. USA total crop area spared by application of improved technology on 17 food, feed and fiber crops in period 1938-40 to 1997-98