"AGRICULTURAL RESEARCH FOR SUSTAINABLE DEVELOPMENT"

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I will address my testimony today to the crucial role of agricultural research in meeting U.S. foreign policy goals for the world's poor countries. It is an honor to make this presentation before a Congressional committee whose focus so closely mirrors my life's work. I have been engaged in agricultural research and rural development in the Third World for almost 50 years, and have probably met with more farmers in more countries than any man alive. During my career I have seen notable improvements in the agriculture of many developing countries, have seen dramatic changes in attitudes about what is possible, have seen the fortunes of developing country agricultural research programs rise and fall, and have seen disruptive fads and bandwagons -- generally initiated in affluent, food-surplus countries -- come and go. What I see today is that we have accomplished much, but that immense challenges and opportunities are still before us. Foremost on our agenda is the urgent need to improve food production and distribution to alleviate hunger, poverty, and human misery, with the larger goal of preventing social, economic and political upheavals in developing countries.

Critical Issues in Sustainable Development

A brief digression on the importance of agriculture and agricultural research in sustainable development will help set the stage for my subsequent remarks. The Earth Summit crystallized global opinion that poverty, environmental degradation, and population growth are the dominant problems of the developing world. The three problems interact strongly, and the convergence of alarming trends on all three fronts has brought the issue of sustainable development to the foreground. But the pivotal problem here is poverty. Poverty drives farmers to focus on short-term output for survival, at the expense of the environment; poverty is a major factor in high birth rates and death rates; and poverty among the masses limits governments' abilities to provide education, health services, employment, and other programs to address the nexus of problems. Thus, any effort to slow population growth or heal the environment will have short-run success at best unless poverty is alleviated through income growth.

The world's poor -- both urban and rural -- rely heavily on agriculture, either as the source of the foodstuffs on which they spend the bulk of their limited budgets, or as their principal source of income or employment. An average 60% of the total population in the poorest developing countries are subsistence farmers or landless laborers, and rural poverty -- especially in Africa -- is the most acute problems these countries face. To raise incomes, then, we *must* increase the productivity of agriculture, for it is the engine that powers change *in all other sectors of the economy* -- generating greater returns to farmers, providing more employment opportunities both on- and off-farm, enhancing the availability of food, and lowering food prices. There are three major ways to increase agriculture's productivity: through the development and use of improved technologies, more effective policy, and better infrastructure. And to design better policies and technologies, research is indispensable.

For the purposes of this discussion, I will rely on a variation of the definition of sustainable agriculture put forward by the Brundtland Commission, that is: "Sustainable agriculture should involve the successful management of resources for agriculture and forestry to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources." Note that this implies agricultural and forestry sectors with *dynamic production potential* to meet the additional food and fiber demands of the future, as well as one which is environmentally benign. Sustainable agriculture must also be farmer-friendly -- economically advantageous, drudgery-mitigating, and simple enough that poor farmers are able to adopt the new techniques. A key component, then, of sustainability are productivity-enhancing, resource-conserving technologies that farmers will be able to implement.

In this context, four issues rank highest on our agricultural research agenda for the next 20 years. First is to enhance the genetic potential of plants and animals, making them more efficient at converting inputs -- water and nutrients -- into outputs for human consumption. Second is to develop improved crop, forestry, livestock, and ecosystem management techniques to permit the greatest aggregate expression of genetic potential while protecting agriculture's natural resource base. Improvements in genetics and management practices will also reduce the risk of crop, forestry and livestock losses to pests and disease. Third is to strengthen global capacity for preserving and benefiting from biodiversity. And last is to frame more sensitive policy measures to motivate farmers to adopt sustainable farming practices to benefit generations to come.

I will touch on each of these issues in turn. To illustrate where I see research heading, I will cite several examples of recent outputs from the international agricultural research centers which are members of the Consultative Group on International Agricultural Research (the CGIAR). The U.S. government, through USAID, was a founding member of this consortia of research institutes, and has been its leading supporter throughout its 23-year history. In a time when we hear so much about development failures and funds misspent, the U.S. should be proud of the tremendous successes it has sponsored through the CGIAR. These successes consist not only of improved yields and increased production in developing countries, but also of large spillover benefits to U.S. agriculture via increased productivity and reduced risks for farmers here at home. These are not the only success stories to be reported -- there are many -- nor have researchers in the CGIAR done it alone. But as a long-time veteran of this system, they are the stories I know best.

Genetic Improvement

With apologies to my colleagues making significant genetic advances in animal, fish and forestry research, I will focus here on crop improvement -- work which involves plant breeders, geneticists, agronomists, soil scientists, physiologists, pathologists, cereal technologists, and applications of biotechnology towards four objectives: (1) to increase yields; (2) to develop varieties with greater nutrient efficiency; (3) to ensure greater yield stability through resistance to pests, diseases, and environmental stresses; and (4) to develop new plant types that fit into more environmentally benign cropping systems.

Increasing yields: The goal of continually increasing the yield potential of the world's foodstuffs must remain paramount. Just to keep pace with population growth and rising incomes, the world will need to produce an *extra* 32 million tons of grain (principally rice, wheat and corn) every year. The increased demand in the future will have to be met almost entirely through intensifying cultivation and by using more productive varieties. To repeat: increased productivity is the *only* way to ensure low (and declining) food prices, which guarantee the food and income security of consumers and underpin the entire economic growth process -- while still generating profits for farmers.

This may be obvious, but what is less apparent is that by sustaining adequate levels of output on land already being farmed in environments suitable for agriculture, we restrain and even reverse the drive to open more fragile lands to cultivation. A compelling case in point is that of India. Were that country to produce its current wheat harvest with the technologies of 30 years ago, farmers would have to bring over 100 million acres of land of *equal* quality into production. More, actually, since most of India's good land is already under the plow. But with wheat varieties which now yield more than three times what they did in the early 1960s, a tremendous onslaught on fragile lands and forest margins has been avoided. As economist Dennis Avery of the Hudson Institute's Center for Global Food Issues stated before House Agricultural Committee staff in September 1993, on a global level, high-yielding varieties have saved some 10 million square miles of wilderness from cultivation -- more than the total area of North America.

Increased nutrient-efficiency: Another major goal is to breed plant varieties which are more efficient in converting water and plant nutrients into food. Here we are building on the successes which gave rise to the Green Revolution of the 1960s, in which the "architecture" of wheat and rice plants was reshaped so that much more of the plants' energies went into producing grain instead of straw. The International Rice Research Institute is now working on yet another transformation of the rice plant.

Research is also leading to varieties that can match or exceed current yield levels with less water or even under drought conditions. Drought-resistant corn recently developed at the International Maize and Wheat Improvement Center (known by its Spanish acronym, CIMMYT) offers great promise for areas where rainfall is irregular -- as frequently occurs in Africa -- and should provide farmers with more than $100 million in additional income each year. Likewise, we can expect to see plants that are more efficient at using nitrogen and other nutrients, thereby "stretching" the value of those costly inputs.

Plants are also being developed which survive harsh temperature or soil conditions, such as new varieties of rice, wheat, corn, sorghum, and soybeans that tolerate the acidic soils covering more than 1.5 million square miles of savanna in South America and Africa. These new varieties will open the way to sustainable farming systems involving rotations of the above crops along with improved pasture grasses. The International Center for Tropical Agriculture (CIAT) is already promoting an improved rice-pasture farming system on acidic soils in South America which can accommodate several times more cattle and produce significantly greater weight gain than native savanna, while contributing to the recovery of overgrazed pasture land.

Genetic resistance to pests and diseases: Genetic resistance dramatically reduces the use of toxic pesticides or fungicides, and significantly increases yield stability (or put conversely, lowers the risk of wide fluctuations in yields due to pest and disease attacks). For example, CIMMYT has incorporated into wheat durable resistance to that crop's number one and two diseases -- stem and leaf rust. Worldwide stem rust resistance was achieved 40 years ago, with leaf rust resistance dating back 12 years; leaf rust alone formerly cost farmers an average of $750 million per year in crop losses. The International Potato Center (CIP) is now leading an international network to strengthen genetic resistance to a new strain of potato late blight fungus (the disease that caused the 19th century Irish potato famine) that hgas appeared in Europe, Asia and East Africa. Twenty years ago, CIP produced the first batch of potatos with broad genetic resistance to late blight, enabling the spread of potato cultivation across Africa and a production increase of 140% compared to the early 1960s. CIP has already developed breeding lines resistant to the new fungus strain, and is sharing these globally. (Parenthetically, both rounds of work on late blight has benefitted greatly from collaboration with the Mexican national research system.) In both rust-resistant wheat and blight-resistant potatoes, science has in effect substituted genes for chemicals.

Advances in biotechnology add to the "tool-kit" of conventional plant breeding towards these ends. Among the biotechnology tools already being used are molecular mapping techniques to identify useful genes and gene combinations, and to screen for these genes/gene combinations in the "offspring" of plant crosses; molecular transformations that insert alien genes directly into plants; methods to evaluate the actual expression of these foreign genes in their new hosts; and tissue culturing, which enables us to clone and grow plants from single, transformed cells. These and other new methods will short-cut and speed up progress, especially for plant traits which are derived from single or relatively few genes (we know that specific kinds of insect resistance, for example, are simply controlled). However, for more complex characteristics such as high yield, mainstream breeding will continue to be the principal route to future achievements.

Let me stress that in all these cases, the input efficiency embodied in modern varieties will require less technical skills and management on the part of farmers than alternative approaches. For example, a variety incorporating resistance to a particular pest usually will be easier to diffuse to farmers than will the intricacies of integrated pest management (IPM). Moreover, pest-resistant varieties typically form an important component of general IPM strategies. In much the same way, future research can be expected to provide new plant types that will fit into more environmentally benign cropping systems, such as varieties that perform well under conservation tillage practices (with resistance to new diseases that emerge under these cultivation practices), or which are shade-tolerant to fit into erosion-controlling agro-forestry schemes.

Crop and Natural Resources Management Research

Crop management research (CMR) has long played an important role in identifying the cultivation practices required so that the higher yield potential of modern varieties can be expressed. Often, this has involved research on the efficient use of external inputs such as fertilizers and pesticides. Crop management innovations include changes in the timing and methods of planting (e.g., beds vs. furrows, with differential impact on labor, plant nutrient, and water requirements) and in the application of fertilizers and pesticides, as well as new crop rotations. Some of our most noteworthy recent achievements have built on CMR to develop integrated pest management systems. IPM adds to the portfolio of crop management practices, measures such as careful monitoring of insect populations so that insecticides are used only when most needed, and the detection and introduction of natural parasites and predators that are pest-specific. Using such an approach, CIAT and the International Institute for Tropical Agriculture successfully battled the cassava mealy bug, a pest introduced from Latin America into Africa without its natural enemies, and which caused African cassava farmers tens of millions of dollars in crop losses every year. CIAT scientists identified the mealy bug's foes in its native environment, and the two institutes found a way to mass breed and release them across Africa; research continues to identify additional means of natural pest control.

As concerns about the environment mount, CMR is evolving into an even more sophisticated set of activities falling under the heading of "natural resources management research" (NRMR). Whereas CMR puts more emphasis on controlling the impact of environment on crops, in NRMR greater emphasis is placed on the effect of crop production on the environment. Compared to the near-term focus of CMR, NRMR is more concerned with understanding processes of resource degradation, developing technologies that slow or reverse these processes while improving productivity, and exploring opportunities for policy change to encourage farmer adoption. The complexity of natural resource management research also requires the participation of a broad host of actors, frequently at the local level.

There are also numerous efforts underway to study systems interactions as they relate to resource quality. One notable example is addressing slash-and-burn agriculture, a practice which presently causes the annual loss of more than 25 million acres of tropical rainforest. As an aside, it is worth mentioning that slash-and-burn techniques supported agriculture in traditional societies for millennia. It was not until population pressures accelerated the demands on this system that it became "unsustainable"; nowadays, some 300 million people are caught in its net of poverty. The International Center for Research on Agroforestry (ICRAF) is coordinating a global effort to find alternatives to this system; ICRAF's objectives include slowing rates of deforestation and reclaiming degraded land in these areas.

Conservation of Biodiversity

We are concerned about biodiversity for two very practical reasons (as well as for other less tangible reasons). First, for the major food crops of the world, biodiversity represents the storehouse of genetic source material for further advances in yield potential and for insect and disease resistance. The hallmark of modern plant breeding has been the ongoing incorporation of this diversity into commercial varieties through crosses with land races and related species and genera. A case in point are the "Veery" wheat varieties developed by CIMMYT, which are a cross between winter and spring bread wheat varieties (a combination that would have been very unlikely in nature) and have the genes from almost 50 landraces and 18 countries in their lineage. Thus, instead of diminishing the genetic diversity of our most important food crops, we are actually expanding it -- but only through applying our increasingly sophisticated knowledge of the genetic characteristics of a vast pool of potential breeding materials.

The second reason for seeking to preserve diversity in the plant kingdom is the sense that countless noncommercial species under increasing threat of extinction may hold as-yet undocumented promise for mankind, because of their food, medicinal or other properties. To realize this promise, the global community will have to develop and implement more systematic measures to identify and preserve species of high potential value. Given the magnitude of the task and limited resources available, a realistic approach must entail some method of prioritizing conservation efforts in this regard. Biodiversity conservation will require both *in situ* protection as well as a global network of gene banks. The latter system is already partially in place via the CGIAR's collections of most of the world's major commercial food crops, which complement the holdings of gene banks in developed and developing countries around the globe (including the "super-power" of all gene banks, that of the U.S. Department of Agriculture). But simply collecting plant varieties will not be enough; exhaustive research will also be needed to document the genetic makeup and potential value of these species.

One of the centers of the CGIAR -- the International Plant Genetics Resource Institute -- has the explicit mandate to promote the conservation and use of plant genetic resources for sustainable development, in partnership with governmental and nongovernmental organizations throughout the world. It also bears repeating that one of the most effective ways to prevent the destruction of biodiversity habitats, especially of noncommercial plant species and wildlife, is to minimize the pressure from farmers to open new lands for cultivation -- by maintaining high levels of productivity on land already being farmed.

Policy Research

Policies affect the implementation of sustainable agricultural practices directly, as well as indirectly through their impact on poverty, population growth and the environment. To cite but two examples of the former, policies governing the security of land tenure will directly affect farmers' willingness to invest in long-term conservation measures, while subsidies or taxes on inputs will affect farmers' decisions regarding the use of water, fertilizers and pesticides vs. alternative management practices. As powerful as these direct policy effects may be, policies that *indirectly* affect the sustainability of agriculture may ultimately prove to be more influential. Given the interaction between poverty, environment, and population growth which I described at the outset, any and all policies that affect economic growth, income distribution, employment generation, population growth, and poverty alleviation can be said to affect the sustainability of agriculture indirectly. As might be expected, there are too many of these to list.

Agricultural research must help inform the process of policy formulation. Knowledge of farmers' circumstances gained through research (especially farming systems research) can be useful in the design of institutional innovations. At the very least, research must make explicit some of the costs associated with resource degradation and pollution when comparing alternative technologies and options for farmers and for society. When off-site effects are included, when inputs and products are properly valued, and when costs associated with degradation of the natural resource base are included, regenerative technologies may be more profitable than conventional technologies. The information needed for such comparisons can only come from careful research.

The Global Division of Labor on Agricultural R&D

The examples I have cited above are but a sample of the hundreds of research activities currently underway in the international agricultural research centers of the CGIAR addressing issues in sustainable development. But as I said in my opening remarks, the international centers are by no means the only players in this arena. Over the last 40 years or so, a complex global network of research and extension has painstakingly been built up, and has carried countless new discoveries into farmers' fields. This network embraces advanced research institutes in the industrialized countries (including U.S. universities), national agricultural research systems in developing countries (including universities there and national extension systems), private sector seed companies and agribusinesses, nongovernmental organizations, and of course farmers around the world.

Each has a special area of advantage, and all must work in partnership. International centers have major contributions to make to breeding; to research on strategic concerns which affect large areas and transcend national boundaries; and to developing methodologies which can be used by others for studying natural resource issues. To evaluate and carry the results of the international centers to farmers, and to "cross-fertilize" agricultural research worldwide, international testing networks involving thousands of scientists in national programs have played a critical role. National and local research bodies, and NGOs involved in technology transfer and direct work with farmers have an important function in location-specific issues. The private sector will play a part in developing and disseminating some new varieties and management techniques, but we must not expect too much here as many of the technologies required for poorer farmers will not yield a direct return to their developers (i.e., they are by nature non-proprietary).

The paradox facing all of us in research and extension today is that just when the need for greater effort in agricultural development has become so urgent, support to this work is being gutted. The U.S. Agency for International Development reduced its support to developing country agriculture by 50% in real terms since 1988, and the World Bank's support dropped by 25% over the same period. Even the successful work of the CGIAR centers is being threatened by cuts from numerous international development assistance agencies, including USAID (so far, the World Bank and Japan are the only notable exception). Indebtedness and inflationary pressures in developing countries have both worsened problems there and crippled governments' capacities to carry out essential research and extension work to farmers. The lament is not for the potential dismembering of institutions, but rather for the loss to the world's capacity to address sustainability issues.

It will be our children who realize the magnitude of this loss, and it will take years to recover. Agricultural research is not a one-shot deal, but an ongoing process addressing continually evolving problems. Not only will demands for food increase, but any new pattern of production will generate requirements for new research. All agricultural research entails a long time horizon (it typically takes 10-15 years from the time a problem is diagnosed until a solution reaches farmers' fields); natural resource management research requires even longer to monitor and effect gradual changes in physical resources. And it takes years to build up international cadres of scientific and extension staff, and the collaborative mechanisms to deliver the goods to farmers. In this regard, I must emphasize that solutions to sustainability problems absolutely require sustainable funding. If sustainability is to be more than just another passing fad, the magnitude of support must match the magnitude of the challenge.

The Cost of Inaction

During my lifetime, world population has increased from 1.6 billion to 5.5 billion. We know, sitting here today, that population continues to grow, adding 1 billion more people every decade. As the great biologist Edward Wilson states, "The raging monster upon the land is population growth. In its presence, sustainability is but a fragile theoretical construct."

We know that the majority of the world's new citizens will live in the less developed countries. We know that the only way to provide food for these billions, *and* to generate the income to grow them out of poverty, *and* to protect the environment, is to ensure that agriculture remains vibrant. We know that research is essential to providing solutions, and we're on track to get there.

We are indebteded for today's success stories to those leaders 20 years ago who had the foresight to champion the cause of agriculture. If not for them, today's problems would be infinitely worse; thanks to them, hundreds of millions of people have been saved from misery. We know that, unless we restore the commitment to agricultural research and development, the future is grim for the world's poor. Social, economic and political chaos, and massive migrations of destitute people would be unavoidable. We know the cost of inaction to be incalculable.