Renewal of the CGIAR:
Sustainable Agriculture for Food Security in Developing Countries

A Research Agenda for the Future

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A Research Agenda for the Future

Driven largely by population growth, global agricultural production[1] must more than double over the next 30 years, even as the supply of water and productive land declines. To fail in this effort is to invite social, political, and environmental chaos, with costs so high that failure is simply unthinkable. Doubling production while protecting the natural resources upon which agriculture depends is one of humankind's most pressing challenges. This document highlights the critical role of agriculture and its research in meeting that challenge, and describes the contributions of one important group, the CGIAR.[2]

CHALLENGES AND OPPORTUNITIES

It is widely observed that we have, today, the capacity to feed all the world's people. Yet nearly 1 billion go without adequate food, and each day some 40,000 people, most of them children, die from hunger and related causes,[3] their deaths a grim testimonial to the effects of poverty. Relief costs are soaring while new opportunities for women and minorities are limited by a lack of resources. Natural resources vital to agriculture are in jeopardy, as the poor sacrifice tomorrow's production for survival today. Already we are on a treadmill leading to consequences widely judged to be unacceptable. Each day brings 250,000 newcomers,[4] most of them at risk to the effects of poverty. How do we get off this treadmill, achieve our most noble social aims, and still protect the environment?

The Way Forward

Many in the development assistance community now endorse the idea of sustainable food security for the developing world as a worthy vision of the future.

But in the words of M. S. Swaminathan, sustainable food security requires sustainable economic security, and that requires a clear focus on reducing poverty.[5] In developing countries, poverty and hunger go together. Poverty is also closely linked to environmental degradation. As the poor struggle to survive, protecting the environment quickly becomes a secondary concern, and public programs aimed at protecting natural resources in poor countries require large investments from already limited budgets. Having more children, too, is a practical response to living in poverty, one geared toward survival of the family.

Reducing widespread poverty, then, is the pivotal challenge confronting those who seek to improve, not only the human condition, but the condition of the world's ecosystems. Economic

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[1] As used here, agricultural production refers to food from the land and sea, livestock, and forest products.

[2] To the CGIAR, "agriculture" includes crops, livestock, forests, and fish.

[3] Speth, J. G. 1994. "Food First." *News and Views: A 2020 Vision for Food, Agriculture, and the Environment.* Washington, D.C.: IFPRI.

[4] World Health Organization, 1992.

[5] Swaminathan, M. S. 1994. Presentation at CGIAR International Centers Week, October 1994. Washington, D.C.

development leads to higher incomes, less hunger and malnutrition, and the availability of resources for protecting the environment (and a willingness to invest in that purpose). Development also leads to slower rates of population growth, as rising incomes both reduce the need for larger families and provide resources for programs that specifically reduce birth rates by focusing on women. Paraphrasing one prominent leader in development, lasting peace and security depend on development that offers hope for the future. Indeed, it is doubtful that any of the goals for which the community of nations is working—not peace, not human rights or democratization, not environmental protection, not reduced population pressures, not disease control—can be achieved and sustained except in the context of development. Increasing the incomes of the poor, then, is the first essential step toward treating social, political, and environmental ills.

Agriculture: The Cornerstone of Development

How can we best promote broad based income growth in poor countries? In such countries, 60 to 80 percent of the population works in agriculture. Forty to fifty percent of the average family income is spent on food. Because of agriculture's prominence in such economies, increasing its productivity is critical to promoting growth. Indeed, few poor countries have progressed without first increasing the productivity of their agriculture sectors.

As agriculture becomes more productive, at least three important things happen. First, the incomes of those who work directly in agriculture go up, enabling them to improve the quality of their own lives—a better diet, better housing, more education, more tools, and so on. Second, spending that additional income adds to the incomes of others, who in turn contribute to widening rounds of spending that increase the demand for goods and services throughout the economy. In this way, agriculture serves as an engine of growth and development. Third, because higher productivity leads to increased supplies of food, real prices for staples decline—they become more affordable to more people. Less of the family budget is required for sustenance, more is available for a variety of other purposes. In effect, more productive agriculture lubricates the whole process of economic growth. The greater the relative importance of agriculture in a country, the more these processes will promote its development.

How, then, to make agriculture more productive? New agricultural technologies, improved infrastructure, better government policies, and more education all contribute in important ways to higher productivity—but one of these stands out.

Agricultural Research: Laying the Cornerstone

For at least the past century, new technologies have been the most reliable source of higher productivity in agriculture. This will undoubtedly hold true for the next century, as well. Today's new technologies take the form of resource conserving management practices, new plant varieties that have built in disease and insect resistance and that use available water and nutrients more efficiently, and techniques

for producing hardier livestock and more productive fisheries. Increasingly, prudent government policies encourage farmers and other agricultural producers to use these new technologies. However, new technologies do not simply appear when needed. They are a direct consequence of long-term, practical agricultural research, and of the political will to garner financial support for bringing cutting edge biological and social science to bear on the problems of the poor.

So the way forward in the poorest developing countries is to make agriculture more productive, and research is an essential piece of the productivity puzzle. Research generates the new technologies and knowledge that drive the development process while conserving natural resources. The end result is more food and fiber (produced more cheaply and with less impact on the environment), higher incomes in the agriculture sector, and, through lower prices for agricultural products, higher disposable incomes for the urban poor—in short, less poverty, a healthier environment, and then on to treating other ills.

A GLOBAL RESEARCH SYSTEM FOR DEVELOPING COUNTRIES

Agricultural producers in developing countries are served by a global research system—**global** in the sense that virtually all countries have some investment in such research, and a **system** in the sense that many researchers share results. These producers have access to the fruits of research from a wide spectrum of sources: the local and international private sector, local and developed country universities, publicly financed and usually publicly operated research systems, and from publicly funded, internationally oriented research like that of the CGIAR.[6] How has this mix of agencies and institutions evolved?

Much of the research done on behalf of these producers is in the hands of public institutions funded by individual governments. To date, universities in developing countries have been little involved in agricultural research, and private investment in this activity was little encouraged. Largely because of studies that showed extraordinarily high payoffs to well focused research, governments and development assistance agencies began pouring money into national programs and, in the 1970s, there was a general expectation that, before long, they would provide the new technologies that farmers required.

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[6] There are no accurate, up-to-date estimates of global public sector expenditures on agricultural research. The most comprehensive data on expenditures cover the 1981 to 1985 period and show an annual average expenditure of US$4.8 billion by developed countries and US$4.4 billion by developing countries (adding to US$9.2 billion globally—all expressed in 1980 dollars). The average annual funding for the CGIAR during the same period was about US$0.155 billion (in 1980 dollars), which places the CGIAR as a share of developing country expenditures at about 3.5 percent and of global expenditures at about 1.7 percent (for simplicity, rounded to 4 and 2 percent, respectively). (Anderson, Jock, Philip Pardey, and Johannes Roseboom. 1994. "Sustaining Growth in Agriculture: A Quantitative Review of Agricultural Research Investments." *Agricultural Economics, 10.)* According to a recent set of preliminary and projected estimates, the 1990 CGIAR funding constituted a smaller share (than during 1981 to 1985) of the public expenditures by developing countries and globally. (Pardey, Philip. 1994. "Economic Perspectives on Setting Research Priorities at the Regional Level." Paper presented at ISNAR Roundtable on Regional Priority Setting. The Hague: ISNAR).

ers publicly funded, supplemented the array of research organizations focused on the needs of developing country producers. Training and education aside, their specific research concerns—usually centered on temperate production systems—seldom coincided with those of developing country producers. Although these centers of excellence offered notable advantages in some areas, especially basic research, their contributions to meeting the global challenge in agriculture could have been greater by relating their findings to the needs of the tropical and subtropical environments common in developing countries. Their contributions could also have been enhanced by an awareness of the relative importance of widespread, but not readily evident, problems to which they could have applied their vast human and physical resources.

In the 1960s, it was clear that national programs in developing countries lacked the human resources—trained and experienced scientific and managerial talent—to meet mounting challenges. This led to, among other things, the creation of international agricultural research centers to fill gaps, train national program staff, and show the way toward more effective institutions. The gap-filling side of this work produced the improved varieties of rice and wheat that led to immense increases in productivity, especially in Asia, and to improved varieties of beans, cassava, maize, millet, and other crops, each of which added its portion to higher farm level productivity. Along the way, the skills of over 45,000 national program staff were further enhanced by a variety of training programs offered by international research centers, and through side-by-side working relationships.

In general, national systems seemed to progress during the 1970s much as expected, but three developments changed the landscape for public sector research after the early 1980s. The first was that public funding for agricultural research began to dry up. The second was a growing awareness of the opportunities created by actively encouraging privately funded research. The third, already making its influence felt, but destined to play an even larger role in the future, was the growing complexity of the problems treated by an advancing science.

The fiscal stringency of the 1980s took its toll on public support for research. Agricultural research was especially susceptible because of the long lead time between investment and payoff (typically 10 to 15 years) and because some of the promise of earlier years had not been realized. Meanwhile, the change in attitudes toward private investment in research encouraged increases there—some estimate that it now exceeds US$500 million annually. That investment is selective, occurring where proprietary claims can be established (not always easy to do in agricultural research) and where, because of market size, there are opportunities for profits.

Free trade and, some claim, greater access to intellectual property rights, will encourage further private investment in research. In time, as in the developed world, a growing portion of agricultural research will be in the hands of the private sector. As that happens, publicly funded research will be reoriented toward areas where it has a special advantage. The international

research portfolio will also change. In anticipation of that, the CGIAR is more strongly emphasizing those activities in which the private sector is not likely to invest and where international efforts are an efficient way to get things done. [See the next section for more on this point.]

As for the growing complexity of science, here it is enough to say that it opens new opportunities for collaboration and partnership, with implications for how research is implemented and managed. [This idea is treated more fully later.] There is, then, something of a global system catering to the needs of developing country producers. It is large, uneven in its capacities, funded in various ways, and loosely integrated. Much can be done to make it more effective. Even so, it works.

The individual researchers in this global system focus their efforts on particular outcomes, such as improved potatoes for a certain group of farmers or appropriate farming practices that will reduce erosion while raising yields. Although the system's individual research projects number in the thousands, for the most part they can be grouped into five major undertakings or thrusts most relevant to developing countries.

Increasing Productivity. The first thrust aims at making developing country agriculture more productive, either through genetic improvements in plants, livestock, fish, and trees, or through better management practices. In the past, and even today, the bulk of the global research system's resources have been dedicated to increasing productivity.

Protecting the Environment. A second thrust aims at conserving natural resources, especially soil and water, and reducing the impact of agriculture on the surrounding environment. To date, this thrust has occupied a notably small portion of the energies of the global system, but is now increasing in importance.

Saving Biodiversity. Third, and separated from the second because of a burgeoning interest, is the conservation of biodiversity. Again, while many countries operate genebanks that hold representative varieties of their primary crops, relatively little research attention has been given to this issue until recently, especially in developing countries.

Improving Policies. Fourth, and now a step removed from the goals of poverty alleviation and environmental protection, is work aimed at streamlining the government policies that so strongly influence the spread of new technologies and the use of natural resources.

Fortifying National Programs. Fifth are the training and institution building activities that improve national capacity to effect changes in the first four areas.

Each of these thrusts has consequences for alleviating poverty and protecting the environment in developing countries. Some of the global research system's projects fit in more than one category, and a few are not easily placed in any of the five. The projects of some agencies are more likely to be found in one arena than another; for example, the private sector's efforts are likely to focus more on increasing productivity than on anything else. On the other hand, basic research done by advanced institutions, usually publicly funded, tends to support more than one thrust.

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THE ROLE OF THE CGIAR TODAY

The focus of the CGIAR has shifted over time as the concerns of the development assistance community, new opportunities in science, and stronger national research systems have changed its priorities. Initially, the CGIAR was established to complement the activities of national research systems and to provide a two way bridge to basic and strategic research institutions in industrial countries—both translating their output into forms more useful to national programs and bringing to their attention the aggregated research needs of developing countries. Today, the most advanced developing country research systems are benefiting from collegial relationships with advanced country institutions. Only a few, however, are able to do so. For the many who cannot, bridging mechanisms are still required. Even so, the CGIAR more and more orients its research to the production of significant international public goods. These are products and services for which, no matter how valuable, proprietary claims are difficult to establish and, to make them international, for which there are large economies of size. The first condition makes it unlikely that the private sector will take part and the second reduces the probability that publicly funded national programs will be involved.

How, then, do current CGIAR efforts relate to the five major thrusts described above for the global system? A brief description of its participation follows, accompanied by selected examples of impact.

Increasing Productivity. Better, more productive plants, carefully tailored to specific growing environments, have been the centerpiece of CGIAR efforts in this arena. About 20 percent of the CGIAR's resources are now allocated to research aimed at improving genetic stocks. The payoffs to this work have been quite high.

In the case of plant breeding, for example, many studies have shown that most of the resulting varieties are notably more efficient at assimilating and converting available water, sunlight, and soil nutrients to useful products, contributing to higher and more stable yields at whatever the availability of those resources.

Super Cassava

The contribution of genetic manipulation to productivity is usually measured in terms of moderate but steady changes in annual output. Sometimes, however, the results are dramatic. An example of the latter occurred recently in Ghana. Cassava, a dietary staple in Ghana, is a major food source for more than 200 million people throughout Africa. In 1993, Ghana released three new varieties of "super cassava" that, due to collaborative long-term breeding research by the Ghanaian national program and CGIAR scientists, carried genes for higher yield potential as well as resistance to the cassava green mite, an important insect pest that limits production in many environments. These new varieties are boosting yields in farmers' fields by about 200 percent compared to traditional varieties. Increased supplies of the tuber are not only adding to the diets and incomes of the poor, but kindling commercial interest in processing cassava as a livestock feed, as well.

One important feature of the CGIAR's breeding research is its focus on building into plants greater resistance to the insects and diseases that so adversely affect productivity and the stability of production in the tropics. While protecting farmers from losses, these improved plants protect the environment because they require little, and frequently no, chemical controls.

Black Sigatoka

Black sigatoka is a devastating fungal disease of plantain and banana, two critically important food sources in tropical Africa. The disease was inadvertently transmitted to the continent about 20 years ago. The traditional varieties grown there have little or no natural resistance to the disease, and the chemical controls in use are both expensive and environmentally dangerous. CGIAR researchers have developed hybrid plantains that are highly resistant to the disease and that produce twice the yield of existing varieties. Trials in 12 countries throughout Sub-Saharan Africa are expected to produce varieties adapted to farmers' production circumstances by 1996. The benefit to farmers growing the resistant hybrids (a sustainable technology, as opposed to existing varieties that require the application of fungicides) is estimated at 10:1. If widely adopted, these new varieties could increase the value of annual plantain production from about US$2.8 billion to about US$6 billion, while reducing the production costs and environmental impacts associated with fungicide use.

Beyond improving genetic stocks, CGIAR researchers look for new plant combinations and new ways to manage land and water, capture the sun's energy, and control important diseases, all in an effort to increase the efficiency of producer held resources. Some estimate that up to 50 percent of the gains in productivity come from more effective management of these resources.

Integrated Pest Management

In recent years, the stability of the Andean ecoregion's potato crop has been threatened by an infestation of Andean potato weevils, which routinely damage 50 percent of a farmer's crop. The problem is further complicated by the widespread use of hazardous and largely ineffective insecticide sprays. In response, CGIAR researchers have developed integrated pest management (IPM) practices that control weevils without chemicals. After four years of testing and refining these practices in farmers' fields, weevil damage in the pilot areas has fallen to just 6 percent. Farmers who use the new practices have an average production increase of 3 tons per hectare—equivalent to about US$600 in additional income (per capita annual income in the Andes is US$300). So far, the IPM pilot research and extension projects on Andean potato weevils are generating a return of nearly 60 percent on the CGIAR investment in them.

By now, however, the CGIAR's work on the management side has decreased, handed over to national programs or reshaped to give even more attention to environmental concerns. Still, about 25 percent of the CGIAR's resources are devoted to improving the management of farmer held resources.

One further point about the CGIAR's work on productivity: the pri-

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ority setting process includes an evaluation of the public goods character of proposed projects as well as the potential return to resources to be invested in them.

Protecting the Environment. Indirectly, and until recently little appreciated, land-saving increased productivity has contributed immeasurably to protecting the environment.

Productivity improvements contribute, albeit indirectly, to protecting the environment. The point is a simple one: higher productivity in environments well suited to agriculture reduces the need to bring more fragile environments into production.

Improved Productivity and Environmental Protection

Productivity improvements contribute, albeit indirectly, to protecting the environment. The point is a simple one: higher productivity in environments well suited to agriculture reduces the need to bring more fragile environments into production. For instance, were India to produce the wheat consumed there today with the technologies of the mid-1960s, farmers would need nearly 60 million hectares of additional land, similar in quality to the land in use back then. With such land no longer available, millions of hectares of hillsides and forest margins would have been drawn into production to meet the demand for wheat today, with truly extreme environmental consequences. An even more striking example can be found in the United States, where impressive productivity increases and improved agricultural technology have spared endless hectares of hillsides, forests, wildlife sanctuaries, and grasslands from devastation.

While these efforts have, on balance, benefited natural resources, work aimed directly at resource conservation is an essential—and growing—part of the CGIAR's portfolio. Started in the late 1980s, this research seeks first to understand the interactions among the resource base, the biology of sustainable production systems, and the behavior of producers and consumers, and then to develop productivity increasing, resource conserving technologies that producers will use. Much of the work seems to require new research paradigms, and the CGIAR plays a leading role in their development. What should be measured, how to measure it, what statistical methods to use, and how far to pursue Nature's endless chain of interactions are but a few of the questions that will shape the new paradigms. Research on erosion control, nutrient cycling, water management, and water quality—all important and widespread problems in natural resources management, and all complicated by an awareness that productivity must also be increased—is a part of this thrust.

This is not to suggest that all such work is strategic or the province of the CGIAR. Ascertaining the nature, influence, and projection of chemical and biological processes; laying out questions and methods for diagnosis; and developing prototypes are examples of the CGIAR's terrain. The NARS, closer to the problems of their own farmers, draw on this accumulating knowledge and shape it to their local needs. While this work is crucial to natural resources conservation, little of it offers the profits that would attract private investments, and much of it promises the broad applications that lead to economies of size. This thrust now absorbs about 10 percent of CGIAR resources.

Saving Biodiversity. As in the case of protecting the environment more generally, CGIAR efforts to increase agricultural productivity contrib-

ute indirectly to conserving biodiversity: increased output in areas well suited to agriculture reduces the need to expand production into more fragile areas, thereby leaving more tropical and subtropical forests (where so many species reside), hillsides, and so on. But there is much more to be done, especially in the work dedicated to collecting and conserving selected species. Given that current law and custom limit pecuniary gains from these collections, the CGIAR is increasingly involved in this arena.

Roughly 10 percent of the CGIAR's resources are currently allocated to this work. In a recent development, an accord with FAO was signed that ties the CGIAR's collections into a global conservation effort.

The CGIAR holds in trust one of the largest *ex situ* collections of old and new varieties of the crops on which it works and, in substantial measure, the wild species from which those crops emerged. These species and varieties are held in ways designed to assure their viability far into the future, so they can be available to meet challenges from new pests or other changes in the environment. Duplicates of the varieties held in trust are made available to researchers around the world so that new gene combinations can be brought to bear on current problems. Their use of those duplicates creates new information, widening our knowledge on the performance characteristics of conserved materials, adding to their value. Whole new opportunities are at hand in this arena, but more on that as discussion turns to the future.

Improving Policy. Agricultural producers are heavily influenced by public policy, and studying those effects offers insights into how policy and

CGIAR Genetic Resources and FAO

To strengthen international solidarity, the CGIAR and its centers have accepted the invitation of FAO's Director General to place their collections of genetic material—containing more than 600,000 accessions of more than 3,000 crop, forage, and pasture species, one of the world's largest collections—under the auspices of that organization as the first part of an international network of ex situ collections. It is hoped that others will follow the CGIAR's example and place their collections under the auspices of the FAO Inter-Governmental Commission on Plant Genetic Resources.

The CGIAR has introduced a system-wide approach to its work in the area of genetic resources, and has developed a policy regarding intellectual property rights as they relate to the management of those resources. Individual centers and the CGIAR as a whole are increasing their participation in international fora where issues of intellectual property and access to genetic resources are debated. These include the FAO Commission on Plant Genetic Resources and various groups charged with implementation of the Convention on Biological Diversity and the preparation of its first Conference of the Parties to the Convention. The CGIAR has also committed its support to the preparation of FAO's Fourth Technical Conference on Plant Genetic Resources, which will prepare a status report on the world's genetic resources and a global plan of action.

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micro-level decisionmaking interact. Such studies also reveal the true costs of current policies and can suggest ways in which policy might be changed so as to promote socially desirable ends. Their impact will be manifested in large measure through other thrusts.

Several CGIAR centers work on policy related issues. Virtually all of this work is done in collaboration with specialists in national programs. While examples of these efforts abound, their impact on policy itself has not yet emerged. A growing awareness of the true costs of poor policies and of the payoffs from improving them, along with the pressure to use policy to liberalize rather than to constrain markets, will soon produce numerous examples of measurable impact resulting from CGIAR research on policy.

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Such work currently absorbs about 10 percent of CGIAR resources. While much of this work is done by social scientists, not all of the CGIAR's social science is focused on policy; it is also an integral part of the three preceding thrusts.

Fortifying National Programs. Many agencies are involved in this work, from educational institutions developing human capital to private firms offering counseling on management, to those financing the physical capital required for research. Focusing on what it does well, the CGIAR's role is largely in capacity building—through formal training programs for research staff, side-by-side working relationships with colleagues in national programs, and strengthening skills in research administration and management. As science and the demand for research services change,

Agricultural Development Drives Economic Growth

Following the green revolution in Asia, agricultural development was a central force driving overall economic growth in rural areas. Higher productivity led to lower real prices for food (benefiting the poor in rural and urban areas), higher net incomes for farmers, and increased demand for non-food items. It also provided the widespread and sustained level of purchasing power needed to make industrialization feasible. Each extra dollar of agricultural income gave rise to an additional 80 cents worth of non-agricultural output from local businesses that were stimulated by the spending of farm households.

In Africa, however, where benefits of the green revolution were harder to discern, similar studies had drawn more pessimistic conclusions. More recent in depth case studies in Burkina Faso, Niger, Senegal, and Zambia have shown that higher rural incomes from increased production of tradable agricultural products can greatly stimulate further growth in rural incomes. In these countries, the production of each additional dollar's worth of exportable agricultural goods is estimated to generate as much as two dollars of additional income in the countryside, through new spending on nontradable rural goods, like perishable foods, local handicrafts, and services of all kinds. Awareness of such relationships helps policymakers to better decide where to invest scarce public funds.

new pressures emerge in both the research and management arenas. For example, the new emphasis on the environment requires new skills among research staff, new working relationships in the field, and new ways to measure progress. These changes imply the need for new skills in management, if the national systems are to be effective.

In recent years, the CGIAR has allocated up to 25 percent of its resources to capacity building, changing its offerings in response to the changing needs and capacities of national programs.

One important aspect of the CGIAR's work in each of the five thrusts noted above is the emphasis of gender and user perspectives. CGIAR centers are increasingly incorporating gender perspectives systematically into their research planning and implementation. They also play an important catalytic role in advocating wider use of such perspectives by NARS.

DEFINING THE RESEARCH AGENDA FOR 1996 AND BEYOND

The CGIAR has taken important and decisive steps in planning its future research agenda. Its comparative advantage is clear: to research key problems in agriculture relevant to many developing countries. The CGIAR's intention, as national research services grow stronger, is to retreat from its many support roles to focus on the production of strategic scientific information widely useful in developing countries.

Several steps have already been taken toward a new structure for the global agricultural research system, with a changing role for the CGIAR. The fact that the genetic resources collections of the CGIAR centers are held in trust for the world community has recently been formalized by placing the collections under the auspices of the FAO Intergovernmental Commission on Plant Genetic Resources. At the same time, a CGIAR-wide Genetic Resources

Regional Training in Crop Management Research

Training courses offered by the CGIAR continually evolve in response to the changing capacities of national programs, and are becoming ever more collaborative ventures. Maize crop management research (CMR) in Africa is a good example. It became clear in the late 1980s that national programs in Africa and elsewhere had a growing need for staff training in CMR, a far greater need, in fact, than could be met by the CGIAR centers. No alternative suppliers for such training were readily available, so in 1990 training officers from one CGIAR center joined forces with the Kenya Agricultural Research Institute (KARI) and Egerton University in Nairobi in the first of a series of six-month training courses in region specific maize CMR. The course was designed for young professionals from eastern and southern Africa, and emphasized direct practical experience in the planning, execution, and follow-up of a CMR program that stresses on farm work. This course is continuing today, with responsibility for content and execution now largely in the hands of KARI and Egerton University. Its success has motivated similar collaborative efforts in Latin America and Asia. Meanwhile, the center has shifted its training to mid-career researchers

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Program has been set up to be led by IPGRI. This has created a single point for the international community and the CGIAR to interface, offering greater coherence in international actions on plant genetic resources.

Similarly, the CGIAR has moved to establish Global and Regional Fora on international agricultural research in which NARS interact with centers and donors in developing priorities for the global system as a whole. A trial of such fora was held recently under the auspices of the International Fund for Agricultural Development (IFAD), to develop a vision of the CGIAR from the perspective of the NARS. The NARS vision offers an emerging counterpoint to CGIAR priorities and strategies, historically developed internally within the CGIAR itself.

The Lucerne meeting is a part of this transition. We hope the insights gained will guide the CGIAR to a transition which is appealing to our donor stakeholders and can be adopted by the Group at the Mid-Term Meeting in Nairobi, Kenya in May 1995.

THE ROLE OF THE CGIAR TOMORROW[7]

What will be the role of the CGIAR in the longer run, in 2010 or in 2025? Will the challenges that introduced this document be met? Will international public goods still be in demand? As for the first question, several reputable studies draw distinctly different conclusions.[8] For the most part there is agreement on likely needs—the demand side—but there are strong differences of opinion regarding our ability to meet those needs—the supply side. Some are sanguine, some apocalyptic. What separates the two extremes is a seemingly trivial difference in the projected annual growth of output.[9] Each position, however, sees improved technologies and agricultural research as critical to its projections. And even those holding to the most sanguine view would see diminished rates of technological change as threatening.

Planning the future research agenda of the CGIAR required the prediction of trends in four important factors. First, the goals of the international community supporting the Group. As noted earlier, their primary concerns are the alleviation of poverty and the protection of the environment, and these are projected to remain the driving forces behind investments in international agricultural research.

A second important factor is the future of national agricultural research systems and others that use products from the CGIAR centers. National programs need to be strengthened. Human capital is their most costly resource, but is no longer limiting progress. The current constraint on effectiveness is inadequate recurrent funding to mobilize skills and implement priority research programs, and thereby to motivate their scientists. Raising governments' awareness of the pivotal role of agriculture in development will lead to better funding and more effective research pro-

[7] Discussion here rests heavily on documents developed by TAC and endorsed by the CGIAR.

[8] For an insightful summary, see McCalla, A. F. 1994. *Agriculture and Food Needs to 2025: Why We Should Be Concerned.* CGIAR 1994 Sir John Crawford Memorial Lecture. Washington, D.C.: CGIAR Secretariat, World Bank.

[9] This is reminiscent of Charles Dickens' character, Mr. Micawber, differentiating between happiness and misery in terms of a few pennies per week.

grams. An alternative processor of research information will be private investment. This will grow as market access improves and the agriculture sector grows. NGOs will continue to advocate greater attention to the needs of the poor and the environment, and increasingly adapt research information to the needs of the communities they serve.

Science, the third factor, will continue to change rapidly, and each turn of its wheel will bring new understanding, new complexities, and new opportunities. The new complexities will suggest new ways to organize work, and these will favor modifications in the CGIAR's structure. Changes will occur in every aspect of the CGIAR's work, probably most notably in molecular biology, in data processing and communications, and perhaps in the microbiology aimed at the fundamental understanding of biological and physical relationships in the soil. Advances in science carry special implications for work that relates natural resources, biology, and the human element in the pursuit of useful productivity-increasing, resource-conserving technologies.

Fourth, important changes will occur in the markets for agricultural inputs and products. Some of these changes will come about because of rising incomes, which will change what consumers want to buy. Others will relate to urbanization (virtually all developing country population growth will be visible in urban areas[10]), to GATT and trade liberalization, to intellectual property rights, to UNCED's implications for claims on genetic resources, and to experience with transgenic plants. All seem likely to make investment in research more susceptible to economic forces. And beyond these considerations will be the extent of the commitments to Agenda 21 and to the Desertification Convention. Other conventions will certainly emerge, each of which must be assessed for its implications for research in general and for the CGIAR in particular.

Two other, more general points need to be made here. The first relates to the openness of the CGIAR. Growing complexity in science will make it likely that any given effort might involve all parts of the research continuum, from basic through adaptive research. The result is that individual centers, indeed perhaps the CGIAR itself, will probably not have staff to cover all relevant specialties. To be efficient, then, individual parts of the CGIAR must open up to new forms of collaboration. The CGIAR's innovations in "system-wide initiatives" and "ecoregional initiatives"[11] are a response to this challenge.

Greater openness also has implications for priority setting. Some participants (national program staff, for example) will know better the needs and likely responses of producers, while others might have a better idea about the probabilities of success for alternative research efforts. Given the critical importance of these two considerations in setting priorities, the CGIAR must find ways to get relevant

Science will continue to change rapidly, and each turn of its wheel will bring new understanding, new complexities, and new opportunities. The new complexities will suggest new ways to organize work, and these will favor modifications in the CGIAR's structure. Changes will occur in every aspect of the CGIAR's work.

[10] United Nations. 1991. *U.N. Demographic Yearbook. World Urbanization Prospects.*

[11] Such initiatives rest on an approach that brings new balance into international agricultural research. The approach features sustainable improvement of productivity as well as a strategy for the mobilization of the global research system to meet the sustainability challenge. It focuses on both the human and technical dimensions of sustainable production systems, and relies on effective partnerships with national programs and other agencies.

views on the table early. [This point is a principal theme in the document on Governance, which describes new approaches for obtaining input from national public- and private-sector representatives.] What about producers themselves? How are their needs and knowledge to be reflected in priority setting? CGIAR centers will largely rely on national program researchers and NGOs to reflect the needs and priorities of farmers.

Toward 2015

The points made here are taken from CGIAR documents and relate to decisions taken in recent meetings of the Group. Plans are projected to 2015; their implementation can be changed as needed to accommodate new developments in major external environments.

Increasing Productivity. While a number of factors will lead to changes in the productivity research portfolio, several promise potentially large effects. The first is in the growing capacity of national programs and the increasing investment in selected areas by the private sector.[12] These changes will lead the CGIAR to give more emphasis to strategic concerns in genetic improvement, especially for crops, including raising yield plateaus, improving resistance to important pests, and added buffering for other stresses of particular significance like drought, soil acidity, and soil salinity. This work will lead to the introduction of genes from a widening array of sources, including near and wild relatives, and even unrelated species through the use of transformation technologies. These breeding strategies will

[12] This development itself rests on stronger market-supporting institutions and enhancement of what some call "social capital." See Putnam 1993. Serageldin, I., and A. Steer. 1994. *Increasing the Capital Stock.*

Improving Productivity through Synthetic Wheats

Six thousand years ago, quite by chance, a wild grass with 28 chromosomes captured the pollen of another having only 14. The resulting hybrid became one of the world's most important cereals—bread wheat. Scientists at one CGIAR center had the idea that, by duplicating Nature's chance encounter hundreds of times over, they could both improve the productivity and add to the genetic diversity of this long domesticated crop. The early 28 chromosome parent of bread wheat evolved into durum wheat, an important crop in its own right. Using innovative breeding techniques, elite durums are being crossed with the 14 chromosome ancestor of bread wheat—known as goat grass Triticum tauschii)—to produce "synthetic" bread wheats. These synthetics are themselves of little direct use to farmers, but they do carry desirable traits from the T. tauschii parent, such as resistance to certain diseases, tolerance to saline soils and to drought, and higher rates of photosynthesis. Because they are true bread wheats, the synthetics can be easily crossed to elite bread wheat lines, in effect serving as a bridge for transporting useful traits in T. tauschii to elite bread wheats. This novel research—part of an ongoing effort to broaden the genetic base of bread wheat—is providing two important products: bread wheats with higher, more stable yields, and an efficient method for tapping the genetic potential in the wild relatives of modern wheat varieties.

also have the important effect of broadening the genetic base of major crops, a critical counterbalance to the tendencies of the past 40 to 50 years, tendencies that raise the risk of pandemics like the 1970s southern leaf blight episode in the United States. It should be noted, however, that thanks to modern plant breeding, any given improved variety of recent vintage, grown where recommended, is likely to be notably more resistant to pests than the varieties of even 20 years ago. Significant work is already underway in strategic breeding, and such efforts will receive a rising proportion of CGIAR resources.

Genetic improvement will be aided by advances in molecular biology. Part of the CGIAR's requirements here will be met through collaboration with others, including contractual arrangements. Some CGIAR efforts will focus on tailoring methods developed by advanced laboratories to the needs of developing country researchers.

Urbanization, predicted to increase rapidly, and rising incomes, essential to achieving the goals of the development assistance community, will lead to new patterns of demand for staple foods. These trends will shift the relative importance of the CGIAR's products, changing its allocation of research resources.

Taken together, these considerations will lead to a rebalancing of the CGIAR's work in genetic improvement, both permitting and encouraging some concentration of tasks and, at the same time, encouraging the decentralization to others of some activities now important within the CGIAR.

As noted earlier, much research on the management of production systems tends to be nonproprietary and to feature micro-level activities. As national programs become stronger, CGIAR investment in this work will be reduced. What remains within the CGIAR's purview will have a strong connection with the conservation of natural resources and most will shift to that part of the CGIAR portfolio. Even so, management of production systems will remain an important consideration. It should be added that national programs will be encouraged to see their own work on production systems in the context of resource conservation.

Significant work is already underway in strategic breeding, and such efforts will receive a rising proportion of CGIAR resources. Genetic improvements will be aided by advances in molecular biology.

A New Plant Type for Irrigated Rice

The yield frontier for irrigated rice has been stagnant at about 10 tons per hectare since the first modern rice varieties were released. In the early decades of the green revolution, there was a substantial gap between the technological potential and farm-level yields. Today the exploitable gap is small, making it necessary to increase yield potential in order to raise farm-level productivity. The ultimate target is an irrigated rice plant that raises yield potential by 50 percent, from 10 to 15 tons per hectare in the tropics. The first generation of the new plant type was designed in 1989, and today experimental lines with a target of 12 tons per hectare are being evaluated in the field. This rice plant will be released to national programs by 1998. Other generations will follow to reach the ultimate target of 15 tons per hectare. This new plant type will allow Asia to meet the 50 percent increase in rice demand that is projected by the year 2030.

Two final points should be made here. The measure of success in this domain will be declining real prices for basic commodities in poor countries. If real prices do not decline, development will be impeded, with evident consequences for poverty alleviation, population growth, and the environment. To be truly effective, these price declines must result from productivity increases in the areas where poor producers live. Results here will continue to have indirect benefits for parts of the environment.

Protecting the Environment. This research thrust will be one of the most challenging over the next 15 years. Reference was made earlier to the need for new research paradigms to support this work and of the CGIAR's role in their development. Beyond that already formidable task there are questions about how to best manage such work, with its many collaborators. Ultimately much of this work must be done in a hands on way at the micro-level where the natural, biological, and human elements come together. The likely production systems will involve a range of activities, some complementary and some competitive, but each potentially benefiting from the inputs of specialists. Furthermore, investment in relevant basic research is expanding in several advanced institutions. For some portion of the work, macro-level considerations and policies must be brought into play in order to ensure that resource conserving practices are adopted, and much training must be done to sensitize research partners to the important elements and, indeed, to the very importance of such work. Combining these considerations in fruitful ways will require management skill and some patience. Even so, practitio-

Research on Asia's Rice/Wheat Rotation

Nowhere are rice and wheat more important than in South Asia. The area devoted to wheat, grown in the winter season after rice, expanded significantly in the region during the late 1960s with the advent of earlier maturing varieties. Rice and wheat are now grown there in annual rotation on nearly 12 million hectares, providing food for tens of millions of rural and urban families. But in the mid-1980s, researchers became concerned that the cropping system might not be sustainable. Although such a trend was not yet evident in most farmers' fields, scientists from four national programs in the region and two CGIAR centers began detailed diagnostic surveys in the late 1980s. Information from farmers indicates that the productivity of the system is, in fact, declining. To determine why and to develop recommendations for making the system more sustainable will require extended, strategic research—a strong suit of the CGIAR. The CGIAR and its collaborators have established an innovative ecoregional initiative aimed at developing sustainable farming practices for rice-wheat cropping on the Indo-Gangetic Plain. The initiative involves the four original national programs and several CGIAR centers. A lead center in the region will coordinate the work, with research priorities established by an advisory committee containing one member from each participating institution. Innovative institutional arrangements will facilitate the interdisciplinary research needed to address the problem, and all partners are committed to developing practical solutions relevant across sites and national boundaries.

ners are confident that a problem solving orientation will provide the framework through which roles can be identified, effective collaboration initiated, and the desired results can be achieved.

Success here will require effective research paradigms and robust frameworks for participation and collaboration, perhaps more than in any other area of research. The CGIAR's response to these challenges features an ecoregional approach and several ecoregional initiatives.

In addition, other research will look at broad strategic issues. Some argue that work on increasing water use efficiency may well be the single most important research issue of the next 15 years. Overall, given the widespread implications of the problems, the CGIAR will emphasize five themes: (i) water and irrigation management; (ii) watershed, coastal areas, and river basins; (iii) interactions among soils, water, nutrients, plants and animals; (iv) ecosystem restoration; and (v) common property issues. Many of these emerge from Agenda 21. Principles derived from research on these problems will be broadly applicable.

Given the essentially nonproprietary nature of this work and potentially large economies of size, its apparent importance, and the absence of others with the advantages of the CGIAR—strong connections with national programs, advanced institutions, and expanding connections with NGOs—the CGIAR will invest a rising proportion of its resources in this area. Some part of that will have been transferred from production systems research. Again, it is recognized that there is no possibility that the CGIAR could, or should, do all such research for all relevant ecoregions of the developing world. National programs in particular will carry out the bulk of this work; their advantage is obvious. The CGIAR's success will be gauged in terms of shaping effective research paradigms which lead to desirable technologies that producers adopt, and in shaping useful research management strategies, the kind others can apply effectively.

Saving Biodiversity. A rising portion of CGIAR funding over the next 15 years will be dedicated to saving biodiversity. Among other things, additional resources are needed to improve the CGIAR's physical facilities to ensure adequate safekeeping of base collections, to add to selected base collections, to expand somewhat the range of species conserved, to investigate and then to decide on a role in *in situ* conservation, and to shore up the capacities, especially managerial, of conservation activities in many national programs. In addition, the CGIAR's vast storehouse of information on its collections will soon be opened to electronic query via Internet. Many outside the CGIAR will participate fully in these activities, from priority setting to execution.

The next decade or so will see analysis, discussion, debate, and reflection on many issues pertaining to the conservation of biodiversity, involving a myriad of actors, including the CGIAR. [See "CGIAR Genetic Resources and FAO" on page 89.] The strategy pursued by the CGIAR must reflect these exchanges. Through it all, it seems likely that the current intent to commit more resources here will be maintained. To facilitate its work, the CGIAR has established a system-wide initiative in genetic resources, involving all relevant centers and other important players as well.

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Improving Policy. CGIAR investment here is scheduled to increase slightly over the next 15 years from its current level of 10 percent. Before deciding to do this, the CGIAR noted that much of the conventional wisdom about policy argues for letting markets work and that such a generic strategy will require ever less research as evidence mounts to demonstrate its efficacy.

Several considerations, however, call for CGIAR work in this field. The first is equity. The CGIAR works on behalf of the poor, and concern for equity might well argue for rebalancing market-based income distributions. The second is the clear possibility that policy measures will be required to induce producers to adopt resource conserving strategies, even though these strategies also increase incomes over the long-term. The third is the need for clearer guidelines for policy research concerned with marginal allocations among an array of international public goods. The fourth is that there are relatively few professionals in developing countries who are sufficiently sensitive to these considerations and trained in articulating clear-cut choices for policymakers.

In addition, but in a category by itself, is the urgent need for research on managing common property so as to avoid what is widely called the "tragedy of the commons." Many are searching for solutions here and the CGIAR, with its considerable experience on the ground, will be an important participant.

Again, it should be noted that other work goes on in the social sciences as a part of the three preceding thrusts.

Reforming Agricultural Markets

For most developing countries, the past three decades have seen heavy government intervention in agricultural markets. Not only have public interventions been expensive, they have constrained agricultural and rural development rather than fostering it. Many of these governments are now trying to reform their markets. In response, one CGIAR center has developed an ambitious research program focused on reforming agricultural markets in developing countries, particularly in Africa. Projects have been initiated in Ghana, Senegal, Cameroon, Malawi, Tanzania, and Uganda that will design market reform strategies and build the in-country capacity necessary to implement and monitor them. New projects are also being developed for Vietnam, Kyrgyzstan, and the Philippines, and will help to guide policymakers through the reform process. The impact of agricultural market reforms, widely promoted by the international community including CGIAR policy researchers, will be on monetary resources, and agricultural production will be enormous. The CGIAR's work on such reforms in Bangladesh and Pakistan demonstrated that a US$3 million investment for research and training on market reform can help a government save US$124 million. In Bangladesh, 35 percent of recent increased food production is attributed to market liberalization.

Fortifying National Programs. The CGIAR will rebalance the focus of its work in this area. In the past, much effort has gone into training, especially for entry-level national program staff.

The CGIAR is now encouraging the development of regional training programs largely, or ultimately, in the hands of regional or national entities. [See "Regional Training in Crop Management Research" on page 91.] Second, the CGIAR is streamlining its own training programs, especially in Sub-Saharan Africa, which should lead to significant efficiencies. Finally, loans and grants to national programs from bilateral and multilateral sources include larger amounts to defray the costs of training with the result that national funds can be substituted for CGIAR funds. Training still goes on within the CGIAR; it has been scaled down and focused more on mid-career professionals. With these changes in circumstance, there will be some opportunity for scaling back CGIAR financial support in the affected areas.

There is a continuing need for research and training in management and administration. To the extent that research administration and management have common elements across many countries, this activity is characterized by economies of size. It is expected that demands will remain strong for another decade or so, and again there is the possibility of substituting loans for CGIAR funds.

An area of institution building that will increase pertains to information management and communication. Advances in this field have been so notable and cost reductions so dramatic that collaboration is ever more favored and division of labor ever more advantageous. With knowledge-guided collaboration of various kinds increasing at all levels, the need for information management and effective communication can only grow. The CGIAR must ensure that it meets its own requirements, which include effective links with all relevant actors, and that it can offer national programs the benefit of its experience.

Toward 2025

While what might happen in 2025 is quite uncertain, still the CGIAR has given some thought to that period, if for no other reason than to reflect intentions and to point out some areas of concern and call for an international effort. It is assumed that by 2025 national systems, private and public, will be adequate to meet most internal needs and that there will be regional and ecoregional mechanisms for most transnational research, much of it also resting on collaboration.

The CGIAR will then be a largely collaborative system, primarily discharging its responsibilities through contracts with other research institutions. The principal components of its work will include genetic resource conservation; genetic enhancement (much of it what some call "prebreeding") of selected plant, livestock, and fish species of transnational or global importance; strategic research on natural resources conservation and management; strategic research on public policy and management issues of global importance; and global information activities related to the research needs of the time. To the extent that its role is catalytic, the CGIAR itself could have significantly fewer staff than it has today.

What ultimately emerges will depend on the scope for research as an international public good—almost certainly smaller than today—and on cost and reliability questions. In that context, the CGIAR's principal advantages will be in its non-political character, its

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It is quite evident that the CGIAR must carefully monitor developments and be responsive to new trends. The evidence of past change encourages confidence about the CGIAR's capacity for further change and about a culture that sustains change.

evenhandedness, and its ability to combine its special access to knowledge about the needs of producers and of the environment with knowledge about the opportunities through advanced science.

CONCLUSIONS

The evolution of the CGIAR research agenda described here rests directly on several assumptions. The most important of these relate to (i) the strength of national programs and participation by the private sector, (ii) what happens in science, (iii) changes in the policies, laws, and institutions that influence markets and contracts, and (iv) the concerns of the development assistance community. Other forces will also be at play, but these appear to have the largest consequences for the CGIAR's work.

While all projections are uncertain, some are more so than others. In this case, the third and fourth assumptions on which these projections rest seem to be more certain calls than the others. In any case, it is quite evident that the CGIAR must carefully monitor developments and be responsive to new trends. The evidence of past change encourages confidence about the CGIAR's capacity for further change and about a culture that sustains change.

As for the first two considerations, what if national programs do not progress as projected, or what if the promise of, for example, biotechnology, is not realized on the currently anticipated schedule? With very fragile boundaries separating the prophets of plenty and the prophets of doom, falling behind in these critical areas can only tip the balance one way. In particular, if developing country governments fail to strengthen their agricultural research programs, the CGIAR would be obliged to compromise on its comparative advantage. As in the past, more resources would go directly into technology development. It would revert to its role of the 1970s and 1980s rather than the international strategic role predicted for it once NARS were strong.

One final consideration is important to note. In a world so filled with uncertainty, where the consequences of limited food production are so prejudicial to the goals of the global community, why not reinforce research for agriculture, fisheries, livestock, and forestry? Prudence alone would favor this strategy. At the very least, two substantive gains would follow—ever lower real prices for foodstuffs (with all that implies) and ever stronger protection for the environment than will otherwise emerge.