CIMMYT

Sustainable Maize and Wheat Systems for the Poor

People and Partnerships:

Medium–Term Plan of the International Maize and Wheat Improvement Center (CIMMYT)

1998 - 2000+

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CIMMYT is an internationally funded, nonprofit scientific research and training organization. Headquartered in Mexico, the Center works with agricultural research institutions worldwide to improve the productivity and sustainability of maize and wheat systems for poor farmers in developing countries. It is one of 16 similar centers supported by the Consultative Group on International Agricultural Research (CGIAR). The CGIAR comprises over 50 partner countries, international and regional organizations, and private foundations. It is co-sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank), the United Nations Development Programme (UNDP), and the United Nations Environment Programme (UNEP).

Financial support for CIMMYT's research agenda currently comes from many sources, including the governments of Australia, Austria, Belgium, Canada, China, Denmark, France, Germany, India, Iran, Italy, Japan, the Republic of Korea, Mexico, the Netherlands, Norway, the Philippines, Spain, Switzerland, the United Kingdom, and the USA, and from the European Union, the Ford Foundation, the Inter-American Development Bank, the Kellogg Foundation, the OPEC Fund for International Development, the Rockefeller Foundation, the Sasakawa Africa Association, UNDP, and the World Bank.

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People and Partnerships:

Medium–Term Plan of the International Maize and Wheat Improvement Center (CIMMYT)

1998 - 2000+

Director General's Introduction

CIMMYT's research and training strategies are firmly grounded in the three overriding goals of the Consultative Group on International Agricultural Research (CGIAR) — the alleviation of poverty, protection of natural resources, and sustainable food security. We address these goals through research aimed at the development of more efficient, more robust maize and wheat germplasm, through natural resource and economics research designed to enhance the sustainability of maize- and wheat-based production systems, and through a range of related research and training activities.

This Medium-Term Plan (MTP) presents a program of research and training activities that follows on from the Center's Strategic Plan and its 1994-98 MTP. It reflects an extensive process of consultation with many stakeholders, both internal and external, as well as an assessment of changing needs and CIMMYT's comparative advantage in meeting them. Poverty alleviation is a dominant theme in this MTP. Wherever possible, we explicitly consider the likely impact of alternative activities and associated outputs on poor consumers and producers, and especially on poor rural women. Similarly, we have tried to clarify the contributions of our various activities to the CGIAR goal of protecting the environment. We also explicitly respond to the CGIAR's priorities as expressed in the Technical Advisory Committee (TAC) Priorities and Strategies paper, describing where we converge — and where we diverge — from those priorities and why.

This MTP projects the Center's agenda and financial needs forward to the year 2000, but many of the activities described herein will continue well into the next century. We have identified milestones by which progress can be measured throughout the planning period; but in many cases, while significant progress is anticipated by 2000 toward the delivery of most of our outputs, some will be necessarily delivered over the longer term. Hence the reference to a 1998-2000+ planning horizon.

We begin with a strategic overview that includes a review of the overriding importance of maize and wheat to the poor in the developing world and important trends in the global maize and wheat economies. From there we move on to CIMMYT's future role in addressing the challenges implied by those trends, an overview of the process by which we achieved consensus among important stakeholders on that role, highlights of the Center's proposed research and capacity-strengthening projects, and a discussion of the financial aspects of the plan. We call the readers' attention, as well, to the boxes placed throughout this document, in which we highlight several important considerations that underlie our planning for the future.

Finally, it is important to note that CIMMYT has been engaged in a process of change since the early 1990s, initially in response to budgetary influences, but more recently in response to changes in science and our external environments. This process has been accelerated during the past year and will no doubt continue, but it is now driven by the diverse and changing needs of stakeholders. The words "integration" and "interdependence" have come to characterize this process of change. We have now organized all of our work within 20 Global, Regional, and Frontier Projects, as well as 1 Special Focus Project, a move that has crystallized opportunities for integration across CIMMYT's research programs, clarified the need and potential for greater collaboration with numerous research partners, and revealed an extensive interdependence among project activities.

Accordingly, we have titled this MTP "People and Partnerships," because it focuses on the needs of resource-poor people and seeks to address those needs through strategic partnerships with national agricultural research systems (NARSs), advanced research institutions (ARIs), nongovermental organizations (NGOs), the private sector, and other CGIAR centers. We believe this plan comprises an important step toward transparency in research priority setting, and capitalizes on the fact that multidisciplinary, team-based approaches to research more effectively meet the needs of our many partners.

Strategic Overview

CIMMYT's Medium Term Plan for 1998-2000+ is heavily influenced by the following primary considerations:

1) The complex global concerns and associated CGIAR goals on poverty alleviation, natural resource management, and sustainable food security.
2) The mandate of CIMMYT, and its comparative advantage in contributing to strategic partnerships that seek to mobilize and integrate multidisciplinary approaches to addressing these global concerns.
3) New opportunities in science and research methodology that increase the likelihood of success in meeting these complex challenges.

CIMMYT's overarching concern is for sustainable productivity increases, i.e., maize- and wheat-based farming systems that are economically viable, environmentally sound, socially acceptable, and politically supportable. Sustainable systems must be economically viable at the farm household, national, and regional levels in order to help alleviate poverty on the one hand and to provide a platform for subsequent economic growth and development on the other. Environmentally sound systems are, by definition, those based on technologies that protect and enhance soil, water, and air quality in agro-ecosystems, and that enhance agro-biodiversity within a broader framework of biodiversity and sustainable landscape management. Production systems will be more socially acceptable, and hence more sustainable, if they enhance the quality of life for individuals — particularly of poor women and children — and if they strengthen the social fabric of rural communities. This implies the adoption of technologies that encourage equity between groups, between regions, and between generations. Finally, in our view sustainable systems must be politically supportable, i.e., they must contribute to and otherwise encourage the development of policies that facilitate the equitable adoption of new technologies and accrual of associated benefits.

CIMMYT has a strong comparative advantage, as indicated by its impact and successes to date, in producing improved wheat and maize germplasm for developing (and developed) countries. More than 70% of the developing world's wheat land is devoted to CIMMYT-related varieties, and over half of the maize area in developing countries now growing improved varieties is planted to cultivars flowing from CIMMYT's research program. This tremendous impact at the farm level has contributed significantly to economic growth, higher incomes for both urban and rural poor, and enhanced food security.

It is clear, however, that improved germplasm alone will not solve the complex problems of poverty alleviation, natural resource management, and sustainable food security. Just as stronger integration of disciplines and specialties within CIMMYT is needed to meet these more complex challenges, so too a stronger integration is needed at the global and regional levels for sensibly integrating our contributions with those of other research partners. We will therefore expand our already strong collaboration with advanced NARSs situated in strategic areas, with advanced institutions in developed and developing countries having excellence in "cutting edge" science, and with other international centers. Partnerships and networking involving NARSs, ARIs, NGOs, and the private sector will become even more central to our way of doing business in the future.

Identifying Priority Areas

In determining its research resource allocations, CIMMYT took note of the inputs from a broad range of partners and stakeholders, including those from:

- NARSs' Regional and Global Fora;
- TAC's 1996 "CGIAR Priorities and Strategies" paper;
- IFPRI's "2020 Vision" study;
- CIMMYT's 30th Anniversary MTP Consultations with NARS and donor representatives;
- Consultations with CIMMYT's own staff;
- Workshops on maize and wheat research involving internationally recognized specialists; and
- Extensive visits and discussions with NARS leaders and CGIAR members.

In addition, of course, a key reference point for establishing the Center's future priorities was its existing Strategic Plan and current Medium Term Plan, 1994-98. Following the distillation and consideration of all these inputs, the resultant project development process featured the "bottom up" involvement of experienced CIMMYT scientists. A "Project Advisory Group" of scientists was formed, which served to consolidate and channel the ideas of the Group, their peers on CIMMYT's staff, and of management, to produce an initial draft project document that served as the basis of the late-1996 consultative process with the Center's research and financial partners.

The final allocation of resources is in general agreement with the CGIAR priorities as expressed in the 1996 TAC paper. (The exceptions are discussed later in this MTP.) Resource allocations in relation to TAC recommendations are as follows:

- **Prebreeding** — increased emphasis;
- **Resource Conservation/Production Systems** — linkage supported;
- **Post-Harvest Issues** — increased emphasis;
- **Policy Research** — increased emphasis on the interface between technology and policy;
- **Generic vs. Local Natural Resource Management** — increased emphasis on generic applications;
- **Collaborative Links/Outsourcing** — we generally agree with this strategy;
- **Biodiversity** — increased emphasis;
- **Human Resource Development** — increased emphasis on specialized training; and
- **Poverty/Poor Rural Women** — increased emphasis.

The areas of disagreement with TAC's comments and recommendations are mainly a matter of emphasis. They relate to alternative suppliers, the importance of China, and training. However, in the case of the latter, we agree with TAC that alternative funding sources are important. Still, the role of CIMMYT as a provider remains very important to the NARSs, as confirmed during all regional fora. All of these issues are addressed in the body of this MTP.

The Importance of Maize and Wheat

Together, maize and wheat now account for over half of the cereals consumed in the developing world. They are significant staples in the diets of billions of developing country residents, and

China Will Not Starve the World, But...

There has been much discussion recently about China starving the developing world of food supplies. Most analysts agree that China, with its vast population and rapidly growing per capita income, will soon emerge as a major importer of cereals. Projections of China's total grain imports vary widely, depending on the assumptions made about future rates of population and income growth, levels of investment in productivity-enhancing agricultural research, and rates of environmental degradation. One of the most alarming scenarios has been spelled out by Lester Brown of the influential World Watch Institute, who predicts that China's import demand for grain will exceed 200 million tons per year by 2020.

At CIMMYT, we agree with more moderate projections made by analysts at the World Bank, Food and Agriculture Organization (FAO), and the International Food Policy Research Institute (IFPRI), among other organizations. Thus we are not convinced that China's future grain requirements will starve the world. However, we do anticipate that increased imports of grain into China could have undesirable equity effects and adverse environmental consequences, not only within China but throughout the developing world.

One important reason to be concerned about maize and wheat productivity trends in China derives from the large amount of rural poverty that still exists in the country's less economically favored provinces — a fact often lost in aggregate statistics indicating that per capita income for China as a whole is expected to rise sharply. The latest UNDP data indicate that 11% of China's population, representing approximately 130 million people, earns less than US $ 1 per day – equal to nearly half the number of people in this "poorest of the poor" income category found in all of sub-Saharan Africa.

A second reason to be concerned about wheat and maize productivity trends in China is the effect China's import behavior could have on other developing countries. A substantial increase in Chinese wheat and maize imports would almost certainly affect global prices of these two crops, which would reduce their affordability everywhere. Poor consumers in developing countries that import wheat and maize would face rising food prices, especially consumers in urban areas who rely heavily on food imports to meet their consumption requirements.

In the specific case of maize, the prospect of substantial future increases in Chinese imports also raises important environmental concerns. If Chinese maize imports drive up world maize prices, a large amount of rice land in Asia will be diverted into maize production, especially in rainfed upland areas. Substitution out of subsistence-oriented, extensive rice production and into intensive commercial maize production on the hillsides will certainly enhance the incomes of the farmers who will be directly affected (many of whom are poor), but these benefits are likely to exact considerable environmental costs in terms of increased soil erosion and greater use of chemicals.

Because CIMMYT is a major source of improved maize and wheat production technology, we believe that we have a potentially important role to play in China. CIMMYT-China collaboration in the development of productive, environmentally friendly wheat and maize production technology – especially in less favorable production areas – could generate substantial social benefits, both in terms of income enhancement and in terms of environmental protection.

variations in productivity can profoundly influence the relative well-being of the poor.

In the early 1960s, the developing world accounted for just over a third of the global maize production and less than 30% of the global wheat output. By the early 1990s, as a result of tremendous productivity growth in maize and wheat, developing countries accounted for more than 45% of total world production of both cereals. Maize production in the developing world grew at an annual rate of 3.6% per annum between 1961 to 1995; wheat production grew at an even faster rate of 4.5%. Yet despite this growth in productivity, developing country import demand for wheat and maize has also grown during this period. Maize imports grew from 10% of global imports in the early 1960s to 45% in the 1990s. In the case of wheat, just under half the imports were into developing countries in the 1960s. Today they account for two-thirds of all imports. Rising consumption of maize and wheat in developing countries has been driven by rapid population growth and/or growth in per capita incomes, as well as by declining real prices.

Looking ahead — The current cereal supply situation in developing countries should not encourage complacency. Over the next thirty years, developing country population will continue to grow at a rate of at least 1.6% per year. In some regions, particularly, income growth will continue to fuel demand for maize and wheat. As a result, overall demand for wheat and maize is expected to grow at an annual rate of 2.2% over the next thirty years. In the case of wheat, we expect the increased demand to be the result of substitution out of rice and coarse grain cereals as incomes rise and as populations become increasingly urban based. While per capita demand for food maize is expected to decline in all regions except sub-Saharan Africa, the demand for feed maize is expected to rise dramatically as the demand for livestock products increases. By 2020, two-thirds of the world's wheat consumption and 55% of the world's maize consumption will occur in developing countries. Even if productivity growth occurred at current levels, developing countries would need to import some 122 million tons of wheat and 41 million tons of maize annually by the year 2020. The availability of such supplies is questionable. If there is a significant drop in current investment for research and infrastructure development, the supply situation becomes even more critical. IFPRI anticipates that under a low investment/slow growth scenario, developing country maize production would drop by 10% and wheat by 13% by 2020, relative to the baseline scenario.

Even though we anticipate income growth in the developing world, we are acutely aware of substantial differences between regions and within regions in income growth and distribution, and consequently in relative food security. South Asia and sub-Saharan Africa will continue to be the primary focus of CIMMYT's attention, given the continued dominance of poor people in the two regions. Increasing food maize productivity in sub-Saharan Africa and wheat productivity in South Asia will be crucial to enhancing the food security of these regions. We are also concerned about intraregional differences in food security, particularly for people living in unfavorable production environments, and especially in low rainfall, drought-prone environments. Even in the productive regions, however, inter-household differences in productivity and food security will persist due to inequitable access to production resources. At the intra-household level, we anticipate significant gender-related variability in access to food production resources, as well as food and nutritional security. Women and children face higher risks of malnutrition due to poorer access to food. We will target our efforts at addressing more directly the needs of resource-poor farmers, especially women farmers (see Annex 1 for more detail on the global maize and wheat economies).

Changes in External Environments

This MTP has been developed in response to changing environments for CIMMYT's work. Many facets of these changes were reflected in the extensive consultative process which underpins our Plan. Under separate headings, changes in science, the financial environment, and CIMMYT's internal management are described. In addition to these it is also important to address changes in the external environment as they relate to CIMMYT's work over the coming years.

Knowledge Intensive Technologies (KITs) — The complexity of technologies that farmers must adopt is increasing. As shifts occur from embodied technologies (such as new crop varieties) to disembodied technologies (such as integrated pest management), the development and dissemination of research results necessarily changes. In responding to this issue CIMMYT has carefully considered its comparative advantages and the potential — as well as actual — contributions of others.

CIMMYT's major comparative advantage is, and will remain, the development of improved germplasm for maize and wheat — embodied technology. We will continue to emphasize this and make every effort to embody in our germplasm as many desirable characteristics as possible for sustainable productivity increases. However, we believe we need to have a better understanding of the external environment where this technology must make its impact to achieve our objectives. In other words, we need greater knowledge of the socioeconomic and natural resource systems where maize and wheat are important food crops.

Accordingly, CIMMYT has strengthened its Economics Program and its Natural Resource Management Group, not only with a view to building in-house skills or technology useful anywhere in the world (for example, gender analysis, participatory research, crop-soil modeling, and geographic information systems — GIS), but more importantly to act as a credible and effective interface with partners who have comparative advantages in these areas of work.

It is our belief that the new partnerships to be formed — partnerships necessary for effectively developing and transferring both embodied and disembodied technologies to farmers — will not occur spontaneously. Therefore, CIMMYT has invested in high quality staff to initiate, negotiate and facilitate new partnerships with those who have major skills dealing with disembodied technologies. These partners include NGOs, consultants and farmer groups.

Intensification of Wheat and Maize Cropping Systems — In most regions of the world, but particularly in Asia, the frequency and intensification of cropping has increased drastically. In addition to wheat and maize being grown more frequently in traditional areas, they are now making significant inroads into regions where rice has been the prime food crop. As a result, the pressures of both biotic and abiotic stresses have increased significantly. In wheat this has taken the form of greater incidence of diseases, such as yellow rust, fusarium head scab, helminthosporium leaf blights and barley yellow dwarf. It is therefore necessary to place greater research emphasis on these diseases in order to protect food security. Not only does this entail more and better research on durable host plant resistance, but also on regional strategies in the case of wheat rusts, to place "genetic barriers" to control their spread. CIMMYT has responded to this challenge in its new projects on wheat stresses and associated regional projects.

In the case of maize, while biotic stresses are important, abiotic stresses are assuming even greater significance as maize is grown in harsher environments, where water stress, low soil fertility, soil toxicities and deficiencies, and waterlogging are regularly encountered. Increased research emphasis on abiotic stress in maize is therefore incorporated into CIMMYT's new plan. This intensification also exacerbates soil degradation and accelerates the need for more sustainable land management practices, a point covered in the Regional Projects of this MTP.

Resourcing of Agricultural Research (North and South) — This is a major issue influencing CIMMYT's external environment. In many countries, agricultural services are being asked to do more with less, often much more with much less. On the other hand, the private sector is putting enormous resources into biotechnology. These trends require a major shift in strategies for alliances and research partnerships. In order to foster collaboration with the private sector, CIMMYT must consider its position on two important issues — intellectual property rights (IPR), and the potential influence of private sector funding on the real and perceived independence and objectivity of our research for the resource poor. These matters are under consideration and will be steadily developed throughout the planning period. In relations with NARSs and ARIs, who often have lesser resources, the situation is equally complex, as innovative approaches to research funding and resource sharing have to be further developed.

One of the very positive elements of relevance to this issue is the continuing emergence and growth of regional NARS organizations, including the Southern African Centre for Cooperation in Agricultural Research (SACCAR), the South African Development Community (SADC), the Asia-Pacific Association of Agricultural Research Institutes (APAARI), the Association for Strengthening Research in Eastern and Central Africa (ASARECA), the Association of Agricultural Research Institutions in the Near East and North Africa (AARINENA), and others. CIMMYT has had significant success working with these organizations, particularly in the development and management of research-based networks. These regional organizations provide a sound basis for collaboration and integration between CIMMYT and the region concerned, and also between national programs within each region. For these reasons, we seek to strengthen our relationships with these groups in order to encourage and facilitate effective partnerships.

CIMMYT therefore commits itself under this new MTP to be highly responsive to current and prospective partners and willing to work in a range of ways, so that, collectively, we can achieve more with less. On a more optimistic note, there are signs that during the planning period there will be a greater realization among decision-makers that food does not come from supermarkets but from farms, which are subject to the vagaries of climate and the ravages of pests, diseases and weeds that are constantly changing and adapting. Increased emphasis on communication and public awareness of the importance of agriculture is a component of CIMMYT's new External Relations Program.

Changes in Research Management

In light of all the above, we are adopting a project-based research agenda that will provide an enabling framework for a multidisciplinary approach within CIMMYT and, more importantly, between CIMMYT and its partners. Some of these projects have a **global** and/or thematic approach in which the major activities relate to genetic resources, pre-breeding, and breeding, and the main products are enhanced germplasm. A series of **regional** projects seeks to catalyze the incorporation of this germplasm into the natural resource and socioeconomic systems where it must make its impact; these projects expand the traditional Genotype x Environment (G x E) paradigm to a G x E x Management x People paradigm, which will entail considerable input from partners, including expanded collaboration with NGOs.

CIMMYT plans to enhance the application of advanced scientific methodologies to its research efforts through a set of **frontier** projects designed to complement and reinforce its thematic projects. While these Frontier projects may generally have a higher risk of failure than those based on established technologies, their potential payoffs are so large that significant investment in them is warranted. A key feature of these projects is to also provide a clearly visible focal point for collaboration with the private sector, as well as ARIs and the stronger NARSs.

For strategic reasons, CIMMYT is changing its management organization to a flatter, leaner structure (see diagram) — one that is more appropriate to the Center's new working environment and more sustainable in the current and foreseeable financial climate. These changes will have a significant impact on the way research is managed and coordinated in the Center, with stronger roles for the Director General, a Research Coordinating Committee (RCC), and the Program Directors.

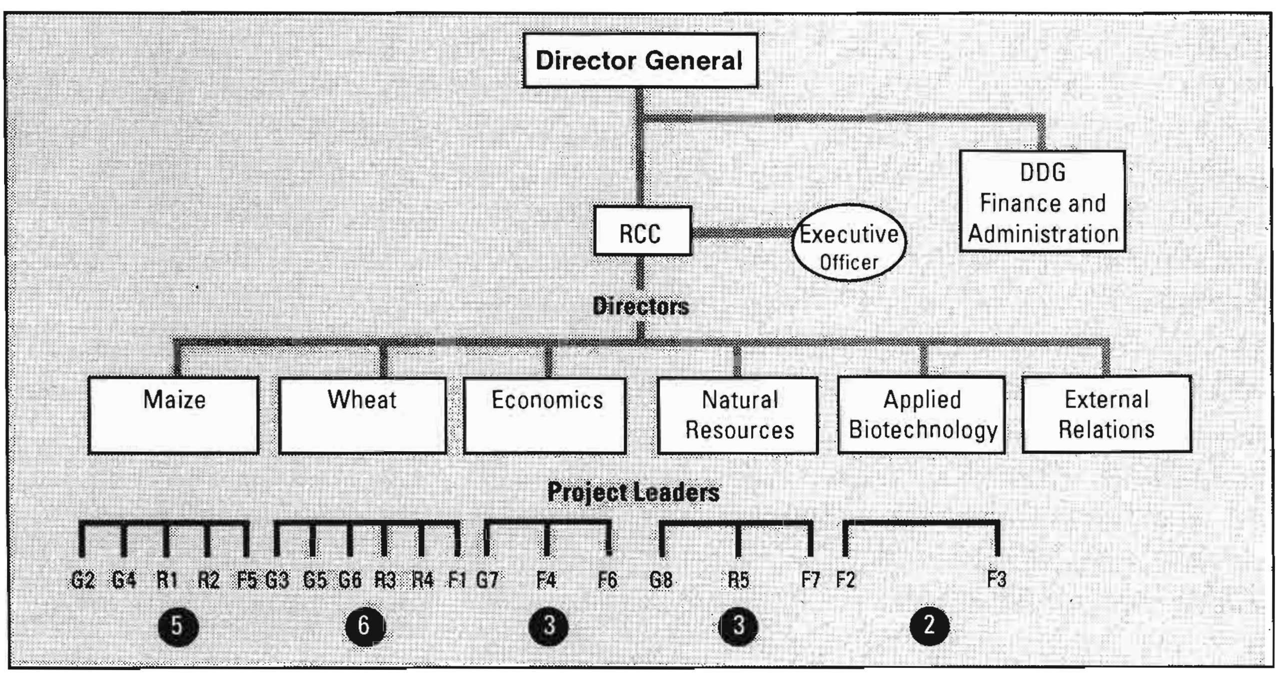
The RCC will play a pivotal role in the resourcing, coordination, and oversight of CIMMYT's research agenda. The Committee has the following composition:

- Director General (Chair)
- Deputy Director General of Finance and Administration
- Director Maize Program
- Director Wheat Program
- Director Economics Program
- Director Applied Biotechnology Center
- Director Natural Resources Management Group
- Director External Relations (*ex officio*)
- Executive Officer (*ex officio*)
- Secretary

The RCC now meets once each month (at a minimum), and is focused on: issues of cross-program coordination; decisions on resourcing of Global, Regional, Frontier and Special Projects; research policy (not to be confused with the Board of Trustee's role); and taking a "helicopter" view of CIMMYT research.

In addition, the new Project Leaders will have responsibilities for coordinating and facilitating more multidisciplinary and integrated project teams, while working in strategic alliances with partners.

An Executive Officer will be hired to assist the Director General in the research management process, and this person will also provide support to



the RCC, which will be chaired by the Director General.

Moreover, we have consolidated our information and donor relations activities into a single External Relations Program, in order to streamline and strengthen the Center's two-way communication with its financial supporters. We expect that all these changes will result in a number of important payoffs, including:

- enhanced research coordination and integration within CIMMYT;
- enhanced efficiency and transparency of resource allocations among programs and projects;
- improved communication between researchers and senior management, as well as with financial supporters; and
- enhanced focus, targeting, and impact of CIMMYT's research efforts.

Changes in Training

In relation to human resource development and capacity strengthening — of individuals and of organizations — CIMMYT plans to build on its substantial global successes to date. Again, there is a change of emphasis to these human resource development/training proposals. New efforts will focus on developing additional courses in biotechnology and offering these within several of CIMMYT's client regions. Courses will also be offered in GIS, and crop and soil modeling. In addition, a new course on "The Principles and Practice of Sustainable Cropping Systems" is being developed in collaboration with several ARIs and in response to strong demand from the NARSs. Established courses on crop management research are being progressively regionalized, and this process should be substantially completed during the period of this plan.

A Concluding Remark

By virtue of the extensive consultative process we have followed in developing this MTP, we are convinced that this plan builds on CIMMYT's comparative advantages and positions the Center in the global agricultural research system in a way that catalyzes and encourages effective and efficient partnerships to overcome the burgeoning challenges of poverty alleviation, sustainable natural resource management, and sustainable food security.

Priority Setting and Resource Allocation

CIMMYT's Strategic Plan provides a base for setting priorities for research and for the allocation of resources. These resources were allocated to competing activities after considering the relative importance of maize versus wheat, the size of mega-environments associated with specific research challenges, alternative sources of supply, likelihood of success, poverty, and the relative strength of NARSs, among others. This plan has been kept current by a series of Evergreen Reports in which the main factors affecting CIMMYT's operating environment (changes in science, changes in the supply and demand of maize and wheat, changes in the strength of NARSs, changes in alternative suppliers, changes in the physical environment, and changes in the CGIAR) were reassessed and effects of changes evaluated. Now we have added gender as a further important consideration.

On the basis of these, we believe that CIMMYT's investment in wheat should be slightly more than in maize because of potential imbalances between supply and demand. This belief is reflected in our allocation of unrestricted funds. However, due to the interests and actions of CGIAR Members, we have considerably more restricted funding for maize than wheat, and thus our total 1997 investment in maize will be slightly greater than in wheat. This is a good example of the power that external forces can exert over internal resource allocations. Still, over the longer term, we anticipate achieving a resource allocation more closely aligned with the relative priority we give to wheat research.

Prebreeding: Linking Germplasm Conservation and Utilization

Prebreeding is defined by the TAC as the process by which commercially useful genes are incorporated in genotypes which are not themselves suitable for use as crops, but which may be used as parents that will give rise to cultivars following further research. In doing so, prebreeding provides a bridge between related species and landraces, often conserved in germplasm banks, and elite modern varieties.

Using their improved understanding of genetics and progeny testing, plant breeders early this century began the revolution in cultivar performance that, when combined with improved production practices, eventually formed the basis of the Green Revolution. As a consequence, a widening gulf in productivity between cultivars and landraces began to occur. This dramatic change was also accompanied by another effect, also a direct result of plant breeding success. Because farmers in many cases preferred to grow improved cultivars, often over large contiguous areas, landraces and wild relatives were displaced, and erosion of genetic diversity of wheat and maize occurred. Fortunately, in the last 40 years most of these landraces and wild relatives have been collected and conserved in gene banks in many parts of the world, and there is growing interest in *in situ* conservation of those that remain. Over time, however, the performance gap between improved varieties and landraces has widened, especially when compared across environments. Breeders have become increasingly reluctant to cross landraces with improved germplasm because, in addition to traits of interest, they carry undesirable genes which result in poor outcomes in segregating populations, and consequently result in few improved advanced lines.

In order to use germplasm bank collections, this gap has to be narrowed by prebreeding. Maize landraces, for example, are grown out and screened for traits of interest, and those which perform the best are crossed to form a germplasm "pool." This pool is then improved for its agronomic performance by increasing frequencies of desirable alleles and eliminating traits linked to poor performance. With time this pool is then ready to be used as a source of useful genetic variation that can be transferred to elite germplasm lines and populations by backcrossing. This activity is now often called "conventional prebreeding," and provides a link between germplasm bank accessions and the general purpose, elite high-yielding germplasm found in all advanced breeding programs.

Attempts at direct utilization of landrace accessions without this intermediate step have often resulted in failure, and experience in CIMMYT's Maize Program suggests that only 2-5% of landraces screened for abiotic stress tolerance will ultimately be incorporated into elite breeding populations and pools. Examples of where this process has resulted in success are: the formation of CIMMYT's maize back-up pools (project G2), which now are at a level of general performance where they can provide useful new genetic variation to advanced elite populations and serve as a source of inbred lines; our maize insect-resistant populations, MBR and MIRT; our more recently formed drought tolerant source populations, DTPW and DTPY, and two low N-tolerant pools (project G4). New populations are continually being formed as inbred lines are recycled, and this, too, can be considered a prebreeding activity.

An alternative strategy in prebreeding, used mainly by CIMMYT's Wheat Program, is to transfer desirable genes from donor landraces to recipient elite lines through limited backcrossing, while carefully eliminating undesirable traits. This process is repeated until the desired genes or traits are suitably introgressed into agronomically acceptable cultivars or high-yielding base populations. Examples of this type of prebreeding in wheat are the transfers of Karnal bunt resistance, salinity tolerance, and helminthosporium spot blotch resistance from *Aegilops squarrosa*-based hexaploid synthetics; Russian wheat aphid tolerance from Turkish landraces; the large peduncle trait from old Oaxacan cultivars; scab tolerance from Chinese landraces; heat tolerance from the Indian landrace *Khapli*; and wet soil tolerance from Ethiopian durum wheat (projects G3, G5 and G6).

New tools in molecular genetics have greatly expanded the possible usefulness of landraces and of prebreeding. Landraces can be "fingerprinted" using molecular markers to determine whether they differ genetically in important ways, and a single representative landrace from among a group of similar collections can be selected for further use. This information may also be used to assign landraces to putative heterotic groups on the basis of genetic distance. Secondly, if the genomic location of a trait, such as the anthesis-silking interval in maize, is generally known, landraces and F_2 populations of recycled lines can be screened for the presence of favorable alleles at that locus prior to field validation, thus greatly reducing the number of genotypes sown and the cost (project G1). Thirdly, once the genetic location of a desirable trait has been determined accurately, marker-assisted transfer of that part of the genome carrying the allele(s) of interest, with a minimum of undesirable genetic material, can be accomplished much more rapidly than through conventional backcrossing.

At CIMMYT, traits such as insect resistance and drought tolerance are in the process of being transferred in this manner to elite but susceptible maize lines. The apomixis trait is also being transferred to maize from its wild relative, *Tripsacum*, using a combination of molecular and conventional techniques (project F2). Similarly, a gene from the soil-borne bacteria, *Bacillus thuringiensis*, responsible for forming a naturally occurring insecticide, has been successfully inserted or "engineered" into the maize genome using biolistics or *Agrobacterium tumefaciens*, and is now providing an exciting new level of host-plant resistance (project F3).

Thus, prebreeding is evolving to take on a different character, one in which the emphasis will be more on identifying traits of interest among landraces or experimental populations, determining their genetic location, and then using molecular markers to transfer those traits into a high-yielding background. The development of broadly adapted, stress-tolerant, and high-yielding germplasm will therefore proceed more rapidly. Landrace accessions and other sources of unique genetic variation are now taking on an enhanced value at CIMMYT as a source of new genetic variation and as a means of sustaining production and maintaining biodiversity within mainline breeding programs.

Based on considerations of poverty, we estimate that our investment in Asia overall (including West Asia) will be slightly higher than in Sub-Saharan Africa. However, during the period of this MTP there will be a greater emphasis on our work in Sub-Saharan Africa – particularly on maize-based systems – than elsewhere. By the year 2000 it is estimated that 40% of CIMMYT's resources will be directed to Sub-Saharan Africa, around 30% to Asia, 20% to Latin America, and 10% to West Asia and North Africa (WANA) (see table).

Allocation of CIMMYT Resources, by Region

	1998	1999	2000
Sub-Saharan Africa	32	36	40
West Asia/North Africa	10	10	10
Asia	32	30	30
Latin America /Caribbean	26	24	20

In the WANA region, we share our mandate on wheat with the International Center for Agricultural Research in the Dry Areas (ICARDA), and there our focus will be mainly wheat and triticale. In West Africa, we collaborate closely with IITA on maize research. In general, our research in maize will continue to emphasize the lowland rainfed tropics and we will increase our emphasis on stabilizing production in lower input and stressed environments. Other maize mega-environments will be emphasized in regions where they have special significance, such as subtropical germplasm for Asia, midaltitude maize for East and Southern Africa, and highland maize for Mexico and the Andean zone.

Wheat research will give primary attention to irrigated production systems in Asia. However, rainfed mega-environments will receive more priority in this MTP, as we strive to deal with the special problems in these more variable and risky production systems.

In relation to the main undertakings of the CGIAR, genetic enhancement of maize and wheat will receive the most resources. This will be followed by work on management of natural resources. The 1994-1998 MTP defined the development of a Natural Resources Management Research Group (NRG) in CIMMYT. This is well underway and will be at its projected staffing level by early 1997. The Group will work with the other programs to develop a comprehensive effort that will involve resources well beyond those assigned to NRG itself. Techniques of system modeling and GIS analysis will be used more broadly.

Defined separately, but closely associated to the work of all our research programs, are our efforts in the area of genetic resources. Research involving the utilization of genetic resources (evaluation, as well as prebreeding; see box) will grow over time, as will our work dedicated to better understanding and managing *in situ* conservation (which we see as including aspects of participatory plant breeding). Our pioneering efforts to evaluate the economics associated with crop genetic diversity will also increase in the future.

CIMMYT's traditional strength in economic analysis and the identification of socioeconomic constraints to technology adoption will be enhanced through recent advances in methods for *ex ante* impact assessment and research priority setting. The interface between technology and policy will continue to be the focal point of economics research at CIMMYT. We plan to improve our capabilities in the broader area of human ecology, especially gender analysis and participatory research, with the objective of identifying the role of the individual farmer and rural societies in the design and development of agricultural technologies.

Work with national programs through networks, training, and information transfer will continue to receive high priority and our investment in this area is expected to exceed the average for the CGIAR System. We see more opportunities in this area than are likely to be funded under current circumstances.

Priorities in Relation to the CGIAR

The 1996 TAC paper "CGIAR Priorities and Strategies" indicates that the current investment in wheat should exceed maize. This ranking, based on the value of production, does not change when production values are modified with weights for poverty and population distribution. However, when projected to 2010 the modified values become almost equal. This reflects a projected stronger demand for maize.

The TAC document also indicates a need to invest more heavily in crops research for Asia, with Latin America ranked second. By 2010 Asia will still warrant the largest investment, and Africa will replace Latin America in second place. For individual commodities, TAC feels that wheat research should concentrate on Asia and WANA, and maize research should focus primarily on Asia, but give increasing attention to Africa.

Finally, we note that TAC, in its "Priorities and Strategies" document, has discussed a number of factors influencing system-wide priorities and has used these to make several recommendations regarding the future of the system. Our reactions to these recommendations are described below.

Higher priority for prebreeding — CIMMYT's crop improvement work will place a greater emphasis on prebreeding in the process of germplasm enhancement (see box). This increase will apply more to wheat than to maize. Activities related to prebreeding include the building of special purpose gene pools, recycling of inbred lines, research on maize and wheat with greater tolerance to biotic and abiotic stresses (Global Projects 4, 5, and 6) including the use of transgenics (Frontier Project 3), and research on apomictic maize (Frontier Project 2). In addition, breeding research will be strengthened by inputs from the new genetic resources center (Global Project 1).

Research on production systems linked to resource conservation — All of CIMMYT's research on production systems, without exception, gives emphasis to resource conservation and sustainability as well as productivity. Most of this takes place in the context of Regional Projects 1-5 which encompass our participation in ecoregional programs and regional networks. These collaborative Regional Projects, designed and implemented with our research partners, aim to integrate, within well-defined production ecologies, improved germplasm with improved maize or wheat system management practices.

Post-harvest and IPM — CIMMYT will begin a new global project on genetic approaches to reducing post-harvest losses (Frontier Project 5), while our continued work on host plant resistance in maize and wheat will make an increasingly important contribution to new and current integrated pest management (IPM) programs. In addition, CIMMYT has been active in the System-Wide Program on IPM, particularly in helping develop a project proposal on sustainable management of cereal stem borers.

Policy research — CIMMYT has initiated an in-depth research effort on the interface between technology and policy. In Frontier Project 6, we will provide forecasts of technologies and their potential impact by agroclimatic and policy environments.

Generic vs. local applications of natural resources management research (NRMR) — CIMMYT intends to commit additional resources to synthesizing lessons learned in our regional partnerships relative to NRMR approaches and methods. These resources will be channeled into a new project entitled, "Learning To More Effectively Confront Problems of Resource Degradation in Maize and Wheat Systems" (Frontier Project 7). In addition, we will strengthen those generic skills (e.g., GIS, crop and soil modeling, participatory research, social science) needed to understand and address sustainability problems in systems featuring our mandate crops.

Collaborative links and outsourcing research — CIMMYT is committed to suitable partnerships with advanced research institutions (including advanced NARSs) and the private sector in our Global and Frontier Projects, and with an even wider variety of stakeholders, including NARSs and NGOs, in all of our Regional Projects. In fact, this new MTP, based as it is on a new project structure, specifically aims to facilitate more — and more effective — partnerships. Contracting research out to others is a strategy we will use when it improves research efficiency, when it can be used to catalyze improved strategic alliances, or when it otherwise makes financial sense. Contracting out will be particularly important in research on biotechnology and in the planning and implementation of our new "flagship" training course on the principles and practice of sustainable systems.

Biodiversity — The level of resources committed by CIMMYT to biodiversity conservation, using both *in situ* and *ex situ* strategies, will increase. In addition, the coherence and effectiveness of our work in this area will be improved by bringing it under a single project (Global Project 1).

Human resource development — CIMMYT is not likely to follow TAC's suggestion of reducing the level of resources devoted to training. Entry-level training will be reduced through the continuing devolution to regional entities of crop management research training, e.g., Egerton University in Kenya or Kasetsart University in Thailand. However, specialty training for more senior researchers and visiting scientists is likely to expand, particularly in the areas of biotechnology, GIS, modeling, etc. Some of these themes, in fact, will be covered in a new course on the principles and practice of sustainable systems, to be launched in 1998. So, the level of resources devoted to human resource development will be slightly larger during the planning period compared to the past. In addition, the coherence of our efforts in working with NARSs in human resource development and institutional strengthening will be improved by bringing our efforts under a single project (Global Project 8).

Relevance to the poor, especially to poor rural women — CIMMYT's contribution to the well-being of the rural and urban poor is rivaled within the CGIAR system only by that of the International Rice Research Institute (IRRI). In the absence of modern maize and wheat varieties developed over the last several decades by CIMMYT and its partners, food prices would have been higher, employment growth (off-farm rural and urban employment as well as on-farm employment) would have been slower, poverty would be more widespread, and population growth would have been more rapid — exacerbating the threat to natural biological diversity over the coming decades.

In addition, we believe that our continued commitment to the development of new productivity-enhancing, resource-conserving practices for maize and wheat systems is critical to employment and income generation for the rural poor (see box). Note that the rural poor, particularly women, often command few or no land resources and, instead, rely on the sales of their labor. For this reason, employment generation through technical change is central to higher rural wages and greater opportunities for the rural poor to benefit from the development process. The role of poor women as farmers or as rural laborers is particularly important in sub-Saharan Africa and South Asia, hence the higher priority given to these two regions than would otherwise be the case.

Note finally that where research focuses on feed maize, not maize for direct consumption, such research will aim to benefit the poor — in this case, poor producers of feed maize rather than poor consumers of maize grain.

Priorities in Relation to Science

In its last MTP, CIMMYT anticipated significant growth in its work in biotechnology. This work has indeed grown substantially since 1990 — including an addition to the Applied Biotechnology building in 1996 — to become the third largest CIMMYT research program. This has been primarily due to the new opportunities offered by the science, as well as the interest of funding agencies to support the research. The program will continue its focus on the application of biotechnology, primarily molecular genetics and genetic engineering, to the major problems faced in maize and wheat production.

An area that continues to grow substantially is the access to, and the management and transfer of, scientific information. CIMMYT has sought to stay abreast of developments in this field, and expects to continue to do so in the future. Toward this end, we have continued to invest in the development of our specialized maize and wheat library, have developed a Home Page on the Internet's World Wide Web, and have established an Information Technology Unit to help guide institutional investments in new information technology.

Finally, all of CIMMYT's research is driven by the latest advances in science. Some of the more important recent undertakings that influence activities in this MTP include new options for producing hybrid wheats, breakthroughs in the development and understanding of apomixis in maize, applications of GIS and crop modeling, participatory research approaches to enhance adoption of farming systems, and new methods for *ex ante* technology forecasting.

Priorities According to Gender

In 1997, we are initiating work that will give us a better understanding of how our products may differentially affect women and men farmers. We will do a preliminary gender analysis, followed by case studies for in-depth analysis of key areas. Once that information is in hand, perhaps by the end of 1998, we will carefully review resource allocations to ensure that those products having the most positive influence on poor women farmers are given sufficient priority.

However, based on extensive experience and what we know at this juncture, the gender criterion has led us to give greater emphasis than would

CIMMYT Research: Serving the Poor in Developing Countries

CIMMYT's research activities are focused squarely on producing outputs that help the poor in developing countries. For example, we are producing maize and wheat germplasm that yields significantly more grain under drought and/or low nitrogen conditions than do current commercial varieties. These new, more efficient materials also respond as well as, or better than, current varieties when production conditions improve. The payoff to poor producers is obvious: higher and more stable yields under adverse production conditions, and competitive yields in more favorable environments, all at no added cost.

CIMMYT also invests heavily in — and continues to be very successful at — research aimed at incorporating durable disease and pest resistance into our maize and wheat materials. This built-in genetic resistance adds to yield stability for poor producers, and does so in a way that is both environmentally friendly and cost effective for resource poor producers, since little or no pesticide use is needed to ensure yields.

In addition to enhancing yield potential and stability, CIMMYT has a long history of research focused on improving the nutrient quality of its crops, particularly in the development of quality protein maize (grain with higher levels of lysine and tryptophan). Budgetary limitations forced a five-year hiatus in this research effort, but we are now reinitiating the work with special project funds, and linking our research to farmer adoption efforts in several African countries. We are also pursuing research aimed at raising the micronutrient levels in both wheat and maize, seeking to increase the availability of vitamin A, iron, and zinc to poor consumers of these staple foods. In all this work, our goal is to provide consumers and producers with a better, more nutritious product at the same or even higher level of yield achieved with current varieties — truly a "win-win" situation.

Two other examples will suffice to illustrate the relevance of our work to the poor. First, we are initiating a program of work, again with special project funding, in collaboration with producers in southern Mexico to conserve, *in situ*, locally important landraces and varieties of maize. This, however, should not be thought of as a static approach to conservation. Rather, we will help farmers in the region to both conserve their preferred varieties *and* to incorporate into them better disease and insect resistance, as well as tolerance to various abiotic stresses. A second and final example: we will soon be starting a research program in southern Africa that will assess the risks associated with alternative maize production practices and systems under varying climatic and soil conditions. However, a key difference in this special project-funded program is that production risks will be assessed through the lens of the farmers' own risk management practices and strategies. The goal of the research, simply stated, is to help researchers design new productivity-enhancing, resource-conserving maize technologies that are more compatible with farmers' broader approaches to managing risk.

Alternative Sources of Supply for CIMMYT's Products and Services

The development and delivery of productivity-enhancing, resource-conserving agricultural production technologies involves four basic types of activity: (1) *strategic research*, (2) *applied or adaptive research*, (3) *technology delivery*, and (4) *human capital development*. If CIMMYT is to use its resources efficiently, it must select from among these four a subset of activities that not only are likely to have high payoffs, but also are unlikely to be duplicated by other organizations. Alternative sources of supply include ARIs, other IARCs, public NARSs, private firms, and NGOs. These alternative sources of supply have different objectives and respond to different incentives, so they are not equally well suited to carry out each type of activity.

CIMMYT consciously seeks to avoid activities in which it does not have a clear comparative advantage. Whenever possible, we borrow research techniques, materials, and/or information developed by others who are more efficient producers. Some of this borrowed technology is used as an input into CIMMYT's own research activities, and some is passed on to our NARSs collaborators (sometimes after considerable modification).

By capitalizing on alternative sources of supply, CIMMYT is able to leverage its own investments in research, technology transfer, and human capital development. But not all of the goods and services considered important by CIMMYT are provided by alternative suppliers. In some cases, even when improved technologies are produced by others, they are not made available to CIMMYT's ultimate clients, the poorest of the poor. These are the areas in which CIMMYT can make its greatest impact.

For wheat a strong case can be made on economic efficiency grounds that CIMMYT should be actively involved in research, especially strategic research and prebreeding. There are clear economies of scale in strategic wheat breeding that can be captured only when wheat breeding is carried out on a global scale. The NARSs, whose closer links to farmers can provide them with a better understanding of location-specific problems, are best placed to assume responsibility for applied/adaptive breeding, as well as technology delivery. The private sector is unlikely to show interest in wheat research unless there are significant technical breakthroughs (e.g., development of commercially viable hybrid seed production techniques) or fundamental changes in IPR systems (e.g., extension of effective IPR protection to self-pollinating crops). The private sector also is not investing significant resources in wheat biotechnology, although this may shift if the above-mentioned commercial options materialize. Investment by the public sector ARIs in biotechnology is significant, particularly in the US, UK and Australia, and CIMMYT's approach is to identify complementary activities. Unlike maize, for wheat we are able to take advantage of much of the molecular genetic information produced in the public sector. Production of transgenics is, however, still limited and CIMMYT must invest significant resources to produce viable products incorporating novel genes.

For maize, an equally strong case can be made that CIMMYT should be actively involved in research, although the case is a bit different than the one for wheat. CIMMYT involvement in maize research is needed primarily to provide an alternate source of research methods and germplasm for use by NARSs, national private seed companies, and participatory organizations. Private firms have demonstrated the ability to develop improved maize production technologies tailored to the needs of commercial farmers, but they are making these technologies available only to those who can afford to pay for improved seed. Farmers who lack the resources to replace seed on an annual basis — most of whom are poor farmers located in marginal production environments — have largely been ignored by private seed companies.

Developing technologies to meet the needs of these farmers and delivering those technologies in areas where opportunities for profit-making are severely limited will require the participation of organizations that respond to incentives other than the profit motive. At the very least, public research capacity is needed to provide smaller seed companies with improved germplasm so they can produce commercial open-pollinated varieties (OPVs) and hybrids and provide a standard of competition in an increasingly concentrated seed industry. To this end, we plan to increase our supply of broadly adapted inbred lines of good combining ability to national private seed companies.

CIMMYT is ideally suited for this role because it can capture economies of scale in breeding, serve as a conduit for proprietary technologies from industrialized countries to developing countries, and provide training for NARS scientists in advanced research techniques.

As opposed to wheat, the application of biotechnology to maize is extremely focused in the private sector, which limits CIMMYT's (and NARSs') access to (and ultimately delivery of) the products of biotechnology. For example, while many quantitative and qualitative genes have been located using molecular markers by private companies, the information is generally maintained as confidential and thus is not available to CIMMYT or our clients. We are able to access the markers themselves and can utilize them in our research to locate the genes of interest to our breeders.

Transgenic germplasm is perhaps more readily available, at least, following deregulation; however, many of the newly inserted genes must be transferred into germplasm adapted to CIMMYT's target environments. While we have been successful in acquiring rights to transfer and evaluate these materials, ultimate delivery to our clients may be limited due to IPRs that are only now being resolved. In addition, many priority traits targeted by CIMMYT for genetic engineering are not being addressed by the private sector, as private organizations focus more on temperate environments and traits perceived as more commercially important.

otherwise be the case to research related to sub-Saharan Africa and South Asia. In sub-Saharan Africa, women typically perform most agricultural activities. In addition, women's ability to take advantage of alternative income-generating activities tends to be severely constrained during periods of labor scarcity. Technologies that sustainably improve maize or wheat system productivity can help improve women's disposable income, while technologies that improve women's labor productivity during peak labor demand periods enhance their ability to engage in other income-generating activities.

In South Asia, many of the very poorest women are either landless or command very few agricultural resources. New technologies for maize or wheat systems that expand employment opportunities — either directly in agriculture, or indirectly in other economic activities whose growth is stimulated by a more dynamic agriculture — can be critical for the survival and well-being of poor women. In addition, women tend to dominate those activities within farming systems related to animal husbandry, crop residue and farm manure management, fuel wood management, etc. Women's input will be needed, then, in any integrated approach to strategies for improving soil fertility in maize or wheat systems through changes in organic amendments to the soil.

CIMMYT Contributions to the CGIAR Agreed Agenda

CIMMYT's overall strategic goal is the development of sustainable maize and wheat production systems for the poor in developing countries. In working toward this goal, we produce

— always in partnership with national agricultural research organizations and ARIs — a number of products that contribute to achieving the Agreed Agenda of the CGIAR: increasing agricultural productivity, protecting the environment, saving biodiversity, improving policies, and strengthening national agricultural research systems.

Contributions of Our Major Products and Activities

Two of CIMMYT's major products are improved maize and wheat germplasm that produce higher and more stable yields, have durable genetic resistance to biotic and abiotic stresses, and are more efficient in using available water, nutrients, and solar radiation to produce grain and biomass. This germplasm contributes significantly to the profitability of resource-poor farmers, often increasing production at little or no added cost, thus helping to alleviate poverty, a primary CGIAR goal. In so doing, CIMMYT germplasm also contributes to higher and more sustainable food security for both rural and urban poor.

Our improved germplasm helps, albeit indirectly, achieve another important CGIAR goal, that of protecting and conserving natural resources. It does so by increasing productivity in favorable production areas already being farmed, reducing the pressure to move intensive agriculture into less productive, more easily degraded environments. In addition, more robust, resilient, and responsive germplasm also reduces the need to apply agricultural chemicals that, when used improperly or to excess, can be harmful to people and to natural ecosystems.

These under-recognized, indirect, environmental payoffs to germplasm improvement research are complemented by CIMMYT's strategic research in several related areas: our natural resource management research is designed to answer key questions confronting CIMMYT and its national program partners: What are the untapped opportunities for environmentally safe increases in maize and wheat yields? How can maize and wheat technologies help slow or reverse resource degradation? And how can the long-term environmental consequences of technical change best be assessed? In addition to this work, we pursue strategic research on economics, biotechnology, and crop physiology, all of which contribute to the development of more sustainable maize and wheat production systems, to the design of better, more effective research methods, and to the flow of new scientific information.

The widespread adoption of CIMMYT-related varieties speaks to their tremendous utility under developing country farming conditions. This success is so far rivaled only by that achieved in rice, and carries with it a major responsibility for maintaining system productivity and for protecting the natural resources upon which future maize and wheat productivity depends. Accordingly, our future research agenda must reflect a new philosophical orientation: we must work to ensure that CIMMYT germplasm achieves more of its potential in farmers' fields; a sustainability perspective must permeate our research agenda; we will take a systems approach to research, including research on cropping systems and on the socioeconomic systems within which maize and wheat are grown; we will do more to increase genetic diversity in farmers' fields, and to ensure greater stability of yields, especially for resource – poor farmers; and we will work in closer partnership with our research and training colleagues in developing and developed countries.

In addition to the activities described so far, CIMMYT engages in other important work. For example, we invest heavily in the collection, evaluation, conservation, and utilization of maize and wheat genetic resources, and have recently completed a major upgrade of our genebank facilities (the new E.J. Wellhausen-R.G. Anderson Plant Genetic Resources Center — see box). We also provide a wide variety of training opportunities and technical consulting services geared toward enhancing the efficiency and effectiveness of our many partners around the world, and, in so doing, improving the productivity of our joint research efforts.

International Public Goods

It is important to note that all CIMMYT products — our improved germplasm, more efficient research methods, and new scientific information — clearly fall into the category of international public goods; their utility transcends geopolitical boundaries and they are produced without consideration for

Spillover Benefits of CIMMYT Wheat Germplasm in Selected Developed Countries

CIMMYT's mandate is to serve developing countries, and that is where its products are most widely used. Nonetheless, CIMMYT wheat germplasm has been used extensively in developed countries, particularly where spring-habit bread and durum wheats are grown. This is most notable in developed countries with spring wheat environments similar to mega-environments 1 (favorable, low rainfall, irrigated) and 4 (low rainfall, rainfed). Based both on objective assessments and the statements of wheat breeders in developed countries, yield potential and disease resistance of CIMMYT germplasm are two of the major reasons for incorporating it into breeding programs.

Spring wheats (both durum and bread) with CIMMYT ancestry are widely grown in European countries with Mediterranean (mega-environment 4A) climates, such as Spain, Portugal, Italy, and Greece. The most detailed quantitative information available, however, exists for Australia, the US, and Canada. In Australia, 86% of all the wheat area was sown to varieties with some CIMMYT ancestry in the early 1990s. In the US, around one-fifth of all the wheat area was sown to CIMMYT-derived wheats in the same time period. The proportions varied significantly by region. In California and Arizona, where wheat-growing environments resemble northwest Mexico, which plays a crucial role in CIMMYT wheat breeding efforts, nearly all wheat planted by farmers is CIMMYT derived. CIMMYT wheats have made notable but smaller contributions as well in the spring bread wheat high latitude environment of the Northern Great Plains, and even in the winter bread wheat areas of the Central and Southern Great Plains. In Canada, about a third of the wheat area of the Prairie provinces, where the vast majority of Canadian wheat is grown, was planted to varieties with some CIMMYT ancestry.

Both the genetic contribution and the economic importance of that contribution derived from CIMMYT wheats can be measured in different ways. None of the measures is clearly superior. It has been estimated that over a 20 year period from 1974 to 1993, the monetary benefit to Australia from the use of CIMMYT germplasm was an average of about US$ 120 million per year in 1993 dollars, with a compounded present value in 1993 of about US$ 3.6 billion. Using varying assumptions, it has been calculated that the US economy gained anywhere from US$ 3.4 billion to US$ 13.7 billion from 1970 to 1993 because of the use of CIMMYT varieties. On the other hand, despite the increasing recent use of CIMMYT germplasm by Canadian wheat breeders, there seems to have been a much lower benefit in Canada over the same period, around US$ 14 million. These differences stem partially from methods used. More important, however, is the interaction between the differences in the amount of wheat produced in the three countries and the similarities between their wheat growing environments and those traditionally targeted by CIMMYT, given its mandate to serve developing countries.

capturing market share or achieving financial profit. Our stocks of maize and wheat genetic resources are held in trust for all countries, and samples are freely available upon request for *bona fide* scientific uses or to replenish the stocks held by other custodians of these vital resources. We also provide training and technical consultation, heavily subsidized in many cases, to thousands of research collaborators in over 100 countries on all continents, irrespective of the prevailing socioeconomic or political systems.

Developing the CIMMYT Plan

The process we have followed in developing this document has been highly consultative. CIMMYT is one of only two CGIAR centers to have participated in all five of the recent regional NARS Fora, and we also participated throughout the Global NARS forum held in October 1996. In all cases, we sought to listen to our partners, to hear and understand their priorities and determine with them how we can best work together to achieve our mutual goals.

CIMMYT continually seeks and receives input about its research and training activities from a variety of sources. Our regional staff serve as a conduit through which national programs' perspectives and priorities are communicated; we hold maize and wheat conferences in various regions each year; and we host periodic external reviews of our science. In addition, we sponsor global consultations nearly every year on issues of key importance. In May 1995, for example, we hosted a global consultation with the top scientists from developing countries who focus their work on improving the productivity and sustainability of wheat in irrigated production environments (known to us as "Mega-environment 1" and comprising some 36 million hectares, or nearly a third of the developing world wheat land). In March 1996, we held two such international consultations — one on breaking the yield barrier in wheat and the other on developing drought and low-nitrogen tolerant maize. These conferences provided critical information, not only about developing country needs, but also about the potential of research for

The Wellhausen-Anderson Plant Genetic Resources Center

In 1996, with financial assistance from Japan and others, CIMMYT completed construction of the new E.J. Wellhausen-R.G. Anderson Plant Genetic Resources Center. These integrated facilities, which comprise a new cold storage vault and renovated facilities for processing seed, as well as an array of new and on-going research activities, are a tangible reflection of the Center's commitment to the preservation of genetic resources on behalf of future generations. They also reflect our belief in the effective use of existing diversity to enhance the productivity and stability of developing country agriculture.

The new facility brings CIMMYT's genetic resource conservation activities together in the same physical location, and significantly expands our long-term storage capacity. We now have space to store nearly 450,000 accessions, over 60,000 for maize and more than 380,000 for wheat. But the Genetic Resources Center is more than a building. It also reflects a conceptual shift in the handling of genetic resources, one that incorporates a variety of related research activities — from the use of the wild relatives of maize and wheat in developing improved germplasm to improved information management that provides easier worldwide access to the resources we hold in trust for all. This Center within a Center is inextricably linked to the activities and outcomes of CIMMYT's global project on the conservation and management of genetic resources (Project G 1), and will enable new, more efficient and more effective ways of fulfilling our responsibilities regarding maize and wheat genetic resources.

addressing them. And in addition to all these consultative activities, two other, very special fora combined to cap the consultative process that underlies this draft MTP. In September 1996, we held a four-day NARS/Donor Consultation that comprised an integral part of the Center's well-attended 30th anniversary celebration. This professionally facilitated session involved a thorough and often high-spirited discussion of CIMMYT's draft plan. Then in early October, we held an in-house consultation with Center staff, following much the same process as that employed with our research and financial partners.

We saw this confluence of events — the regional and global NARS fora, the various CIMMYT-sponsored symposia, and our 30th anniversary consultations — as a unique opportunity to complement our "normal" consultative processes in consolidating the views of our research partners, our donors, and our staff into a single statement of purpose. We believe we have achieved a consensus on CIMMYT's future research agenda, embodied in the projects briefly described below and in more detail in Annex 5. Obviously, the Center cannot be all things to all people, but we believe we have found an appropriate balance that will ensure the greatest good to the greatest number.

Changes in Resource Allocations 1998-2000

In order to implement this Plan, some changes in resource allocation are envisioned between 1998 and 2000. These moves reflect an increased emphasis on high priority areas, and resultant decreases where we believe the need for our involvement is lower, but still important. *(It should be noted that comparisons between outlays for the planning period and 1997 are sometimes anomalous due to the reallocation of CIMMYT's work in line with the TAC Activity definitions released in 1996.)* The following changes are proposed over the planning period:

Increasing Productivity — A small increase (4%) is proposed in this category between 1998 and 2000. The increase reflects greater investment with our partners in the design and development of sustainable cropping systems, addressing the GxExMxP paradigm. This is seen as important in all regions of the developing world, but CIMMYT's spending on this Activity will be greatest in sub-Saharan Africa. This modest increase broadly agrees with TAC recommendations.

Protecting the Environment — This Activity will receive an increase (7%) in resources between 1998 and 2000, as CIMMYT places greater emphasis on sustainability concerns in many of its projects.

Saving Biodiversity — The increase (16%) proposed in this important Activity over the period of the MTP reflects a more highly focused and integrated program of research associated with the Wellhausen-Anderson Plant Genetic Resources Center. Areas of increased emphasis include *in situ* conservation and improvement of maize; studies on biodiversity and conservation strategies and the use of molecular techniques to characterize germplasm. This increase is in line with TAC priorities.

Improving Policies — A relatively constant level of resources is proposed for policy research. However, the nature of the work under this Activity reflects increasing emphasis on the interface between the development/adoption of technology and government policies — which are, in our definition, one of the four components of sustainable agricultural systems.

Strengthening NARSs — This area of direct involvement with our partners will receive greater emphasis as a whole during the planning period than it has in 1997. However, in line with TAC recommendations, resources allocated to the Activity will be reduced during the planning period, 1998-2000, by about 16%, as the devolution of regional crop management research training is completed and less emphasis is given to supporting non-research networks. Our moves with respect to NARS strengthening reflect 1) the strong and continuing demand in this area from our partners, and 2) the changing nature of their needs — both of which were clearly communicated to the CGIAR community via the NARS Regional Fora and at their Global Forum. CIMMYT is responding to the needs of our partners accordingly.

- The increased emphasis on training compared to 1997 reflects new demands from partners for training in more specialized topics than in the past. These include the applications of molecular plant breeding, genetic engineering, GIS technology, and crop and soil modeling. In addition, a new and major emphasis will be placed on "The Principles and Practice of Sustainable Cropping Systems," drawing on CIMMYT's unique experience around the world, with specialist inputs from ARIs and other partners. It also should be pointed out that CIMMYT is receiving an increasing proportion of its revenue from restricted/project resources. Almost invariably donors insist on significant amounts of these being directed toward NARS strengthening.
- The increase in resources for information work compared to 1997 is in line with the rapidly developing needs for information and information systems and technology sought by our partners. This level of resources will remain constant through to 2000.

System-wide Programs — CIMMYT's work in system-wide programs will receive a constant level of funding during the planning period. However, more emphasis will be given to the Rice-Wheat and Mountain Agriculture programs, and less to the Latin American Ecoregional program.

Table 2 (page 37) shows the proposed Center Research Agenda by CGIAR Activity and indicates proposed movements of resources over the period of the Plan. It is assumed that all funding in the year 2000 is unrestricted. As shown in the table, and as described above, the proposed shifts during 1998-2000 can be summarized as follows:

- A small increase in the Activity of Increasing Productivity, reflecting a greater emphasis on pre-breeding and on the design and development of sustainable cropping systems.
- A modest increase in Protecting the Environment.
- A significant increase in Saving Biodiversity, as CIMMYT further enhances its work on new and better methods for the collection, conservation, characterization and evaluation of germplasm. This will include work on African maizes and extensive evaluation of wheat landraces. In addition, greater emphasis will be given to new methods of characterization and development of better information systems.
- Constant resources for Improving Policies.
- A reduction in Strengthening NARSs, mainly due to reduced support for non-research networks (as defined by TAC) and our intention that entry level training will be fully regionalized and devolved to the NARSs, with the focus of CIMMYT's training programs moving to more specialized topics, such as sustainability, biotechnology, and GIS/modeling.
- Funding for System-wide Programs is proposed to remain fairly constant with some shifts of resources towards the rice-wheat systems and mountain agriculture.

Table 3a (page 38) outlines CIMMYT's Research Agenda operating requirements from 1995-2000. While the proposed allocations for 1998 are constrained by a large proportion of restricted funds, the figures for the year 2000 — as requested by TAC — are notionally based on all unrestricted funds. In line with CIMMYT's Strategic Plan and current priorities, the following general resource allocations are proposed:

- Wheat will continue to receive slightly more resources than maize, given the increasing importance of this crop for food security and poverty alleviation throughout the developing world and the lack of alternative suppliers, particularly in the private sector. (We point out again, however, that in 1997 there will be slightly more spent on maize than wheat due to the actions of donors funding restricted projects. It is possible that this trend could continue in the planning period.)

- Biotechnology will receive increased funding over the planning period as its applications increase in CIMMYT's germplasm improvement research and in that of the NARSs.
- The funding for Natural Resources research and the CIMMYT Economics Program will remain fairly constant over the period. Both these groups received significant resources in 1996 and 1997.

A Project-Based Approach

CIMMYT's Strategic Plan led to the Center organizing its work along the lines of large projects based on mega-environments. These large projects were comprised of aggregations of smaller projects. Most of these large projects, however, were *input* oriented. We have now shifted the focus to *outputs* or *outcomes* relative to the problems, issues, and/or opportunities in developing countries being addressed by our research and training efforts. While we are still using mega-environments to target germplasm outputs, CIMMYT's new projects generally involve a more integrated and multidisciplinary approach than earlier on, both between research programs and within programs.

After the extensive consultation described above, we have arrived at a total of eight Global Projects, five Regional Projects, seven Frontier Projects, and one Special Focus Project. **Global Projects** are centered on outputs geared to the needs of many regions and countries. These projects are more "thematic" in nature, with significant spillovers that transcend geopolitical boundaries. They include our work related to the preservation and utilization of maize and wheat genetic resources, improving the productivity, sustainability, and environmental compatibility of maize and wheat systems in fragile areas, as well as in highly productive ecosystems, measuring the impact of new technologies, and strengthening partnerships with, and the capabilities of, national agricultural research systems.

CIMMYT's five **Regional Projects** all pertain to meeting the rapidly growing demand for maize and wheat in different regions by addressing constraints that are more or less specific to each one. These projects provide a mechanism by which we can more effectively collaborate with our partners to integrate outputs from Global and Frontier Projects into the prevailing natural resource and socioeconomic systems within which they must make their impact.

The seven **Frontier Projects** we have designed are, as the name implies, focused on bringing more "cutting edge" science to bear on important problems or opportunities. By definition, the outcomes of these efforts are less certain than for Global or Regional Projects, and are normally more strategic in nature, involving the production of new scientific information and research procedures. However, in our judgment either one or some combination of the following conditions justifies our pursuit of each Frontier Project:

- there exist few (or no) alternative suppliers;
- CIMMYT has a comparative advantage in addressing the problem/opportunity; and/or
- the probability of success is sufficiently high to warrant the investment of "venture" capital.

Finally, we have postulated one **Special Focus Project** that involves activities and outputs geared to the special problems in a specific region, that of the Newly Independent States. Wheat is a very important crop in this region, and we believe that CIMMYT has a comparative advantage relative to other potential suppliers to produce wheat germplasm appropriate for the constraints encountered there.

In terms of management, while these projects all feature an integrated research effort, many by their focus fall naturally within the purview of one or another of CIMMYT's research programs. Accordingly, while the RCC will maintain oversight of the whole project portfolio, prime responsibility for individual projects has been allocated to the Programs as follows:

Maize:

- Global Project 2 — Developing Core Germplasm and Integrating Interdisciplinary Approaches for the Improvement of Maize.
- Global Project 4 — Increasing Maize Productivity and Sustainability in Stressed Environments: Abiotic and Biotic Stresses.
- Regional Project 1 — Improving Food Security in Sub-Saharan Africa.
- Regional Project 2 —Meeting the Accelerating Demand for Maize Development, Production, and Delivery in South and Southeast Asia and in China.
- Frontier Project 5 — Genetic Approaches to Reducing Post-harvest Losses.

CIMMYT Involvement in the Global Plan of Action for Genetic Resources

The Global Plan of Action (GPA) for plant genetic resources for food and agriculture aims to promote the conservation, sustainable utilization, and fair and equitable sharing of benefits of plant genetic resources. It is designed to contribute to the implementation of the Convention on Biological Diversity in the field of food and agriculture.

The GPA foresees a continuing role for the CGIAR as a major component in the global system for the conservation and improvement of plant genetic resources for food and agriculture. It recognizes the collections the Centers have amassed and hold in trust within the International Network of *Ex Situ* Collections, as well as their efforts on germplasm enhancement, breeding, and distribution, including their involvement in crop networks. The GPA also recognizes the CGIAR's continuing scientific and technical contribution to the development of policies and strategies, methodologies, and technologies for genetic resource conservation and utilization. Moreover, the GPA calls for institution and capacity building at all levels, and thus indirectly recognizes the CGIAR's continuing work in training and public awareness, support to national programs and networks, and its provision of advice and information.

In order to support the implementation of the GPA, CIMMYT plans to:

- fully support the System-wide Genetic Resources Program and other CGIAR initiatives that facilitate the System's role in the GPA and related matters;
- enhance its information systems on mandate species' genepools so as to further facilitate access;
- strengthen research on *in situ* conservation and farmer-participatory methods, particularly with maize (this will entail greater emphasis on women farmers and on linkages with NGOs and other participatory groups);
- improve methodology on the management of landraces in *ex situ* conservation to enhance and improve them in ways such that they become more productive when reintroduced into farming systems;
- support initiatives aimed at assisting farmers in disaster situations to restore agricultural systems in which maize, wheat, or triticale are important crops;
- ensure that the collections kept in trust are managed and safeguarded to the highest standards in terms of duplication, regeneration, storage, and other key functions; and
- initiate, implement, and/or support "gap-filling" collection efforts related to mandate species in a carefully targeted manner.

Wheat:

- Global Project 3 — Developing Core Germplasm and Integrating Interdisciplinary Approaches for the Improvement of Wheat.
- Global Project 5 — Increasing Wheat Productivity and Sustainability in Stressed Environments: Abiotic Stress.
- Global Project 6 — Increasing Wheat Productivity and Sustainability in Stressed Environments: Biotic Stress.
- Regional Project 3 — Sustainable Wheat Production Systems in the Indo-Gangetic Plains and China.
- Regional Project 4 — Increasing Cereal Food Production in WANA.
- Frontier Project 1 — Raising the Yield Potential of Wheat.
- Special Focus Project 1 — Wheat Germplasm Development in the Newly Independent States.

CIMMYT Initiatives in In Situ Conservation

An interdisciplinary team of researchers at CIMMYT and national program collaborators are investigating the prospects for enhancing the management and utilization of maize genetic resources in farmers' fields and in germplasm banks. The principal objective of the research is to determine whether population improvement, i.e., increasing the productivity of landraces, is a feasible means of providing incentives for farmers to continue growing key landraces in a center of crop origin. A second objective is to increase the usefulness of *ex situ* maize collections for breeding activities.

A pilot study will begin in 1997 in the state of Oaxaca, Mexico, and will include two components. In the first component, a group composed of anthropologists, agronomists, economists, and maize breeders will study the structure of genetic variation for important traits in sites that differ with respect to agroecological and socioeconomic variables. The team will also study in detail farmers' decisions about varieties, seed selection and seed management. These studies will serve as the basis for understanding the potential impact of breeding strategies that are designed to enhance landraces. The strategies for improvement will be developed collaboratively with farmers and scientists. The second, *ex situ* component is complementary to the first component because it involves the improved characterization of the same landraces to be conserved in national and international collections.

In situ conservation for maize will be much more complex than what has been suggested by classical conservation models based on geographical isolation. First, maize is a cultivated rather than a wild crop, and the decisions of farm households regarding which varieties to grow are affected by their objectives, the economic constraints they face, and policy decisions. Second, maize is an outcrossing plant, which means that the characteristics of its populations constantly evolve under natural and human selective pressures.

The research we have conducted in the Mexican states of Jalisco, Guanajuato, and Veracruz has provided us with the following insights and hypotheses: (1) farmers continually change not only varieties, but the seed for varieties; (2) farmers classify seed from many sources as belonging to their own landrace if it matches the phenotype they associate with the variety; (3) seed selection is an iterative process that occurs from one harvest to the next, rather than a single event, and both men and women in the household may influence selection criteria; and (4) seed sources are larger than the nuclear or extended family for both traditional and modern varieties.

These points have important implications for the genetic and economic impact of landrace improvement and for the relevance of economic models based on the assumption that the farm household is the unit of conservation for genetic resource and diversity.

Economics:

- Global Project 7 — Gauging the Productivity, Equity, and Environmental Impact of Modern Maize and Wheat Production Systems.
- Frontier Project 4 — Improving Human Nutrition by Enhancing Bio-available Protein and Micronutrient Concentrations in Maize, Wheat, and Triticale.
- Frontier Project 6 — Priority Setting and Technology Forecasting for Increased Research Efficiency.

Natural Resources:

- Global Project 8 — Building Partnerships Through Human Resource Development.
- Regional Project 5 — Enhancing Maize and Wheat Production Systems in Latin America and the Caribbean.
- Frontier Project 7 — Learning to More Effectively Confront Problems of Resource Degradation in Maize and Wheat Systems.

Applied Biotechnology Center:

- Frontier Project 2 — Apomixis: Equity in Access to Hybrid Vigor for Resource-Poor Farmers.
- Frontier Project 3 — Using Genetic Engineering to Improve Tolerance to Biotic and Abiotic Stresses in Wheat and Tropical Maize.

Director General's Office:

- Global Project 1 — Conservation and Management of Genetic Resources.

We believe that this approach will facilitate a smooth transition between our current within-program project-based management structure to the new integrated project-based management environment. What follows are highlights of CIMMYT's new projects, organized according to major themes that are closely related to those identified by TAC — and indeed by NARSs, donors, and CIMMYT — as priority research areas.

CIMMYT Involvement in CGIAR System-wide and Ecoregional Initiatives and Programs

CIMMYT staff have participated in meetings held under the auspices of a wide variety of System-wide/Ecoregional initiatives and programs. Currently, Center staff actively participate in the following research activities:

- the Rice-Wheat Consortium for the Indo-Gangetic Plains;
- the African Highlands Initiative;
- the Latin American Ecoregional Program;
- the System-wide Program on Genetic Resources;
- the System-wide Program on Integrated Pest Management;
- the Ecoregional Initiative for the Humid and Subhumid Tropics and Subtropics of Asia; and
- the System-wide Program on Participatory Research and Gender Analysis;
- the Soil, Water, and Nutrient Management Initiative; and
- the Inter-Center Training Initiative.

In addition, CIMMYT leads a range of regional activities in southern Africa under the coordination of SADC/SACCAR. These include a regional maize and wheat network (MWIRNET), which incorporates a maize stress-breeding network (Southern Africa Drought and Low Soil Fertility Project) and a soil fertility network. Similar collaboration with NARSs occurs in the East Africa Cereals Project and the Central America Maize Network (PRM).

Project Highlights

Theme: Conservation of Genetic Resources

CIMMYT is committed to the conservation and management of genetic resources. We are deeply concerned about the growing threats to diverse landraces from rising human populations and changing land use patterns. We take seriously the concern about the under-utilization of genetic diversity in the development of modern cultivars. Efforts are being made to seek complementarities between enhanced *ex situ* conservation and utilization efforts and *in situ* conservation strategies. We are also examining the implications of emerging germplasm acquisition and intellectual property rights policies on the worldwide exchange and utilization of germplasm.

Conservation of Genetic Resources (strength of theme in relation to TAC Activities)	
Increasing Productivity	* *
Protecting the Environment	
Saving Biodiversity	* * *
Improving Policies	**
Strengthening NARSs	**

Our Global Project (G1) on the conservation and management of genetic resources aims to promote the collection, conservation, evaluation, and the equitable sharing of maize, wheat, and triticale genetic resources, and appropriate wild relatives. This project will lead to:

- Enhanced characterization of *ex situ* accessions, including information on the origin, pedigrees, trait characteristics, and molecular fingerprints, which will be made widely available through a global electronic data base.
- Techniques for incorporating diversity into germplasm through the use of cytogenetic and molecular procedures.
- Methods developed for the economic evaluation of genetic resource conservation and utilization, with an emphasis on comparing alternative collection and conservation strategies.

Theme: Germplasm Enhancement

Improved wheat and maize germplasm have contributed substantially to the enhancement of global food security. Meeting the challenge of supplying food to an ever growing global population requires us to maintain high levels of effort on the improvement of wheat and maize germplasm, both for enhanced yields and also for improved yield stability and improved quality. Established techniques, as well as novel ones, such as biotechnology and the exploitation of heterosis, will be used in the effort to sustain the growth in genetic potential of wheat and maize. A group of Global, Regional, and Frontier Projects have been designed to reverse the current slowdown in productivity growth. In the case of wheat the challenge is to find mechanisms for shifting the genetic yield frontier of wheat, while in the case of maize, the challenge is to enhance the level and stability of production in difficult environments.

Germplasm Enhancement (strength of theme in relation to TAC Activities)	
Increasing Productivity	* * *
Protecting the Environment	* *
Saving Biodiversity	* *
Improving Policies	
Strengthening NARSs	* *

The Global maize and wheat germplasm improvement projects (G2 and G3) aim to integrate such disciplinary-based technologies as refined breeding strategies, novel physiological approaches, and crop modeling toward the delivery of superior germplasm. Working closely with the Regional Projects, the Global wheat and maize projects will ensure that new germplasm is better adapted to the target mega-environments and will have enhanced insect and disease resistance, agronomic performance, and input efficiency. The new germplasm will also incorporate a diversity of parental material in order to combat biotic and abiotic stresses effectively. The Global Projects, in association with the Regional Projects, also play a complementary role in strengthening NARS capacity in the development and adaptation of improved germplasm. Thus, Global Projects 2 and 3 will result in:

- high-yielding, widely adapted maize and wheat germplasm (targeted for specific mega-environments) with improved end-use quality and enhanced abiotic and biotic stress resistance, agronomic performance, and input efficiency developed through the integration of disciplinary-based technologies and global testing;
- relevant prebreeding, breeding, and selection methodologies and their dissemination;
- characterization of valuable traits by farmers, including women farmers; and
- the development and distribution of information on relationships (i.e., heterotic patterns) among important maize and wheat germplasm from NARSs, advanced institutions, and CIMMYT.

Global efforts at raising the yield potential of wheat will be enhanced substantially by a Frontier Project (F1) linked directly to the wheat germplasm improvement project. The Frontier Project aims to shift the yield frontier of wheat through:

- exploitation of hybrid technology (heterosis);
- cultivars with modified plant architectures and physiological processes leading to higher yields through increased radiation-use efficiency; and
- crop management systems conducive to the realization of yield potential.

In the case of maize, recent advances in apomixis research could help bring the benefits of hybrid vigor to resource-poor farmers, and a Frontier Project has been designed to explore such a possibility (F2). The introduction of apomixis into farmers' varieties would allow the fixation of beneficial genes and the preservation of advantageous characteristics generation after generation. Apomixis would allow the use of hybrid vigor in small-scale farming systems where the use of hybrids has so far not been economically feasible. The project, developed in collaboration with ORSTOM, will lead to:

- apomictic maize germplasm and markers linked to apomixis gene(s); as well as
- strategies for the deployment and use of apomictic germplasm in breeding and in farming systems.

Theme: Managing Stressed Environments

Farm-level productivity of modern wheat and maize germplasm is affected by a plethora of biotic and abiotic stresses. Developing sustainable systems for the management of the above stresses has been a challenge for maize and wheat scientists for decades. Durable resistance to biotic stresses will improve yield stability while reducing the reliance on pesticides. Improved tolerance to abiotic stresses will help to stabilize income and food security for a very vulnerable part of the population living in high-risk environments, while reducing further environmental degradation. For example, drought-tolerant maize germplasm helps assure farmers of more stable yields and income, and provides an incentive to use other production-enhancing technologies. As a result, drought-tolerant maize can help break the paralyzing cycle of poverty and famine, and can reduce pressures on the marginal, more fragile lands associated with the risk of drought. In addition, farmers could reduce the area they need to plant to maize because the tolerant crop could produce the same yield on a smaller area.

Managing Stressed Environments (strength of theme in relation to TAC Activities)	
Increasing Productivity	* *
Protecting the Environment	* * *
Saving Biodiversity	* *
Improving Policies	
Strengthening NARSs	*

Two Global Projects in wheat (G5, G6) and one in maize (G4) have been designed to provide improved resistance to biotic stresses and enhanced tolerance to abiotic stresses. The Global stress projects link up with the Regional Projects for adapting the germplasm to the primary target environments. The Frontier Project on genetic engineering (F3) will provide "state-of -the-art" technology for enhancing the plant tolerance to stresses, both biotic and abiotic. The work on germplasm improvement will be complemented by crop management research aimed at improving system sustainability.

Our work on the biotic and abiotic stress resistance of maize and wheat germplasm will therefore lead to:

- strategic germplasm development and deployment through enhanced understanding of the etiology, epidemiology and crop losses caused by wheat and maize stresses;
- reduced environmental degradation due to enhanced durable resistance to important wheat and maize diseases, insects and abiotic stresses;
- diverse and durable stress-resistant maize and wheat germplasm developed through the application of biotechnology and new screening methodologies for resistance/tolerance to diseases, pests, and abiotic stresses;
- improved crop management practices that complement genetic-based resistance mechanisms for use by resource-poor farmers in unfavorable production environments;
- management strategies for deployment of transgenics in various farming systems to optimize effectiveness and longevity of the genetically engineered germplasm;
- technological interventions that are attractive to resource-poor farmers, including women farmers, operating in unfavorable environments; and
- improved food and income security for women and other household members operating in unfavorable environments.

Theme: Sustainable Production Systems

The close link between Global and Regional Projects ensures that the germplasm and crop management technologies developed at CIMMYT are relevant to the target mega-environments we work in and that the technologies fit into sustainable production systems.

Sustainable Production Systems (strength of theme in relation to TAC Activities)	
Increasing Productivity	**
Protecting the Environment	***
Saving Biodiversity	**
Improving Policies	**
Strengthening NARSs	**

The interactions between germplasm, the environment, and management practices are highlighted in the linkages between Global and Regional Projects. The problems of declining soil fertility in Africa, soil erosion in intensive hillside maize systems in Asia and Latin America, declining productivity in the intensive rice-wheat production system in the Indo-Gangetic Plain, and sustainable drought management in wheat and maize systems in WANA are some of the region-specific resource management problems on which we are focusing. In each of these cases, work is being done in close collaboration with international centers in the region — with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the International Livestock Research Institute (ILRI), the International Centre for Research in Agroforestry (ICRAF), and the International Institute of Tropical Agriculture (IITA) in Africa, with the International Center for Tropical Agriculture (CIAT) in the hillside management work, with IRRI, ICRISAT, and the International Irrigation Management Institute (IIMI) in the rice-wheat consortium, and with ICARDA in the WANA region.

A Frontier Project (F7) has been designed that will allow us to develop production systems that enhance productivity without exploiting the natural resource base. This project will lead to:

- a framework for research on natural resource management (NRM), acceptable to a wide range of stakeholders, and featuring improved research methods;
- dissemination of productivity-enhancing, resource-conserving and sustainable maize and wheat systems; and
- documentation of regional consequences of resource degradation and the effect of technical change on resource quality and system productivity.

Theme: People and Partnerships

Effective technology development and dissemination cannot occur without a clear understanding of the farm-level incentives and constraints to technology adoption. Understanding the socioeconomic and policy environments in which food production takes place is crucial for ensuring the successful and sustained adoption of modern technology. Ensuring technologies that are appropriate to local conditions and maximizing the research linkages between the international and national agricultural research systems would require that NARS scientists have access to the most up-to-date knowledge and skills.

People and Partnerships (strength of theme in relation to TAC Activities)	
Increasing Productivity	
Protecting the Environment	
Saving Biodiversity	
Improving Policies	* * *
Strengthening NARSs	* * *

CIMMYT has always had a strong people focus in its research efforts and has consistently pursued a policy of building strong partnerships with national program scientists. We have designed a Global Project (G7) and a Frontier Project (F6) that directly address the impact of technology on people, and the ways in which people and policy concerns can be brought into technology development and dissemination. We have also designed a Global Project (G8) that aims to enhance our partnerships with wheat and maize scientists around the world. All three projects link closely with CIMMYT's Regional Projects and support their activities.

The Global Project on technology impact (G7) aims to provide a balanced assessment of the productivity, equity, and environmental impacts of modern maize and wheat production systems. The project will provide:

- improved methods for evaluating the impact of new maize and wheat technologies;
- reliable and relevant information for objective assessment of the impacts of technology adoption and returns to investment in maize and wheat production systems; and
- information on impacts of technical change on different groups in society, e.g., men vs. women, consumers vs. producers, resource-rich vs. resource-poor farmers, and so on.

A Frontier Project on technology forecasting (F6) will complement the efforts in the Global Project on impact. While the Global Project looks back at the impact of technologies that have been disseminated, the Frontier Project develops methods for looking ahead and assessing, *ex ante*, the potential impact of technologies that have yet to be released, in many instances technologies that are still in the design stage. This project will thus lead to, among other things:

- improved methods for research resource allocation at the national program and international agricultural research center (IARC) levels; and
- systematic inclusion of poverty and gender as factors in setting priorities among alternative research investments.

The Global Project on building partnerships (G8) aims to improve the efficiency of research resources through human resource development and the enhancement of CIMMYT-NARS collaboration. This project will be closely linked to Regional Project efforts in strengthening NARS capacity. CIMMYT's training programs and its information activities and products will be central to the effective implementation of Project G8, and will provide strategically important inputs into NARS-strengthening aspects of the Regional Projects. This Global Project will result in:

- trained and motivated national system staff in CIMMYT's areas of competence, including crop management, crop improvement, biotechnology, GIS, crop modeling, and sustainable cropping systems;
- regional crop management training centers in Asia, Africa, and Latin America for maize and in Asia and Latin America for wheat; and
- enhanced research partnerships between CIMMYT, ARIs and NARSs.

Theme: Post-harvest Issues

In recent years, CIMMYT has been giving increasing attention to post-harvest concerns. There are two primary areas of post-harvest research in which we have been active: improving the nutrient content of maize, wheat, and triticale; and reducing post-harvest losses from insects and diseases. In both cases our approach has been through improved germplasm, a reflection of our clear comparative advantage. For this planning period, we have designed two Frontier Projects in the above areas. The first is a project on enhancing the nutrient content of maize, wheat, and triticale (F4), and the second (F5) is a project designed to reduce post-harvest losses from insects and diseases through genetic improvements and tolerances.

Post-harvest Issues (strength of theme in relation to TAC Activities)	
Increasing Productivity	* * *
Protecting the Environment	* *
Saving Biodiversity	
Improving Policies	
Strengthening NARSs	*

The goal of Frontier Project 4 is to reduce nutritional deficiencies in the diets of the poor in developing countries, especially women and children, through the enhancement of bio-available protein and micronutrient concentrations in the grain. This project is a "win-win" proposition — in some key production environments more efficient cultivars will not only increase yields, but can also produce more nutritious grain. The goals of the project are to develop:

- improved, locally adapted maize cultivars, equal to or superior in yield to conventional locally available cultivars, but with increased protein quality;
- information on the genetic basis and variation of micronutrient concentration in maize, wheat, and triticale; and
- maize, wheat, and triticale varieties that contain enhanced levels of zinc and iron (while remaining fully competitive for yield) developed through conventional and biotechnology approaches.

Frontier Project 5 will focus on developing:

- information on the management and genetic basis and variation of resistance to major storage pests in maize; and
- maize varieties that possess improved storage qualities and storage pest resistance.

CIMMYT's Regional Projects

Our research and training agenda includes five Regional Projects that will serve to integrate the outputs from Global and Frontier Projects into the natural resource and socioeconomic systems where they must make their impact. The collaboration of our partners, both as individual NARSs and through the various regional fora that now exist, will be critical to transforming global and/or frontier outputs into on-the-ground impact.

Regional Project 1 focuses on augmenting food security in sub-Saharan Africa through improvements in maize and wheat. Maize in this region occupies around 20 million hectares and wheat around 2 million hectares. This project addresses issues of low and unstable maize production in a region with rapidly rising population and where the production of this staple is strongly affected by drought, stem borers, declining soil fertility, and intractable weed problems. Demand for both wheat and maize is rising, and there is an apparent increase in dependence on food aid, especially in extreme years. Political instability and lack of infrastructure have limited growth in trade, and many countries in the region simply cannot afford to import food. This Regional Project will lead to:

- improved maize and wheat varieties that are more input efficient; that possess built-in, robust resistance to the pests, diseases, and environmental stresses of the region, particularly drought, low soil fertility, borers, and *Striga*; and that are determined by farmers, including women farmers, to fit well into prevailing farming systems and to meet household consumption requirements;
- better crop production systems that conserve natural resources and increase productivity, focusing especially on soil and water conservation, fertility maintenance, and pest management; and
- information and policies regarding the economics and impacts of improved maize and wheat farming systems in the region.

Regional Project 2 reflects the rapidly increasing demand for maize as food and feed in South and South East Asia and China. Presently maize occupies around 39 million hectares in this region, though approximately 18 million are sown to temperate maize in China. Demand for maize in this land-scarce part of Asia is projected to rise by 5% per year, and maize must fit into intensive cropping systems currently dominated by higher value crops such as rice and wheat. Private sector investments in varietal development are increasing, especially for more productive environments, though the policy environment for an expanding seed industry is not always favorable. This Regional Project will provide:

- early maturing maize germplasm with high input use efficiency and built-in resistances to major biotic and abiotic stresses, suitable for both summer and winter growing conditions and the needs of the emerging private sector;
- enhanced stress tolerance in full-season maize cultivars;
- cropping systems for integrating improved germplasm into existing crop rotations; and
- information on existing seed industries and constraints to their expansion.

Regional Project 3 will center its attention on sustaining the wheat production systems of South and East Asia (including China). The combined wheat area in this vast region is some 65 million hectares. Annual wheat production averages nearly 180 million tons and average yields approach 2.8 tons per hectare. The region has a large and rapidly growing population and includes two of the world's largest river valleys, the Indo-Gangetic Plains and the Yangtze River Basin. There are large variations across the region in soil types, temperature and rainfall regimes, and production systems. The rice-wheat system predominates throughout the Indo-Gangetic Plains and the Yangtze River Basin, though cotton-wheat, soybean-wheat, and maize-wheat rotations are common as well. This Regional project will lead to sustainable productivity increases through:

- new, higher yielding germplasm fortified with durable disease resistance, tolerance to important abiotic stresses, and improved nutritional and end-use qualities;
- improved agronomic management practices for rice-wheat and other wheat-based production systems;
- recommendations for overcoming causes of stagnant/declining productivity of the rice-wheat system;
- improved agricultural policy decisions through a better understanding of the constraints to sustaining productivity growth;
- greater farmer participation, including by women farmers, in the research process; and

- expanded employment opportunities from more productive and diverse farming systems, of benefit to resource-poor and landless farmers and rural inhabitants, including poor rural women.

Regional Project 4 pertains to increasing wheat and maize production in the WANA region. This region currently grows some 28 million hectares of wheat and 2.5 million hectares of maize. There is considerable variation in climatic factors and water availability, ranging from the irrigated Nile River Valley, to the high rainfall North African Mediterranean Coast, to the semiarid Central Plateau of Turkey and Iran. CIMMYT works in close partnership with Turkey, ICARDA, and NARSs in the region to produce:

- improved bread wheat and durum wheat germplasm that is more efficient and which possesses built-in, robust resistance to pests, diseases, and environmental stresses for the region;
- strong, good combining maize inbreds;
- better crop production systems, especially for soil fertility maintenance, moisture conservation, residue management, and insect pest management control;
- improved agricultural policy decisions through a better understanding of the constraints to sustaining productivity growth;
- higher adoption rates for triticale (for feed and forage) in the WANA region's semiarid zones;
- better research methodologies for the region's difficult environments; and
- better trained agricultural scientists.

Finally, *Regional Project 5* focuses on the needs of maize-, wheat- and barley-based production systems in Latin America (the barley work is done in collaboration with ICARDA). Maize occupies around 27 million hectares, wheat 10 million hectares, and barley around 0.5 million hectares in this region. Area expansion and productivity of these commodities has been constrained by a widespread incidence of acid soils. Maize in Mesoamerica and the Andean zone is often intercropped on steep slopes subject to erosion during cultivation, and wheat and barley also suffer from a declining natural resource base. In the high mountain valleys of the Andes earworms are a major pest of maize. This project will lead to:

- improved maize, wheat, and barley varieties with increased tolerance to soil acidity and to drought, enhanced nutrient-use efficiency, and improved resistance to prevailing lowland diseases;
- improved highland maize cultivars with tolerance to diseases and earworms; and
- sustainable maize, wheat and barley production systems, through the use of suitable cultivars, appropriate crop rotations and efficient fertilizer use, and, where appropriate, improved conservation tillage and residue management.

General Statement on Reduced Funding

In the event that funding for any year does not reach the anticipated level, we will first try to determine if this is a one-year event or part of a longer term trend. If it is a temporary shortfall due to gaps between special projects or some definable cause, we will use Center reserves to bridge the problem. If, however, the shortfall is seen as part of a steady trend in funding, we will take steps to reduce the research program according to program priorities and where sources of funding allow changes to be made.

Financial Highlights

CIMMYT is basing its 1998-2000+ budget on a funding estimate of US$ 30 million per year in constant 1997 dollars. This is slightly less than the average annual average funding for the period 1992-1996, which was US$ 31 million. Because of the gradual downward trend in funding to

CIMMYT in recent years, a US$ 30 million budget seems prudent under the current circumstances. Any increase over the base amount will probably be small and is not likely to shift the strategic directions of the Center. In general, these increases will be used to fund contractual research and will not be used to increase the size of the Center, *per se*.

Based on current trends, we expect that an increasing part of our funding will be restricted in one form or the other. We anticipate that approximately 54% of the Center's funding will be unrestricted. Our 1998-2000+ plan calls for us to mobilize some US$ 4 million to US$ 5 million per year in restricted core and special projects. This will require an active fund-raising effort, as well as effective financial management to meet the reporting requirements of different funding agencies.

Operating Budget

CIMMYT's operating budget is currently allocated to projects as shown in Table 1b. Each project is supported by a combination of restricted funding, where the restrictions define the assignment to particular activities, and of unrestricted funding, which is used to ensure that all activities are funded in accordance with Center priorities. All of these projects support the CGIAR Agreed Agenda.

Funds can also be allocated by Programs (Table 3a) and by object of expenditure (Table 5). Expenses for salaries and allowances are targeted to remain below 60% of the operating budget. Other operating costs will remain constant in line with long-term trends. Costs in Mexico are likely to increase gradually as the economy recovers and the Mexican peso stabilizes. This is not likely to have a significant impact on costs during this budget period.

The current overhead rate authorized by the Board is 27% for projects conducted at headquarters and 19% for projects conducted in the regions. Overhead recovery in 1995 and 1996 was well below the expected rate. This is due primarily to a reluctance of many agencies to pay overhead, which forces the center to self-finance the overhead costs for projects considered critical to the research objectives. Our goal will be to recover a higher rate of overhead costs in future years.

Personnel Inputs

The expected staffing pattern is shown in Table 8. The program will be based on 82 senior international staff which is below the average of the first part of the 1990s. We project that three other scientists will be hired directly by others. Post-doctorates and associate scientists (short-term appointments) are likely to vary around historical levels, depending on the availability of funds, especially restricted and special project funds, from which most short-term appointments are funded. National staff are also expected to remain at current levels. The most serious challenge to management will be to change staff assignments as special projects begin and end.

Capital Budget

We do not foresee any unusually large capital expenditures during the period (Table 6). The major need, a new genebank, was completed in 1996, and other maintenance and renovations are being done regularly as required. We do not propose any capital expenditures above the normal amount set based on depreciation, and we forecast a gradual growth in the capital fund to take care of any major unanticipated needs in the future.

Financial Ratios

This MTP presumes the availability of US$ 30 million per year in real terms. We do not plan to use any working capital during the 1998-2000 period, and will maintain about 100 days of working capital in order to meet the fluctuations in funding that are becoming more frequent.

TABLE 1a: 1997 CIMMYT AGENDA PROGRAM AND PROJECT OPERATING REQUIREMENTS

(expenditure in $'000)

	Center Projects	Center Programs									System-Wide Programs				External Review	Totals
		Increasing Productivity					Strenghtening NARS									
		Enhancement and Breeding	Production Systems Dev. and Mgt. Crops	Protecting the Environment	Saving Biodiversity	Policy	Training	Info.	Consulting	Networks	Rice/ Wheat	Latin Am. Eco	Mtn Agric.	Other		
		1	2	6	7	8	9	10	11	12	14	15	17	18		
1	Increasing the yield of lowland tropical maize germplasm	1,130		175	437											1,742
2	Increasing the yield and stability of subtropical maize germplasm	566		292	97											955
3	Increasing the yield and stability of mid-altitude maize germplasm	400		179	156											735
4	Increasing the yield and stability of highland maize germplasm	265		146	136											547
5	Increasing the yield and stability of bread wheat germplasm for irrigated conditions	750		402	224											1,376
6	Increasing the yield and stability of bread wheat germplasm for rainfed conditions	1,265		300	272											1,837
7	Increasing the yield and stability of facultative and winter bread wheat germplasm	400		201	68											669
8	Increasing the yield and stability of durum wheat germplasm for irrigated and rainfed conditions	552		242	78											872
9	Increasing the yield and stability of triticale germplasm for irrigated and rainfed conditions	206		116	156											478
10	Increasing the yield and stability of barley germplasm for high rainfall and irrigated areas in Latin America	180		136	78											394
11	Strategic research supporting maize and wheat improvement	1,254		583	437											2,274
12	Using applied biotechnology for maize and wheat improvement	1,094		826	621											2,541
13	Control of insects and diseases through host plant resistance and integrated pest management	1,249		650												1,899
14	Adding abiotic and biotic stress ressistance to lowland tropical maize germplasm	463		437	49											949
15	Developing sustainable maize-based cropping systems for the poor		408	422												830
16	Developing sustainable wheat-based cropping systems for the poor		428	197												625
17	Developing maize-based cropping systems for drought prone areas in Southern Africa		224	273												497
18	Developing maize-based cropping systems in the tropical Asia ecoregion													104		104
19	Strategic research supporting maize and wheat based cropping systems		384	389												773
20	Preserving, documenting and understanding maize, wheat and triticale biodiversity				1,015											1,015
21	Analyzing the economics of genetic diversity of maize and wheat					384										384
22	Research on the economics of maize and wheat improvement					749										749
23	Training of national program scientists in research methods and new technologies						2,844									2,844
24	Providing information and technology to maize and wheat scientists							495								495
25	Consulting with national program scientists in maize and wheat								1,433							1,433
26	Maize and wheat research networks									2,286						2,286
27	Understanding and improving rice-wheat cropping systems in the Indo-Gangetic plains										581					581
28	Improved sustainability of hillside maize cropping systems in Mesoamerica											1,389				1,389
29	Improved maize-based cropping systems in the Africa highlands												198			198
30	External Review														300	300
	Program Totals	9,774	1,444	5,966	3,824	1,133	2,844	495	1,433	2,286	581	1,389	198	104	300	31,772
	Total Operating Requirements	31,772														
	Less: Center Income	2,300														
	Total Funding Requirements	29,472														

TABLE 1b: 1998 CIMMYT AGENDA PROGRAM AND PROJECT OPERATING REQUIREMENTS
(expenditure in $'000)

		Center Programs									System-Wide Programs				
		Increasing Productivity					Strenghtening NARS								
		Enhancement and Breeding	Production Systems Dev. and Mgt. Crops	Protecting the Environ-ment	Saving Biodiversity	Policy	Training	Info.	Consulting	Networks	Rice/ Wheat	Latin Am. Eco.	Mtn. Agric.	Other	
Center Projects		**1**	**2**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**14**	**15**	**17**	**18**	**Totals**
G1	Conservation and management of genetic resources	493	0	0	1,233	247	100	147	0	0	0	0	0	0	2,220
G2	Developing core germplasm and integrating interdisciplinary approaches for the improvement of maize	794	99	181	361	0	361	181	0	0	0	0	0	0	1,977
G3	Developing core germplasm and integrating interdisciplinary approaches for the improvement of wheat	1,366	50	645	595	0	129	0	0	258	0	0	0	0	3,043
G4	Increasing maize productivity and sustainability in stressed environments: abiotic and biotic stress	338	62	428	162	0	31	62	31	31	0	0	0	0	1,145
G5	Increasing wheat productivity and sustainability in stressed environments: abiotic stress	515	90	1,191	317	0	0	95	95	95	0	0	0	0	2,398
G6	Increasing wheat productivity in stressed environments: biotic stress	341	171	807	371	0	0	86	86	0	0	0	0	0	1,862
G7	Gauging the productivity, equity, and environmental impact of modern maize and wheat production syste	0	0	0	0	399	59	59	59	88	0	0	0	0	664
G8	Building partnerships through human resource development	0	0	0	0	0	3,067	120	565	113	0	0	0	0	3,865
R1	Improving food security in Sub-Saharan Africa	1,559	530	630	315	100	0	0	120	315	0	0	250	0	3,819
R2	Meeting the accelerating demand for maize development, production, and delivery in South and Southea	395	182	287	144	159	134	46	83	144	0	0	0	100	1,674
R3	Sustainable wheat production systems in the Indo-Gangetic plains and China	168	80	341	84	84	84	84	0	0	550	0	0	0	1,475
R4	Increasing cereal food production in WANA	508	0	235	162	0	207	30	58	62	0	0	0	0	1,262
R5	Enhancing Latin American maize and wheat production systems	446	180	400	220	80	214	120	120	183	0	1,400	0	0	3,363
F1	Raising the yield potential of wheat	347	0	0	0	0	0	20	20	0	0	0	0	0	387
F2	Apomixis - Equity in access to hybrid vigor for resource poor farmers	297	50	0	53	0	0	0	0	0	0	0	0	0	400
F3	Using genetic engineering to improve tolerance to biotic and abiotic stresses in tropical maize and in whe	398	0	478	192	0	50	38	0	0	0	0	0	0	1,156
F4	Improving human nutrition by enhancing bio-available protein and micronutrient concentrations in maize	212	77	0	0	0	23	27	23	0	0	0	0	0	362
F5	Genetic approaches to reducing post harvest losses.	100	17	143	0	0	0	17	0	0	0	0	0	0	277
F6	Priority setting and technology forecasting for increased research efficiency	95	71	71	0	115	0	0	47	0	0	0	0	0	399
F7	Learning to more effectively confront problems of resource degradation in maize and wheat systems	0	47	150	80	31	47	50	47	0	0	0	0	0	452
SP1	Wheat germplasm development in the Newly Independent States.*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Program Totals	8,372	1,706	5,987	4,289	1,215	4,506	1,182	1,354	1,289	550	1,400	250	100	32,200
	Total Operating Requirements	**32,200**													
	less: Center Income	**2,200**													
	Total Funding Requirements	**30,000**													

* It is expected that approximately $300K p.a. will be needed for this project. Additional funds are being sought for this work.

Table 2: CENTER RESEARCH AGENDA - BY CGIAR ACTIVITY, 1995-2000
(expenditure in current $'000 and %) *

			1995 Actual	1996 Actual	1997 Budget	1998 Plan	1999 Plan	2000 Plan
A. CGIAR Activities								
Theme I Increasing Productivity								
	1	Germplasm Enhancement & Breeding	11,861	11,401	9,774	8,372	8,536	8,700
	2	Production Systems Development & Mgmt: CROPS	884	1,644	1,444	1,706	1,753	1,800
		Total Increasing Productivity	**12,746**	**13,045**	**11,218**	**10,078**	**10,289**	**10,500**
Theme II	6	Protecting the Environment	3,330	4,436	5,966	5,987	6,194	6,400
Theme III	7	Saving Biodiversity	904	1,942	3,824	4,289	4,632	4,975
Theme IV	8	Improving Policies	577	1,023	1,133	1,215	1,208	1,200
Theme V		Stengthening NARSs						
	9	Training	944	2,035	2,844	4,506	3,916	3,325
	10	Documentation, Publications, Information Dissemination	1,214	1,697	495	1,182	1,191	1,200
	11	Organization & Management Consulting	1,099	1,433	1,433	1,354	1,577	1,800
	12	Networks**	415	1,080	2,286	1,289	895	500
		Total Strengthening NARSs	**3,673**	**6,245**	**7,059**	**8,331**	**7,578**	**6,825**
		TOTAL CGIAR ACTIVITIES	**21,230**	**26,691**	**29,200**	**29,900**	**29,900**	**29,900**
B. System-Wide Programs								
	14	Rice/Wheat Interactions	350	607	581	550	625	700
	15	Latin America Ecoregion	687	1,258	1,389	1,400	1,200	1,000
	17	Mountain Agriculture	38	161	198	250	325	400
	18	Other	204	37	104	100	150	200
		TOTAL SYSTEM-WIDE PROGRAMS	**1,279**	**2,063**	**2,272**	**2,300**	**2,300**	**2,300**
C. System-Wide Initiatives (Design Phase)								
		TOTAL SYSTEM-WIDE INITIATIVES	0	0	0	0	0	0
External Review					300			
		TOTAL: ALL CENTER ACTIVITY	**22,509** (a)	**28,754** (b)	**31,772**	**32,200**	**32,200**	**32,200**

* Expenditure is in current values, and includes all Center overhead costs
** The reduction in "Networks" does not indicate any intention to withdraw resources from research-based networks. According to the TAC definitions these resources are now shown under the appropiate research activities rather than under "Networks".
(a) N.B. Excludes $5,117K outside agenda.
(b) N.B. Excludes $1,595K outside agenda.

Table 3a: RESEARCH AGENDA OPERATING REQUIREMENTS BY PROGRAM 1995-2000

OPERATING BUDGET	1995 Actual	1996 Actual	1997 Budget	1998 Plan	1999 Plan	2000 Plan
	$000	$000	$000	$000	$000	$000
Research Programs						
Maize	6,398	8,417	8,997	9,200	9,100	9,000
Wheat	6,414	8,361	8,954	9,185	9,200	9,200
Economics	727	1,121	2,136	1,850	1,850	1,850
Natural Resources	750	842	1,145	1,300	1,300	1,300
Biotechnology	1,278	1,618	2,021	2,000	2,085	2,185
Total Research	**15,567**	**20,359**	**23,253**	**23,535**	**23,535**	**23,535**
Research Support						
Laboratories	112	203	220	230	230	230
El Batan Station	285	327	358	360	360	360
Biometrics	124	120	185	180	180	180
Systems and Computing Services	286	570	303	345	345	345
Total Research Support	**807**	**1,220**	**1,066**	**1,115**	**1,115**	**1,115**
Information						
Information	592	1,113	751	850	850	850
Library	296	198	284	250	250	250
Total Information	**888**	**1,311**	**1,035**	**1,100**	**1,100**	**1,100**
Research Management						
Administration:						
Board of Trustees	70	174	151	200	200	200
Director General's office	924	1,097	927	1,000	1,000	1,000
External Relations			500	550	550	550
Administration/finance	1,383	1,306	1,375	1,400	1,400	1,400
Accruals, translation effect	250	122	100	200	200	200
Subtotal Administration	2,627	2,699	3,053	3,350	3,350	3,350
Operations:						
Physical plant services	1,071	1,496	1,465	1,500	1,500	1,500
External review			300			
Total Research Management	**3,698**	**4,195**	**4,818**	**4,850**	**4,850**	**4,850**
Depreciation	1,549	1,669	1,600	1,600	1,600	1,600
Total Operating Requirements	**22,509**	**28,754**	**31,772**	**32,200**	**32,200**	**32,200**
Working capital	4,560					
Capital fund	956	390				
Less: Center Income						
Investment Income	543	476	400	350	350	350
Overhead Recovery	493	44	1,600	1,600	1,600	1,600
Other Income/unexpended funds	426	664	300	250	250	250
Total Center Income	**1,462**	**1,184**	**2,300**	**2,200**	**2,200**	**2,200**
AGENDA FUNDING REQUIREMENTS	**26,563**	**27,960**	**29,472**	**30,000**	**30,000**	**30,000**
NON AGENDA FUNDING REQUIREMENTS	**5,117**	**1,595**	**0**			
TOTAL FUNDING REQUIREMENTS	**31,680**	**29,555**	**29,472**	**30,000**	**30,000**	**30,000**

Table 3b: NON-AGENDA OPERATING REQUIREMENT BY PROGRAMS 1995-1996

OPERATING BUDGET	1995 Actual	1996 Actual
	$000	$000
Research Programs		
Maize	2,175	961
Wheat	1,951	482
Economics	222	0
Natural Resources	172	91
Biotechnology	96	3
Total Research	**4,616**	**1,537**
Research Support		
Total Research Support		**14**
Information		
Information		
Library	8	
Total Information	**8**	**0**
Overhead	493	44
Total Operating Requirements	**5,117**	**1,595**

Table 4a: ANNUAL ANTICIPATED FUNDING FOR RESEARCH AGENDA PROJECTS, 1997 (IN $'000)

CGIAR Member	Unrestricted Funding	Restricted Funding
ADB		200
Austria	150	
Australia	720	414
Belgium	98	328
Canada	875	907
China	80	
Colombia		117
Denmark/Danida	1,895	67
EU	250	2,404
Ford	400	
France		407
Germany	539	425
ICRAF		57
IDB		1,360
IFAD		240
IFPRI		68
India	80	
INIA-Uruguay		100
IPGRI		74
Iran		100
Italy	100	71
Japan	2,602	110
Korea	50	30
Mexico		200
Netherlands		462
Nippon Foundation		207
Norway	125	40
ODA		887
Pakistan	100	
Phillipines	80	
Rockefeller		474
South Africa		50
Spain	20	80
Sweden		95
Switzerland		821
UNDP		1,377
USA	4,320	207
World Bank	3,873	
*Others	200	236
Total Restricted		**12,615**
Unrestricted Pool		
Total Funding	16,557	
Center Income	2,300	

* Others:		
	OPEC=	24
	Pioneer=	13
	IARC=	12
	Stanford Univ=	12
	Cornell Univ=	40
	Nafinsa=	3
	Leverhulme Trust=	24
	Colciencias=	58
	Bangladesh=	50
	Total=	**236**

Table 4b: ANNUAL ANTICIPATED FUNDING FOR RESEARCH AGENDA PROJECTS, 1998-2000 (IN $'000)

CGIAR Member	Unrestricted Funding	Restricted Funding
ADB		500
Austria	150	
Australia	700	600
Belgium	168	358
Canada	870	977
China	80	
Colombia		175
Denmark/Danida	1,537	167
EU	500	2,317
Ford	400	
France		511
Germany	625	625
ICRAF		131
IDB		1,000
IFAD		450
IFPRI		68
India	80	
INIA-Uruguay		100
IPGRI		74
Iran		212
Italy	100	71
Japan	2,400	110
Korea	60	30
Mexico		130
Netherlands		466
Nippon Foundation		225
Norway	160	40
ODA		887
Pakistan	100	
Phillipines	80	
Rockefeller		478
South Africa		50
Spain	20	80
Sweden		95
Switzerland		1,112
UNDP		1,400
USA	4,665	216
World Bank	3,214	
*Others	200	236
Total Restricted		**13,891**
Unrestricted Pool		
Total Funding	16,109	
Center Income	2,200	

* Others:		
	OPEC=	24
	Pioneer=	13
	IARC=	12
	Stanford Univ=	12
	Cornell Univ=	40
	Nafinsa=	3
	Leverhulme Trust=	24
	Colciencias=	58
	Bangladesh=	50
	Total=	**236**

Table 5: SUMMARY OF COSTS BY OBJECT OF EXPENDITURE 1995-2000
(in current $'000s)

	1995 Actual	1996 Actual	1997* Budget	1998 Plan	1999 Plan	2000 Plan
I. Research Agenda						
Personnel	12,314	15,137	15,815	16,215	16,620	17,036
Supplies and services	7,053	9,896	10,810	11,147	10,938	10,847
Operational travel	1,593	2,052	3,247	3,238	3,042	2,717
Depreciation	1,549	1,669	1,600	1,600	1,600	1,600
	22,509	**28,754**	**31,472**	**32,200**	**32,200**	**32,200**

	1995 Actual	1996 Actual
II. Non-Agenda		
Personnel	1,744	359
Supplies and services	2,643	1,138
Operational travel	237	54
Depreciation	-	-
	4,624	**1,551**

* External Review costs are not included in these figures.

Table 6: CAPITAL BUDGET 1995-2000
(in current $'000)

ASSET ACQUISITION EXPENDITURE

	1995 actual		1996 actual		1997	1998	1999	2000
	Research agenda	Non-agenda	Research agenda	Non-agenda	Budget	Plan	Plan	Plan
Physical Facilities								
Land								
Buildings	755		989	90	200	320	320	320
Subtotal	**755**	-	**989**	**90**	**200**	**320**	**320**	**320**
II. Furnishing and Equipment								
Farming	423	2	180	10	150	240	240	240
Laboratory and Scientific	140	9	276	14	150	240	240	240
Office	17	5	66	2	100	160	160	160
Computers	430	7	527	13	200	320	320	320
Vehicles	738	120	664	26	150	240	240	240
Other Assets	4	12	183		50	80	80	80
Subtotal	**1,752**	**155**	**1,896**	**65**	**800**	**1,280**	**1,280**	**1,280**

ASSET FINANCING AND CAPITAL FUND RECONCILIATION

	1995 actual		1996 actual		1997	1998	1999	2000
	Research agenda	Non-agenda	Research agenda	Non-agenda	Budget	Plan	Plan	Plan
I. Sources of Asset Financing								
Capital fund	(2,662)		(3,039)		(1,000)	(1,600)	(1,600)	(1,600)
II. Capital fund reconciliation								
Balance, January 1	320		346		(495)	155	205	255
+: depreciation charge	1,549		1,669		1,600	1,600	1,600	1,600
+/-: disposal gains/losses	183		139		50	50	50	50
+: other allocations *	956		390		-	-	-	-
equals: Balance, December 31	346		(495)		155	205	255	305

* Additional contributions were made in 1995 and 1996 to the capital fund to finance higher-than-normal acquisitions

TABLE 7: STATEMENT OF FINANCIAL POSITION 1996-2000
(in current $'000s)

Assets	1996 Actual	1997 Budget	1998 Plan	1999 Plan	2000 Plan
Current Assets					
Cash and Cash Equivalents	10,131	9,827	9,928	10,030	10,182
Accounts Receivable:					
Donors	3,633	3,824	3,790	3,817	3,636
Employees	240	233	235	238	220
Others	509	494	499	504	457
In-Trust Accounts	19	18	19	19	19
Inventories	134	130	131	133	153
Total Current Assets	**14,666**	**14,526**	**14,602**	**14,740**	**14,667**
Fixed Assets					
Property, Plant and Equipment	31,498	32,498	34,098	35,698	37,298
Less: Accumulated Depreciation	(17,157)	(18,757)	(20,357)	(21,957)	(23,557)
Total Fixed Assets - Net	**14,341**	**13,741**	**13,741**	**13,741**	**13,741**
Total Assets	**29,007**	**28,267**	**28,343**	**28,481**	**28,408**
Liabilities and Net Assets					
Current Liabilities					
Accounts Payable:					
Donors	4,435	4,301	4,146	4,139	4,215
Employees	41	40	40	41	35
Others	412	350	369	358	314
In-Trust Accounts	147	133	144	146	143
Accruals and Provisions	1,475	1,235	1,346	1,410	1,358
Total Current Liabilities	**6,510**	**6,059**	**6,045**	**6,093**	**6,065**
Long-Term Liabilities					
Employee Severance Benefits	161	150	150	100	100
Total Liabilities	**6,671**	**6,209**	**6,195**	**6,193**	**6,165**
Net Assets					
Capital Invested in Fixed Assets:					
Center Owned	14,341	13,741	13,741	13,741	13,741
Capital Fund	(495)	155	205	255	305
Operating Fund	8,490	8,162	8,202	8,292	8,197
Total Net Assets	**22,336**	**22,058**	**22,148**	**22,288**	**22,243**
Total Liabilities & Net Assets	**29,007**	**28,267**	**28,343**	**28,481**	**28,408**

Table 8: STAFF COMPOSITION (number), 1996-2000

RESEARCH AGENDA		(actual) 1996 Center Hired	(actual) 1996 Other Hired	(budget) 1997 Center Hired	(budget) 1997 Other Hired	Plan 1998 Center Hired	Plan 1998 Other Hired	Plan 1999 Center Hired	Plan 1999 Other Hired	Plan 2000 Center Hired	Plan 2000 Other Hired
I	**Internationally-recruited staff**										
	Research	52	3	60	3	59	3	59	3	59	3
	Research Support	8		8		8		8		8	
	Training/Communications	6		8		8		8		8	
	Research Management	8		7		7		7		7	
	Total	**74**	**3**	**83**	**3**	**82**	**3**	**82**	**3**	**82**	**3**
II	**Post-doctoral Fellows and Associate Scientists**	18	6	19	6	18	6	18	6	18	6
III	**Supervisory Staff (local hire)**	35		35		36		37		37	
IV	**Support Staff (local hire)**	564		610		604		603		603	
	Total Agenda Staff	691	9	747	9	740	9	740	9	740	9

NON - AGENDA		(Actual) 1996 Center Hired	(Actual) 1996 Other Hired
I	**Internationally-recruited staff**		
	Research	9	
	Research Support		
	Training/Communications		
	Research Management		
	Total	9	
II	**Post-doctoral Fellows and Associate Scientists**	1	
III	**Supervisory Staff (local hire)**		
IV	**Support Staff (local hire)**	42	
	Total Non Agenda Staff	52	

Annex 1: The Importance of Maize and Wheat in the Developing World

Trends in Maize and Wheat Production and Consumption

Since the 1940s, and particularly during the last thirty years, maize and wheat have become increasingly important in developing countries. In the early 1960s, the developing world accounted for just over a third of global maize production and less than 30% of global wheat output. By the early 1990s, developing countries accounted for more than 45% of total world production of both cereals. Maize production in developing countries grew at an annual rate of 3.6% from 1961 to 1995; wheat production at an even faster rate of 4.5%.

Nonetheless, demand for maize by developing countries grew even faster, at 4.2% per year over the same period. The wheat consumption growth rate was almost identical to the production growth rate. As a result, developing country maize consumption increased from one-third to one-half of total world consumption over a thirty year period; wheat consumption in developing countries rose from 36% to 56% of the global total over the same period. Developing countries, which accounted for only 10% of world maize imports in the early 1960s, now account for about 45% of all imports. Developing country wheat imports were already high, at just under half the total at the beginning of the 1960s; today they are approaching two-thirds of total imports.

Many factors have influenced these trends. Rising consumption of maize and wheat in the developing world has been driven by rapid population growth, growth in per capita incomes, and declining real prices. Urbanization and commercialization in and of themselves also affect the pattern of consumption of wheat and maize, as do historical consumption patterns in individual countries or regions. These historical consumption patterns are, in turn, often related to local production possibilities.

Population in developing countries grew at a rate of 2.2% per year from 1961 to 1995. The fact that maize and wheat consumption grew even faster suggests that income and price factors have played a role in the spectacular growth of developing country utilization of these cereals. The relatively low income elasticities* for staple cereals are well documented. We also know that these elasticities decrease as incomes rise. Even so, incomes in developing countries have generally been low enough to make income growth an important factor in the overall growth of demand for cereals.

Important distinctions also exist in the income elasticities among cereals and in the patterns of change in cereal consumption as incomes rise. In general, maize replaces other coarse cereals such as sorghum and millet in the diets of people as their incomes increase from a very low level. In turn, beyond a certain income level maize is replaced by rice and wheat. This general tendency differs, of course, between specific countries or regions depending on historical consumption patterns and local production possibilities. Of all the cereals, wheat appears to have the highest income elasticity, although part of the growth in the demand for wheat that comes with rising incomes results from the phenomena of urbanization and commercialization, because wheat is often an important ingredient in convenience foods.

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* Income elasticities measure, approximately, the percentage change in per capita consumption of a product in response to a one percent increase in per capita income.

This pattern is also reflected in levels of per capita consumption for individual cereals. At very low levels of per capita income, for example, per capita wheat consumption is low and relatively stable with small, incremental changes in income. As incomes increase more substantially, per capita demand increases even though incomes are still very low. Over a broad range of middle income countries, three general patterns of change in consumption have been observed. For countries that have not been traditional wheat consumers, per capita wheat consumption increased very rapidly with rising incomes. For countries that have consumed greater amounts of wheat historically, per capita wheat demand increases more slowly with increasing incomes, and then may decline slowly. Finally, at high income levels (i.e., levels that imply a country is no longer considered "developing"), per capita wheat demand may decline (see table).

The consumption pattern of maize is different from that of wheat. Direct (human) per capita consumption of maize tends to decline at much lower income levels than for rice or wheat. However, the importance of maize as a livestock feed means that increasing incomes can often have a substantial indirect effect on the demand for maize. This phenomenon has been observed in countries with incomes as low as those in China (GNP per capita of slightly over US$ 500 per year in 1994).

These factors are reflected in the rates of growth in per capita maize and wheat consumption in the developing world over the last thirty years or more. Per capita wheat consumption has grown at an average annual rate of 2.2% per year. In the past decade, this rate of increase has shown some signs of slowing. Per capita maize consumption has grown slightly more slowly than the rate for wheat, at just under 2% per year. Unlike the situation for wheat, the rate of growth in per capita maize consumption shows no signs of deceleration. Furthermore, the rate of increase in per capita maize *feed* use in developing countries, some 3.8% per year, has been much higher than the overall increase for maize. Overall, use of maize as feed in developing countries has grown from about 30% of total use in the early 1960s to about 50% today.

Despite the switching out of maize as a directly consumed human staple as incomes grow, per capita *food* use of maize also increased at the small but

Per Capita Wheat Consumption Patterns, Selected Countries

Consumption Pattern	1994 GNP per capita (US $)	Countries
Stable to slightly increasing per capita consumption of wheat at low income levels. Per capita demand increases at higher GNP per capita.	$0 to $350	Bangladesh, Vietnam, India, Pakistan, other South Asia countries, Eastern sub-Saharan Africa (SSA), Nigeria, Madagascar
Countries in which wheat is not a traditional crop: Rapidly increasing per capita demand, then declines.	$350 to $12,500	Myanmar, Philippines, Malaysia, Thailand, Indonesia, Northern SSA, Central-West SSA, Southern SSA
Countries in which wheat is a traditional crop: Stable/slowly increasing per capita demand, then declining.	$350 to $12,500	China, Egypt, other WANA countries, South Korea, Mexico, Argentina, Brazil
Declining per capita demand.	$12,500 and above	Japan, Australia, EC 12, USA

statistically significant rate of 0.6% per year since the early 1960s. Maize remains an important food consumption item for the poor in certain world regions, notably eastern and southern Africa, Mexico and Central America, and Egypt. Similarly, wheat plays a substantial role in the consumption patterns of the poor in South Asia and in WANA.

Real cereals prices have also trended downward over much of the past thirty years. The recent sharp increases in prices have returned them, in real terms, only to the levels of the mid-1980s. These generally declining prices for cereals have also influenced, in a positive way, the demand for maize and wheat in developing countries. Pricing policies in individual countries have also played a significant role. In general, developing country pricing policies have tended to protect domestic producers of maize and wheat. Still, this tendency has often been more than compensated for by overvalued exchange. Furthermore, in many countries where maize and wheat are politically sensitive staples for large proportions of the population, consumer subsidies have also been applied. Although recent policy trends have been toward more liberalized markets, the overall effect of government policies in the past has been to favor increased cereals consumption in many cases.

Technological Change and the Use of Improved Varieties

Despite the fact that, in the aggregate, developing country maize and wheat production did not keep pace with demand over the past thirty or more years, production of both cereals increased at historically unprecedented rates. Without these production increases, demand would certainly not have grown at the rates that it did, and cereals prices would now be considerably higher.

Yield increases have been the primary component of production growth in developing country wheat production since the 1950s, and in growth of maize output since the 1960s (see Figure). Growth in wheat yields has been particularly high from the mid-1960s to the mid-1980s, and the growth of maize yields has been quite high from the mid-1960s onward.

The underlying cause of yield growth over this period has been technological change that has featured higher-yielding varieties, increased fertilizer consumption, some changes in other management practices, and, particularly in the case of wheat in Asia, expansion of wheat area under irrigation. This intensification has been driven by population pressure and/or improving access to markets.

In developing country maize, the use of hybrids and improved open-pollinated materials grew from almost nothing to about 60% of total area by the

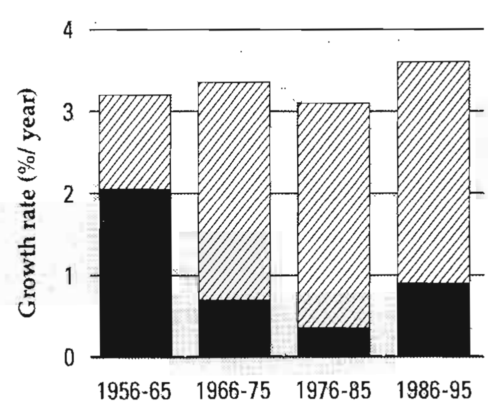

Fig. 1a. Sources of Growth in Maize Production in Developing Countries

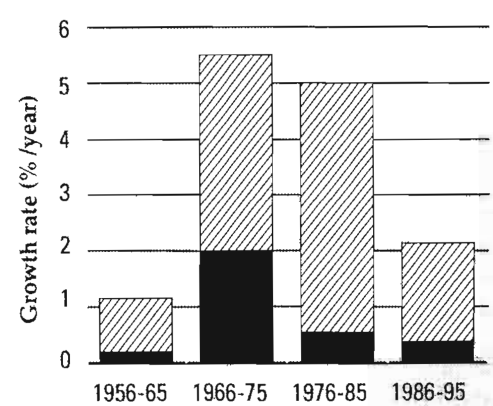

Fig. 1b. Sources of Growth in Wheat Production in Developing Countries

early 1990s. About 45% of total maize area is now planted to hybrids. These figures are highly influenced, however, by patterns of varietal use in the mostly temperate, commercial producer countries such as China, Argentina, and Chile, and two other countries with substantial commercial production in subtropical environments, Brazil and South Africa. In the aggregate, some three-quarters of the maize area in these countries is planted to hybrids. Together, they account for about 60% of total developing country maize output. When they are excluded from the calculation, improved maize covers only about 40% of the area in smaller maize-producing nations having more tropical, subtropical, or tropical midaltitude environments, 20% of it in hybrids and 20% in improved open-pollinated varieties.

In the more widely known case of the "Green Revolution" in wheat, high-yielding, semidwarf wheats have spread over the last thirty years until they now cover 70-80% of all wheat area in developing countries. As with maize, several large wheat producing countries dominate developing country production. China and India together produce over 60% of developing country wheat; these two countries, plus Turkey and Pakistan, produce nearly 80%. In contrast to maize, use of high-yielding wheat varieties does not show markedly different patterns in these large wheat-producing countries than it does in smaller wheat-producing nations.

The Next Thirty Years

Many of the factors that have influenced trends in developing country maize and wheat consumption over the past thirty years or more will continue to affect consumption in the foreseeable future, although in relatively different proportions. Different models have been constructed to predict the possible courses of production, consumption, trade, and prices, for example by FAO and IFPRI. Here we follow, for the most part, the IFPRI "2020" model when discussing projected consumption.

Over the next thirty years, population in developing countries will continue to grow, albeit at a slower rate (some 1.6% annually) than over the past three decades. Income growth will continue to fuel demand for maize and wheat, following the patterns described above. Per capita demand for food maize will decline in almost all countries/regions except sub-Saharan Africa, but per capita demand for feed maize will continue to increase in almost all developing countries. The real price of both maize and wheat is expected to decline, but at a much more gradual rate than over the past three decades.

The aggregate results are that per capita demand for both maize and wheat in developing countries is expected to grow at about 0.6% per year to 2020, and overall demand by 2.2% annually, with significant regional variations. By 2020, developing countries are, in the aggregate , expected to account for about half of total world production in both maize and wheat. Two-thirds of the world's wheat consumption and 55% of the world's maize consumption will occur in developing countries, implying that they will import some 122 million metric tons of wheat and about 41 million metric tons of maize annually.

These projections, however, are based on the assumptions that rates of public investment in agricultural research and infrastructure will remain at the already reduced levels prevailing in the late 1980s and early 1990s, and that income growth rates in developing countries will remain high, although varying by region. Researchers at IFPRI have explored several other sets of assumptions, including a "low investment/slow growth" scenario in which international and national agricultural research investments will be cut even further, by an annual total of about US$ 1.5 billion, and investment in health, education, and sanitation will be reduced by 20% by 2020. In this scenario, they also assume that non-agricultural income growth will be reduced by 25%, thus lowering the demand for agricultural commodities.

Under this "low investment/slow growth" scenario, by 2020 developing country maize production would drop by 10% and developing country wheat production by 13% over the baseline scenario. In contrast with the baseline scenario of continued but slower declines in cereals prices, real global wheat prices would rise slightly by 2020 and real world maize prices would be almost the same as in 1990 in the "low investment/slow growth" scenario. Developing world imports, particularly for wheat, and particularly in Asia, would be higher in this scenario than in the baseline scenario. Based on changes in world maize and wheat imports and higher wheat prices, developing countries would face annual losses of US$ 1.4 billion (in 1990 dollars) in the maize subsector and US$ 7 billion in the wheat subsector. This is not a complete welfare analysis of the differences between the two scenarios, but it does suggest that further declines in public investments in agricultural research have a high probability of resulting in large welfare losses.

Several key factors are also likely to be important in judging future developments in maize and wheat production and consumption in developing countries and the role research plays in these developments. First, it is clear that, with the exception of a few maize growing countries, nearly all the increases in maize and wheat production in the developing world will have to come from increased yields, not increased area. Therefore, agricultural research will continue to play a critical role in bringing forth the necessary increases in the production of these crops. Furthermore, the task of agricultural research will be increasingly complex as the costs of agricultural production in terms of environmental losses become better understood. In the few areas where area expansion can still lead to increased production, debates over whether the loss of environmental amenities is greater than the value of additional cereal output are likely to become increasingly strident. At the other extreme, areas that are now producing cereals, particularly wheat and rice, in intensive rotations with other cereals are showing signs of declining productivity in many instances, in the sense that more inputs are often required to get the same level of output as before. Achieving the requisite yield increases under such circumstances will be more difficult than it has been in the past.

Second, policy reforms and changes in the world economy are likely to make the world markets for maize and wheat more competitive in the next three decades than they have been in the past three. The ability of individual governments to influence the actions of their maize and wheat consumers and producers will become less pronounced. This has implications for interactions between research benefits and cereals consumption in richer and poorer developing countries. If production of maize and wheat falls further behind consumption in richer developing countries, cereals and livestock consumers will be affected in more than those countries alone. The consumption of the poorer countries will be affected as well, countries that are less able to pay the higher world prices accompanying a less productive world cereals economy. In other words, targeting maize and wheat research *only* at the "poorest of the poor" may not be the optimal strategy even if poverty alleviation is a major goal of such research.

Nonetheless, in both the baseline and "low investment/slow growth" scenarios, food security — measured by IFPRI as the predicted number of malnourished children — will remain a problem in 2020. Under the baseline assumptions, this measure is only marginally improved over the next thirty years. In the "low investment/slow growth" scenario, food security is considerably worse than it is today. Both scenarios predict that the major incidence of food insecurity will be in South Asia, where wheat is significant in the diets of the poor, and in sub-Saharan Africa, where maize will still be an important staple of the poor over the next three decades.

Annex 2: Wheat Improvement in West Asia and North Africa (WANA)

The global mandate of CIMMYT is to improve sustainable wheat and maize systems while the mandate of ICARDA is to promote sustainable improvements in the agricultural systems of the dry areas of the world. Given the overlapping commodity mandates of the two centers in the WANA region, close collaboration between CIMMYT and ICARDA is clearly essential. The two centers have agreed on a plan for the efficient deployment of resources for the benefit of wheat researchers and farmers of the WANA region. This objective will be achieved through close association to carry out a collaborative wheat improvement program called the CIMMYT/ICARDA Wheat Program for WANA.

The two Centers have agreed to a joint program on spring bread wheat and durum wheat improvement to address all the wheat growing environments in WANA. CIMMYT will station a spring bread wheat and a durum wheat breeder at ICARDA; ICARDA will provide input of other scientists and support staff for all the disciplines, including breeding. *

The two Centers have agreed that a joint program on the improvement of facultative and winter bread wheat will operate as the Turkey/ CIMMYT/ICARDA program. Two facultative and winter wheat breeders will be employed by CIMMYT and another one by ICARDA. Other ICARDA staff and concerned Turkish and Iranian scientists will complement the work of the breeders.

A major concern of the two Centers is the efficient storage of duplicate collections of genetic resources of wheat and the wild relatives, as well as the storage of passport and evaluation data. To minimize chances of losses, both Centers seek to duplicate their respective collections and associated databases in at least two locations. ICARDA also has the global responsibility for a base collection of cultivated barley and CIMMYT has this responsibility for triticale.

The ICARDA staff located in regional programs will support the implementation of the joint wheat programs. ICARDA will continue its efforts in agroclimatic zoning research as well as on crop management, including on-farm water use, and soil fertility management for all important farming systems.

Trainees and visiting scientists from the WANA region are encouraged to go to the center most appropriate to their needs. Generally those interested in the dry areas would go to ICARDA while those interested in high rainfall or irrigated wheat production would go to CIMMYT-Mexico. All publications from the joint program will give full acknowledgments to the contribution of all collaborators.

Recognizing the importance of the effective operation of all aspects of this agreement, the Directors General will meet at least once a year to review the implementation of the collaborative agreement.

* In addition, the Centers have agreed to a joint ICARDA/CIMMYT program for the improvement of barley for South America under which ICARDA will maintain a breeder at CIMMYT-Mexico, with CIMMYT providing all logistical support.

Annex 3: Spillover Benefits of CIMMYT Wheat Germplasm in Selected Developed Countries

CIMMYT's mandate is to serve developing countries, and that is where its products are most widely used. Nonetheless, CIMMYT wheat germplasm has been used extensively in developed countries, particularly where spring-habit bread and durum wheats are grown. This is most notable in developed countries with spring wheat environments similar to mega-environments 1 (favorable, low rainfall, irrigated) and 4 (low rainfall, non-irrigated). Based both on objective assessments and the statements of wheat breeders in developed countries, yield potential and disease resistance of CIMMYT germplasm are two of the major reasons for incorporating it into breeding programs.

Spring wheats (both durum and bread) with CIMMYT ancestry are widely grown in European countries with Mediterranean (mega-environment 4A) climates, such as Spain, Portugal, Italy, and Greece. The most detailed quantitative information available, however, exists for Australia, the US, and Canada. In Australia, 86% of all the wheat area was sown to varieties with some CIMMYT ancestry in the early 1990s. In the US, around one-fifth of all the wheat area was sown to CIMMYT-derived wheats in the same time period. The proportions varied significantly by region. In California and Arizona, where wheat-growing environments resemble northwest Mexico, which plays a crucial role in CIMMYT wheat breeding efforts, nearly all wheat planted by farmers is CIMMYT derived. CIMMYT wheats have made notable but smaller contributions as well in the spring bread wheat high latitude environment of the Northern Great Plains, and even in the winter bread wheat areas of the Central and Southern Great Plains. In Canada, about a third of the wheat area of the Prairie provinces, where the vast majority of Canadian wheat is grown, were planted to varieties with some CIMMYT ancestry.

Both the genetic contribution and the economic importance of that contribution derived from CIMMYT wheats can be measured in different ways. None of the measures is clearly superior. It has been estimated that over a 20 year period from 1974 to 1993, the monetary benefit to Australia from the use of CIMMYT germplasm was an average of about US$ 120 million per year in 1993 dollars, with a compounded present value in 1993 of about US$ 3.6 billion. Using varying assumptions, it has been calculated that the US economy gained anywhere from US$ 3.4 billion to US$ 13.7 billion from 1970 to 1993 because of the use of CIMMYT varieties. On the other hand, despite the increasing recent use of CIMMYT germplasm by Canadian wheat breeders, there seems to have been a much lower benefit in Canada over the same period, around US$ 14 million. These differences stem partially from methods used. More important, however, is the interaction between the differences in the amount of wheat produced in the three countries and the similarities between their wheat growing environments and those traditionally targeted by CIMMYT, given its mandate to serve developing countries.

Annex 4: CIMMYT Collaboration with Advanced Research Institutes

CIMMYT has an extensive and growing set of collaborative research relationships with advanced research institutes around the world, both in developed and developing countries. We seek to expand our partnerships with such institutions as a key part of our strategy to bring the power of cutting edge agricultural science to bear on the challenge of sustainable maize and wheat production in developing countries. The following list of collaborating institutions is not all inclusive, but will give the reader a sense of the breadth and quality of these important partnerships:

APSRU, Australia
Agricultural Research Service (ARS) of the US Department of Agriculture
Agriculture Canada
CIAT
CINVESTAV, Mexico
CIRAD, France
CNPMS, Brazil
Cornell University
CPRO, Wageningen
CSIRO, Australia
IARI, India
IGER, UK
IITA
Iowa State University
John Innes Institute
Kansas State University
Maize Research Center, Serbia
Michigan State University
Mississippi State University
North Carolina State University
Ohio State University
Oregon State University
ORSTOM, France
Texas A & M University
Texas Tech University
US National Seed Storage Laboratory
University of California, Berkeley
University of Queensland
University of Gottingen
University of Hannover
University of Hawaii
University of Hohenheim
University of Louvain La Neuve
University of Massachusetts at Amherst
University of Mississippi
University of Missouri
University of Nebraska
University of the Philippines
University of Reading
University of Sydney
University of Zurich
Wageningen University

Annex 5: CIMMYT's Project Portfolio

Global Projects

1: Conservation and Management of Genetic Resources

2: Developing Core Germplasm and Integrating Interdisciplinary Approaches for the Improvement of Maize

3: Developing Core Germplasm and Integrating Interdisciplinary Approaches for the Improvement of Wheat

4: Increasing Maize Productivity and Sustainability in Stressed Environments: Abiotic and Biotic Stresses

5: Increasing Wheat Productivity and Sustainability in Stressed Environments: Abiotic Stress

6: Increasing Wheat Productivity and Sustainability in Stressed Environments: Biotic Stress

7: Gauging the Productivity, Equity, and Environmental Impact of Modern Maize and Wheat Production Systems

8: Building Partnerships through Human Resource Development

Regional Projects

1: Improving Food Security in Sub-Saharan Africa

2: Meeting the Accelerating Demand for Maize Development, Production, and Delivery in South and Southeast Asia and in China

3: Sustainable Wheat Production Systems in the Asian Subcontinent, Especially the Indo-Gangetic Plains and China

4: Increasing Cereal Food Production in WANA

5: Enhancing Maize and Wheat Production Systems in Latin America and the Caribbean

Frontier Projects

1: Raising the Yield Potential of Wheat

2: Apomixis — Equity in Access to Hybrid Vigor for Resource-Poor Farmers

3: Using Genetic Engineering to Improve Tolerance to Biotic and Abiotic Stresses in Wheat and Tropical Maize

4: Improving Human Nutrition by Enhancing Bio-Available Protein and Micronutrient Concentrations in Maize, Wheat, and Triticale

5: Genetic Approaches to Reducing Post-harvest Losses

6: Priority Setting and Technology Forecasting for Increased Research Efficiency

7: Learning to More Effectively Confront Problems of Resource Degradation in Maize and Wheat Systems

Special Focus Project

1: Wheat Germplasm Development in the Newly Independent States

Global Project # 1

Conservation and Management of Genetic Resources

Problems Being Addressed:

- Threats to genetic diversity from rising human populations and changing land use patterns.
- Genetic erosion and gaps in *ex situ* collections.
- Under-utilization of genetic diversity in the development of modern cultivars.
- Inadequate documentation or characterization of current holdings, and a lack of general access to current information by potential users.
- Limited equitable sharing of germplasm between countries and within countries.
- Uncertainties in the emerging germplasm acquisition and IPR policies.
- Lack of information on socioeconomic and policy determinants of diversity in maize and wheat grown in farmers' fields.

Project Objective:

To promote the collection, conservation, evaluation and the equitable sharing of maize, wheat, and triticale genetic resources, and appropriate wild relatives.

Anticipated Research Outputs:

- Narrow gaps in collection and conservation of genetic diversity of landraces, wild relatives, and diverse cultivars for crop improvement.
- Extensively characterized accession collections — development of trait descriptors, including passport data and DNA fingerprinting.
- Information on the origin, pedigrees, and characteristics of germplasm bank accessions widely available through a global electronic data base.
- Prebreeding techniques developed for incorporating diversity in new germplasm, through the use of cytogenetic/molecular procedures and conventional approaches.
- Guidelines for improved policies on equitable sharing and exchange of germplasm developed and promoted.
- Enhanced knowledge of germplasm longevity and methods of secure storage.
- Methods developed for the economic evaluation of genetic resource conservation and utilization, with an emphasis on comparing alternative collection and conservation strategies.

Anticipated Impacts:

- Reduced genetic vulnerability in farmers' fields.
- Enhanced conservation and utilization of genetic diversity.
- Identification of novel germplasm with new genes/desirable traits for use in future breeding efforts.
- Complementing germplasm usage by novel conventional and molecular technologies.
- Improved food security and grain quality through use of genetic diversity.

CIMMYT Programs Involved:

Maize, Wheat, Applied Biotechnology, Economics, and Natural Resources.

Partners:

Other CGIAR Centers, NARSs, ARIs, and developed and developing country germplasm banks.

Milestones: By the year 2000...

- CIMMYT will have developed the necessary functions in the new International Crops Information System to manage genetic resources information for any collection. This system will include management of passport data, characterizations, and evaluations, and will encompass genetic and molecular information.
- We will be able to determine the full costs of genebank operations for the conservation of maize and wheat, compared to other conservation options.
- Maize genetic resource holdings will reach 20,000 accessions, all bar coded.
- A partial core collection "designation" will be completed (approximately 40%).
- SINGER data on the Internet will include visual image data of the core maize collection.
- About 30% of maize accessions will be characterized for seed chemical content.
- Molecular fingerprinting and statistical techniques will be established for the screening and characterization of complex populations and landrace collections.
- About 100,000 accessions of bread wheat, durum wheat, triticale, barley, and landraces will be regenerated and stored in the Wellhausen-Anderson Plant Genetic Resources Center.
- Some 10,000 wheat landraces from Iran, Turkey, and Oaxaca will be evaluated and characterized for yield components, and for physiological and agronomic traits.
- A small, experimental special trait enhancement crossing program will be underway, involving crosses between landraces and elite bread wheats and the establishment of a molecular fingerprint database of all germplasm included in the experimental program.
- The identity of all cultivars in the overall wheat collection will be verified and any gaps in the collection will be identified.
- All existing wheat genetic resources information will be entered in the International Wheat Information System (IWIS), and made freely available to partners via CD-ROM.
- About 5,000 accessions of *Triticum* spp. will be evaluated for yellow rust, tan spot, and fusarium head blight at selected hot spots for these diseases; data and seed of selected accessions will be made available to partners.
- Methods will be developed for estimating: 1) the economic value of accessions in the wheat collection, 2) the economic impact of different types of genetic resources and their diversity on productivity and yield stability in farmers' fields, and 3) the economic and genetic impact of on-farm improvement of landraces in rural Mexican communities.

Resource Allocations by TAC Activity Categories (percent of total CIMMYT budget)

Conservation and Management of Genetic Resources	%
Enhancement and Breeding	1.53
Production Systems Development and Management	
Protecting the Environment	
Saving Biodiversity	3.83
Policy	.77
Training	.31
Information	.46
Organization/Management	
Networks	

Global Project # 2

Developing Core Germplasm and Integrating Interdisciplinary Approaches for the Improvement of Maize

Problems Being Addressed:

- Need for maize germplasm that combines high yield with tolerance to major biotic and abiotic stresses and agronomic traits, and that adapts well across regions and climates, available to NARSs as a source of broadly adapted populations and inbred lines.
- Inadequate exchange of superior germplasm and research information on a global basis.
- Inadequate integration of conventional breeding with emerging molecular techniques.

Project Objectives:

- To increase maize productivity in the current maize farming systems through improved cultivars in developing countries.
- To develop germplasm pools with cross-regional and cross-climatic adaptation for the development of novel genotypes, yet also suited to specific mega-environments.
- To facilitate the exchange of maize germplasm on a global basis, with appropriate scientific information for their most efficient use in developing superior cultivars.
- To use the tools of molecular biology for the development of high-yielding, input-efficient, stress-tolerant, and widely adapted maize cultivars.
- To work closely with Global Project 4 to improve stress tolerance/resistance of CIMMYT's maize germplasm.

Anticipated Research Outputs:

- High-yielding, input-efficient, stress-tolerant, lodging-resistant, stable, and environmentally compatible cultivars for maize-based systems in developing countries.
- Superior performing, stable populations and inbred lines with cross-regional and cross-ecology adaptation and stress tolerance, which will enhance CIMMYT's capacity for the global exchange of germplasm and the creation of novel genotypes.
- A forum for efficient exchange of germplasm, experiences, and information among global maize scientists.
- More efficient transfer of CIMMYT's research outputs which would impact resource-poor farmers positively, through NARSs and especially through CIMMYT's regional programs.
- Information on population and line performance in a wide array of environments, and on efficient means to build broadly adapted populations using molecular and conventional approaches.
- Information developed and distributed on relationships among important maize germplasm groups from NARSs, ARIs, and CIMMYT, resulting in more efficient development of superior cultivars and a more scientific use of improved international maize germplasm.
- Maize germplasm from NARSs, developed countries, and CIMMYT, classified with respect to heterotic patterns.

Anticipated Impacts:

- Higher maize yields in different farming systems where maize is produced in the developing countries.
- More input-efficient and stress-tolerant maize cultivars.
- Reduced encroachment into tropical rainforests and other fragile ecosystems to meet maize needs.
- Less use of chemicals because of integration of pest resistance into high-yielding cultivars.

- Greater awareness and exchange among maize scientists throughout the world of each other's germplasm, and effective research methodologies.
- Enhanced collaboration and communication among conventional maize breeders and biotechnologists.

CIMMYT Programs Involved:

Maize, Applied Biotechnology, Economics, and Natural Resources.

Partners:

Other CGIAR Centers, NARSs, and ARIs.

Milestones: By the year 2000...

- A total of 150 broadly adapted, stable inbred lines with good general combining ability and general resistance to major foliar diseases, insect pests and abiotic stresses, and characterized for heterotic response, will be released for use by partners.
- Some 80 new open-pollinated varieties (including synthetics) will be developed and tested through international trials.
- About 150 new high yield potential and stable hybrids will be developed and tested through international trials.
- Approximately 40 inbred lines and 25 varieties will be released by national programs as hybrids or varieties, and seed produced by national private seed companies.
- All products released in this period will be characterized for abiotic and biotic stress tolerance.
- In close collaboration with Global Project 4, 20 inbred lines with good general combining ability, specific abiotic and biotic stress tolerances, and excellent performance potential in unstressed environments, will be identified as source germplasm and released.
- In close collaboration with Global Project 4, 10 source OPVs with specific stress tolerances but excellent general performance will be identified through testing in Mexico and elsewhere.
- Molecular marker-assisted breeding will be routine for at least two traits.
- Gender-sensitive breeding traits associated with quality of food product (color, flour recovery rate, cooking time, texture) will assume greater importance in breeding.
- Major heterotic patterns in tropical and subtropical maize identified, used by several NARSs, and published widely.
- About 80 national researchers will be trained in applied maize breeding.

Resource Allocations by TAC Activity Categories (percent of total CIMMYT budget)

Developing Core Germplasm and Integrating Interdisciplinary Approaches for the Improvement of Maize

	%
Enhancement and Breeding	2.47
Production Systems Development and Management	.31
Protecting the Environment	.56
Saving Biodiversity	1.12
Policy	
Training	1.12
Information	.56
Organization/Management	
Networks	

Global Project # 3

Developing Core Germplasm and Integrating Interdisciplinary Approaches for the Improvement of Wheat

Problems Being Addressed:

- Increasing demand of food production in the face of rapidly increasing population growth.
- Declining rate in productivity gains and deteriorating soil fertility.
- Restricted supply of adapted high yielding wheat germplasm with durable resistance to pathogens and tolerance to abiotic stresses.
- Limited genetic diversity in farmers' fields.
- Inadequate dissemination of new methodologies that increase the efficiency and effectiveness of the breeding process.
- Limited preparation of some scientists in the areas of breeding and mid-career decision making.
- Consequences of the reduction in resources for the improvement of regionally adapted cultivars.

Project Objective:

To increase food security through the development and distribution of superior wheat lines, the dissemination of technical guidance, and the integration of wheat technologies.

Anticipated Research Outputs:

- Integration of disciplinary-based technologies, such as refined breeding strategies, molecular methods, novel physiological approaches, and crop modeling towards the delivery of superior germplasm.
- Diverse adapted lines for each of the target mega-environments that address major constraints and requirements and that contain genetic variability for various stresses.
- Widely adapted germplasm with enhanced disease resistance, agronomic performance, and input efficiency.
- Relevant breeding/selection methodologies and their dissemination.
- Trained NARS scientists in breeding research and its management.
- Frequent scientific exchanges and recommendations among research partners on priorities, outputs, methods, and work distribution.
- Understanding of the role of wide and specific adaptation as it relates to the needs of NARSs.
- A forum for visiting scientists, trainees, and mid-career fellows to develop their research and management skills.

Anticipated Impacts:

- Efficient global access to multidisciplinary information developed in CIMMYT and other institutes.
- Higher and more stable yields.
- Increased genetic diversity in farmers' fields.
- More input-efficient germplasm per unit of output.
- Reduction in the need for chemical control of pathogens and pests.
- Promotion of global partnerships among wheat scientists, including efficient exchange of germplasm.
- Reduction in the need to expand the global wheat-growing areas.
- Enhanced collaboration and communication among conventional wheat breeders and biotechnologists.

CIMMYT Programs Involved:

Wheat, Applied Biotechnology, Economics, and Natural Resources.

Partners:

Other CGIAR Centers, NARSs, and ARIs.

Milestones: By the year 2000...

- CIMMYT will have expanded the genetic variability of experimental wheat germplasm adapted to different mega-environments.
- More than 60 new varieties from a wide range of different crosses will be released by NARSs.
- We anticipate a breakthrough in yield potential, especially in bread wheat, of at least 10% over the 1990 yield level.
- Improved plant breeding methodologies involving the integration of applied biotechnology techniques in such areas as molecular markers (marker-assisted selection) and transgenics will be in use, especially for development of resistance to leaf rust and barley yellow dwarf virus.
- At least two varieties arising from hybridization of bread wheat x *Aegilops squarrosa*-derived synthetics will be growing in Mexican farmers' fields.

Resource Allocations by TAC Activity Categories (percent of total CIMMYT budget)

Developing Core Germplasm and Integrating Interdisciplinary Approaches for the Improvement of Wheat

	%
Enhancement and Breeding	4.24
Production Systems Development and Management	.16
Protecting the Environment	2.00
Saving Biodiversity	1.85
Policy	
Training	.40
Information	
Organization/Management	
Networks	.80

Global Project # 4

Increasing Maize Productivity and Sustainability in Stressed Environments: Abiotic and Biotic Stresses

Problems Being Addressed:

- Low maize yields cause by a high incidence of biotic and abiotic stresses in developing country subsistence production systems.
- Lack of maize cultivars with adequate resistances/tolerances to biotic and abiotic stresses.
- Inadequate quantitative knowledge for maize on the incidence, intensity and losses resulting from various stresses.
- Inadequate knowledge of indigenous management of unfavorable production systems, especially with regard to risk.
- Injurious and indiscriminate use of pesticides from a lack of understanding of integrated pest control methods, leading to environmental and health dangers.
- Inadequate attention to land and resource management systems for unfavorable environments.

Project Objective:

To reduce maize yield variability caused by biotic and abiotic stresses through the development of cultivars with appropriate resistances and tolerances, and through the development of complementary crop and resource management technologies.

Anticipated Research Outputs:

- Through close collaboration with Global Project 2, develop research methods that result in stress-tolerant and stable maize varieties for stress-prone and variable environments.
- Technological interventions that are attractive to resource-poor maize farmers operating in unfavorable environments.
- Improved knowledge of the incidence, timing and intensity of biotic and abiotic stresses of maize.
- Improved, efficient selection methodologies, both conventional and molecular, for identifying genotypes with resistances and tolerances to major stresses.
- Enhanced understanding of the etiology, epidemiology and crop losses caused by maize pests through adequate monitoring of their global distribution.
- Enhanced knowledge base of physiology, genetics and management factors involved in stabilizing yields under abiotic stress.
- Improved understanding of the interactions between cultivars and management practices in stress management.

Anticipated Impacts:

- Reduced environmental impact and conserved biodiversity through the use of stress-tolerant germplasm in marginal and variable environments.
- Increase in stability of aggregate production in regions characterized by large variability in pest, weather, and other stress factors.
- Improved agronomic and crop management systems that increase productivity and reduce risk in biotic and abiotic stress environments.
- Trained scientific manpower in stress-specific selection techniques from among the NARSs.
- Better characterization of stressed environments.

- Efficient selection methods to identify sources of tolerance to stresses, suited to NARSs' circumstances.
- Higher and more stable family incomes in marginal areas, benefiting especially women and children.

CIMMYT Programs involved:

Maize, Applied Biotechnology, Natural Resources, and Economics.

Partners:

Other CGIAR Centers, NARSs, and ARIs.

Milestones: By the year 2000...

- We will have greatly improved knowledge of the incidence, timing and intensity of drought, acid soil, cold and heat stresses in tropical maize-growing areas through modeling and GIS.
- More efficient techniques will be developed and verified for selecting for tolerance to insects, diseases, drought, low N and acid soils; these will *stabilize* production under stress, and will be developed in close collaboration with Global Project 2.
- More cost-effective molecular methods for transferring traits from resistant sources to recipient elite germplasm will be investigated and documented, again in close collaboration with Global Project 2.
- Also in close collaboration with Global Project 2, we will identify and document sources with high levels of resistance to major biotic and abiotic stresses.
- Marker-assisted backcrossing will be used to convert seven lines to drought tolerance, insect resistance, or ear rot resistance.
- *Bt* will be transferred to 10 inbred lines, and *Bt*-maize will be deployed in two partner countries.
- Enhanced knowledge of disease etiology and response of plants to stress will be passed to crop modelers and used when characterizing environments.
- Some 30 NARS staff will be trained in selection and management techniques for stressed environments.

Resource Allocations by TAC Activity Categories (percent of total CIMMYT budget)

Increasing Maize Productivity and Sustainability in Stressed Environments: Abiotic and Biotic Stresses	%
Enhancement and Breeding	1.05
Production Systems Development and Management	.19
Protecting the Environment	1.33
Saving Biodiversity	.50
Policy	
Training	.10
Information	.19
Organization/Management	.10
Networks	.10

Global Project # 5

Increasing Wheat Productivity and Sustainability in Stressed Environments: Abiotic Stress

Problems Being Addressed:

- Low and unstable farm-level yields and aggregate regional production from rainfed environments.
- Inadequate quantitative knowledge of the incidence, intensity and losses resulting from drought, temperature extremes, low nitrogen, low phosphorus, soil acidity, high aluminum saturation, micronutrient deficiencies and excesses, salinity, and waterlogging.
- An absence of efficient selection methodologies for improving tolerances to these stresses while preserving yield potential, hence the lack of tolerant wheat cultivars.
- Inadequate attention to efficient land and resource management systems for unfavorable environments.

Project Objective:

To improve the productivity, stability and sustainability of wheat production systems in areas subject to soil, water, and temperature stresses.

Anticipated Research Outputs:

- Improved knowledge of the incidence, timing, and intensity of abiotic stresses.
- Improved and efficient selection methodologies, both conventional and molecular, for identifying genotypes with tolerance to deficiencies or excesses of water, nutrients, extremes of temperature, soil acidity, and salinity.
- Genetic sources of tolerance to abiotic stresses identified and made available to NARS breeders.
- Sustainable crop and resource management systems developed on a region-specific basis for unfavorable production environments.
- An enhanced knowledge base of physiology, genetics, and management factors involved in stabilizing and improving wheat yields under abiotic stress.
- Technological interventions that are attractive to resource-poor farmers operating in unfavorable environments.

Anticipated Impacts:

- Better characterization of stressed environments.
- Efficient selection methods to identify sources of tolerance to stresses, suited to NARSs' circumstances.
- An increase in the stability of aggregate wheat production in regions characterized by large variability in rainfall, nutrient status, salinity, etc.
- Improved agronomic management systems that increase productivity and reduce risk in unfavorable environments.
- NARS scientists trained in stress-specific selection techniques.

CIMMYT Programs Involved:

Wheat, Applied Biotechnology, Natural Resources, and Economics.

Partners:

Other CGIAR Centers, NARSs, and ARIs.

Milestones: By the year 2000...

- CIMMYT will have more closely integrated the disciplines of plant breeding, genetic resources, wide crosses, physiology and biotechnology to achieve better selection criteria for tolerance to such stresses as drought and heat.
- We will have significantly enhanced (and documented) knowledge of genetic basis of heat tolerance, drought tolerance, aluminum toxicity tolerance, and waterlogging tolerance.
- We will have significantly enhanced (and documented) knowledge of the genetic, physiological and molecular basis of nitrogen and phosphorus nutrition, and of micronutrients such as zinc and boron.
- More efficient selection procedures for abiotic stresses will be developed and made available to partners.
- We will know considerably more about the drought tolerance of wheat landraces from Iran, Turkey, and Oaxaca.

Resource Allocations by TAC Activity Categories (percent of total CIMMYT budget)

Increasing Wheat Productivity and Sustainability in Stressed Environments: Abiotic Stress

	%
Enhancement and Breeding	1.60
Production Systems Development and Management	.28
Protecting the Environment	3.70
Saving Biodiversity	.98
Policy	
Training	
Information	.30
Organization/Management	.30
Networks	.30

Global Project # 6

Increasing Wheat Productivity and Sustainability in Stressed Environments: Biotic Stress

Problems Being Addressed:

- Lack of yield stability due to high disease incidence, coupled with limited genetic diversity in farmers' fields.
- Inadequate levels of resistance to emerging and mutating pathogens that can cause extensive crop losses.
- Limited research capacity in certain NARSs in the area of disease and pest ecology, epidemiology, and in the use of efficient resistance screening techniques and modern biotechnology.
- Poor understanding of the potential complementarity of combining sources of durable disease resistance with proper crop management practices.

Project Objective:

To identify, understand, and use sources of durable resistances/tolerances to the major wheat diseases and pests in order to reduce genetic vulnerability and protect yield gains.

Anticipated Research Outputs:

- Enhanced understanding of the etiology, epidemiology, and crop losses caused by wheat rusts through adequate monitoring of their global distribution.
- Elucidation of the genetic basis of durable resistance to wheat rusts and other important diseases.
- Application of molecular biology to incorporate diverse, durable resistances into wheat germplasm.
- Elaboration and implementation of efficient methodologies for screening germplasm — developed both by CIMMYT and by NARSs — for resistance/tolerance to diseases encountered in major wheat-based production systems.
- Better understanding of the interactions between the expression of resistance mechanisms and crop management practices.
- Development and enhancement of sound information networks to facilitate the effective control of wheat diseases.

Anticipated Impacts:

- Better understanding of global wheat disease etiology and epidemiology, especially in relation to rusts, septoria, helminthosporium, and barley yellow dwarf virus.
- Strengthen knowledge of mechanisms associated with durable host resistance and the extent of genetic diversity for durable resistances.
- Wheat cultivars with diverse durable resistances that will contribute to increased yields and more stable production on farmers' fields.
- Sound production practices that combine durable host-plant resistances with sustainable crop management techniques.

CIMMYT Programs Involved:

Wheat, Applied Biotechnology, Economics, and Natural Resources.

Partners:

Other CGIAR Centers, NARSs, and ARIs.

Milestones: By the year 2000...

- CIMMYT's understanding of the global epidemiology of important wheat diseases, especially the rusts, will be significantly enhanced through networking, and NARSs will be routinely advised of such occurrences to avoid large-scale vulnerability.
- Molecular markers (marker-assisted selection) will be in use to select durable disease resistance, and especially for pyramiding minor genes for leaf and yellow rust resistance.
- We will have an expanded and documented knowledge of the genetic basis of resistance to leaf rust, yellow rust, *Septoria tritici*, barley yellow dwarf virus, tan spot, helminthosporium leaf blotch, and fusarium head scab.
- We will have notably increased and documented our knowledge base for breeding durable disease resistance into wheat.

Resource Allocations by TAC Activity Categories (percent of total CIMMYT budget)

Increasing Wheat Productivity and Sustainability in Stressed Environments: Biotic Stress

	%
Enhancement and Breeding	1.06
Production Systems Development and Management	.53
Protecting the Environment	2.51
Saving Biodiversity	1.15
Policy	
Training	
Information	.27
Organization/Management	.27
Networks	

Global Project # 7

Gauging the Productivity, Equity, and Environmental Impact of Modern Maize and Wheat Production Systems

Problems Being Addressed:

- Lack of reliable data on the positive and negative impacts of modern wheat and maize production systems.
- Poor policy formulation caused by the lack of reliable, country-specific information on maize and wheat impacts.

Project Objective:

To provide a balanced and objective assessment of the impacts of modern maize and wheat production systems.

Anticipated Research Outputs:

- Improved methods for evaluating the impact of new maize and wheat technologies.
- Reliable and relevant databases available for objective assessments of the impacts of technology adoption and the returns to investment in modern maize and wheat production systems.

Anticipated Impacts:

- Improved policy formulation for research and extension investment in maize and wheat research.
- A balanced assessment of maize and wheat impacts available to governmental and non-governmental groups concerned with agricultural development.

CIMMYT Programs Involved:

Economics, Wheat, Maize, Applied Biotechnology, and Natural Resources.

Partners:

NARSs.

Milestones: By the year 2000...

- A global wheat germplasm impact study will be completed.
- A global maize germplasm impact study will be completed.
- We will have accessed the gender differences in sub-Saharan African maize farming systems.
- The spillover benefits for Latin America of maize and wheat research will be assessed and the implications for enhancing the efficiency of the region's research systems will be derived and documented.
- The impact of maize technological change in Ghana will be quantified.
- A global assessment will be done of the impact of the Green Revolution in wheat and future prospects for productivity growth.

Resource Allocations by TAC Activity Categories (percent of total CIMMYT budget)

Gauging the Productivity, Equity, and Environmental Impact of Modern Maize and Wheat Production Systems

	%
Enhancement and Breeding	
Production Systems Development and Management	
Protecting the Environment	
Saving Biodiversity	
Policy	1.24
Training	.18
Information	.18
Organization/Management	.18
Networks	.27

Global Project # 8

Building Partnerships through Human Resource Development

Problems Being Addressed:

- Limited preparation of agricultural scientists in some developing countries in theoretical and applied research methods, especially methods for conducting research on sustainable maize and wheat systems.
- Limited access of NARS researchers to results of research on sustainable maize and wheat systems conducted in other countries or regions.
- Limited access of NARS researchers to other kinds of scientific and policy information.
- Limited opportunities for NARS researchers to interact professionally with colleagues in the global scientific community.
- Ineffective linkage within NARS among disciplines, between research and extension, and among institutions, leading to inefficient use of available human resources in addressing priority problems.

Project Objective:

To improve the efficiency of research resources through human resource development and the enhancement of partnerships with NARSs.

Anticipated Research Outputs:

- Several hundred additional NARS staff each year that are trained and motivated in CIMMYT's areas of competence, particularly crop improvement, biotechnology, GIS, crop and soils modeling, and sustainable systems, through formal training courses.
- A significant number of additional NARS staff each year that develop their research skills, and their capacity to use new research methods, through interaction with CIMMYT staff as Visiting Scientists.
- The devolution of crop management research training to national systems on a regional basis, featuring independent funding and locally recruited training coordinators.
- The integration of training activities into a global learning process featuring regional research, synthesis of lessons learned relative to methods for research on sustainable systems, development of training materials, and strengthening of NARS research capacity.
- Improved NARS research management, featuring improved links among disciplines and institutions, through NARS participation in networks and ecoregional programs that integrate germplasm and maize and wheat system management for defined production ecologies.
- Enhanced access to and participation in international agricultural information networks.

Anticipated Impacts:

- The empowerment of national system staff to do research and share their expertise with others.
- A worldwide fellowship of collaborators in agricultural research and development.
- Enhanced linkages among disciplines, between research and extension, and among institutions.
- Better feedback on CIMMYT's research focus and impact.

CIMMYT Programs Involved:

Natural Resources, Maize, Wheat, Economics, and Applied Biotechnology.

Partners:

Other CGIAR Centers, NARSs, donor agencies, and ARIs.

Milestones: By the year 2000...

- At least 1,000 NARS scientists will receive training by CIMMYT in areas of the Center's competence.
- A similarly large number of NARS scientists will have worked as Visiting Scientists at CIMMYT, thereby improving their research skills.
- Crop management research training for maize and wheat systems will be fully devolved to NARS-led regional training initiatives in Asia, Africa, and Latin America.
- CIMMYT will have three years of experience in conducting its new sustainable systems training course, helping NARS scientists to become better aquainted with the principles and practice of research on sustainable systems, and how research integration can serve this end.
- Major NARS research partners will have measurably better access to international agricultural information networks, in part through CIMMYT-facilitated endeavors.

Resource Allocations by TAC Activity Categories (percent of total CIMMYT budget)

Building Partnerships through Human Resource Development

	%
Enhancement and Breeding	
Production Systems Development and Management	
Protecting the Environment	
Saving Biodiversity	
Policy	
Training	9.52
Information	.37
Organization/Management	1.75
Networks	.35

Regional Project # 1

Improving Food Security in Sub-Saharan Africa

Problems Being Addressed:

- Low and unstable maize and wheat production in the face of rapidly increasing demand, resulting in inadequate food supplies, lack of food security, and the need to import grain or, in extreme cases, to depend on food aid.
- Reduction in the quality of land and other resources, as a result of increasing population pressure, which leads rural inhabitants to bring more marginal lands under cultivation and ultimately increases rural poverty.
- Lack of adequate human resources in the region to address priority food production and supply problems.
- Lack of appropriate policies regarding input distribution, pricing, and use.

Project Objective:

To enhance food security through increased maize and wheat production and productivity in sub-Saharan Africa, while minimizing adverse impacts on the environment and the natural ecosystems.

Anticipated Research Outputs:

- Development and dissemination in the region of improved maize and wheat varieties that are more efficient and which possess built-in, robust resistance to pests, diseases, and environmental stresses.
- Identification and promotion of better crop production systems, especially for soil fertility maintenance and pest management, that conserve natural resources and increase productivity.
- Strategic research on ecosystem management initiated through partnerships with the African NARSs.
- The economics and impacts of improved maize and wheat farming systems in sub-Saharan Africa studied and documented, and policy implications disseminated, with particular emphasis on gender and equity concerns.

Anticipated Impacts:

- An enhanced and stable supply of grain for food and feed, and reduced prices to consumers of maize and wheat products — both contributing to the well-being of rural and urban poor and to food security at the national and regional levels.
- Reduced maize and wheat imports, with consequent benefits for national balances of trade and reduced dependence on international food aid.
- Diminished environmental degradation, as a result of the more efficient use of land, water, and other inputs.

Geographic Focus:

Sub-Saharan Africa.

CIMMYT Programs Involved:

Maize, Wheat, Economics, Natural Resources, and Applied Biotechnology.

Partners:

Other CGIAR Centers, NARSs in the region, regional and non-governmental organizations, and regional research coordinating institutions such as ASARECA and SACCAR.

Milestones: By the year 2000...

- We will have improved characterization of the region for the incidence and intensity of stresses using GIS, models, and crop distribution data.
- Some 20 maize cultivars will be released by NARSs in the region: cultivars having high and stable yields, as well as excellent resistance to streak, gray leaf spot, and increased and more stable production under drought and low nitrogen, yielding 5-10% more than the best local checks in target environments.
- Ten long-term experimental sites will be developed where drought and/or low nitrogen levels, *Striga*, and borers can be carefully managed as screening tools, and where long-term fertility trends can be determined.
- One to two varieties of durum wheat will be released from crosses of CIMMYT germplasm x Ethiopian landraces; these varieties will be adapted to the waterlogged conditions of Ethiopian wheat production areas and have at least 20% higher yields than current varieties.
- We will identify and release 2-5 varieties of bread wheat that are resistant to stem rust, in order to replace the now susceptible variety Enkoy in Ethiopia.
- We will have reduced the danger of yellow rust by releasing resistant germplasm in East Africa.
- A new crop management system will be introduced that uses recently developed planters (furrow openers) to facilitate more uniform germination in farmers' fields in Ethiopia.
- The wheat genetic variability in the region will be expanded by releasing 2-5 well adapted cultivars in African countries where wheat is an important food commodity.
- At least five alternative management options will be developed for maize, each providing more than a 20% increase in the marginal rate of return over farmer's practices, all resource-conserving, and some showing significant degrees of adoption.

Resource Allocations by TAC Activity Categories (percent of total CIMMYT budget)

Improving Food Security in Sub-Saharan Africa

	%
Enhancement and Breeding	4.84
Production Systems Development and Management	1.65
Protecting the Environment	1.96
Saving Biodiversity	.98
Policy	.31
Training	
Information	
Organization/Management	.37
Networks	.98
System-Wide Programs (Mountain Agriculture)	.78

Regional Project # 2

Meeting the Accelerating Demand for Maize Development, Production, and Delivery in South and Southeast Asia and in China

Problems Being Addressed:

- Rapidly expanding maize demand, forcing maize production into marginal environments or short-duration gaps in the rotation.
- Lack of coordination between private and public breeding sectors to meet specific germplasm needs.
- Inadequate seed infrastructure.
- Poor policy environment for the profitable and rapid expansion of the maize seed industry.
- Lack of alternate suppliers for germplasm with tolerance to abiotic and biotic stresses.
- Lack of high yielding, extra-early maize cultivars to fit short-duration gaps in existing crop rotations.

Project Objective:

Increase maize productivity in South and Southeast Asia and China through better availability of improved OPVs and hybrids of varying maturity, while maintaining yield stability through improved tolerance to the major stresses confronted by maize in the region.

Anticipated Research Outputs:

- Extra-early and early germplasm with high yield, and germplasm suitable for main season and winter maize growing conditions.
- Germplasm with resistance to major biotic and abiotic stresses developed using conventional breeding and biotechnology.
- Assessment of the existing seed industry and identification of constraints to its expansion and policies that encourage its development and promotion.
- Cropping systems suitable for integrating improved germplasm into existing crop rotations and agroclimatic conditions.

Anticipated Impacts:

- Increased food security for the Asian region.
- Increased deployment of improved hybrids and OPVs grown in sustainable production systems, resulting in higher productivity and production.
- Reduced maize crop losses to abiotic and biotic stresses and reduction in dependency on chemicals.
- Increased cooperation and coordination between private seed companies and public breeding institutions for more efficient delivery of enhanced germplasm to small-scale farmers.
- Information to policy makers and research managers for setting research priorities for economic and non-economic objectives.
- National scientists trained in biotechnology applications to maize breeding.

Geographic Focus:

South and Southeast Asia and China.

CIMMYT Programs Involved:

Maize, Applied Biotechnology, Economics, and Natural Resources.

Partners:

Other CGIAR Centers, NARSs in the region, national universities, private seed companies, and NGOs.

Milestones: By the year 2000...

- We will have improved characterization of the region for the incidence and intensity of stresses, via consultation with NARSs and using GIS, models and crop distribution data.
- A stakeholders' meeting will be held with the private sector to identify appropriate projects for improving seed industry/public sector links and projects aimed at improving stress tolerance.
- The exchange of germplasm and manpower between the private and public sectors will be improved.
- We will develop, through collaborative testing, and release 20 elite, early maturing, and stress-tolerant inbred lines for use by NARSs.
- Three to five selection sites will be identified and equipped, where drought, low nitrogen, waterlogging and/or borers occur reliably and where they can be properly managed.
- At least one maize hybrid carrying genes for forming the *Bt* toxin will be deployed.
- Some 20 NARS scientists in the region will be trained in breeding and/or in biotechnology applications to breeding.

Resource Allocations by TAC Activity Categories (percent of total CIMMYT budget)

Meeting the Accelerating Demand for Maize Development, Production, and Delivery in South and Southeast Asia and in China

	%
Enhancement and Breeding	1.23
Production Systems Development and Management	.57
Protecting the Environment	.89
Saving Biodiversity	.45
Policy	.49
Training	.42
Information	.14
Organization/Management	.26
Networks	.45
System-Wide Programs (Other)	.31

Regional Project # 3

Sustainable Wheat Production Systems in the Indo-Gangetic Plains and China

Problems Being Addressed:

- Declining soil productivity and the degradation of the resource base in intensively cultivated wheat-based systems.
- Stagnant/declining productivity of the rice-wheat production system that covers 20 million hectares.
- Limited exchange of germplasm with the other wheat-growing areas and hence an increasingly narrow genetic base in the varieties cultivated.
- Limited progress in achieving resistance to leaf and head diseases of wheat.
- Poor end-use/bread-making quality of wheat.
- Poor understanding of the socioeconomic determinants of farm-level productivity growth.

Project Objectives:

To improve the productivity and sustainability of the diverse wheat and rice-wheat production systems in the Indo-Gangetic Plains and China through enhanced research partnerships, shuttle breeding, and human resource development.

Anticipated Research Outputs:

- Improved agronomic management practices for irrigated rice-wheat and other wheat systems.
- New, more diverse, and system-efficient wheat cultivars with built in biotic and abiotic stress resistance.
- A comprehensive assessment of the causes of stagnant/declining productivity in the rice-wheat system, along with the development of specific recommendations for overcoming them.
- Better analysis of the constraints to sustaining productivity growth upon which agricultural policy decisions can be based.
- Cultivars with improved bread-making quality developed through the international exchange of germplasm.
- Enhanced exchange and sharing of information and germplasm in the region.

Anticipated Impacts:

- Staying abreast of the increasing demands for wheat in the region in a sustainable manner.
- Conservation of natural resources through the reduced spread of agriculture to currently uncultivated areas.
- Reduced temporal and spatial production fluctuations in farmers' fields.
- Formulation of supportive agricultural policies.
- Better regional collaboration.

CIMMYT Programs Involved:

Wheat, Economics, and Natural Resources.

Partners:

Other CGIAR Centers, NARSs in the region, and ARIs.

Milestones: By the year 2000...

- Improved agronomic management practices will be developed for the rice-wheat system in the Indo-Gangetic Plains; all will have elements of sustainability, such as ridge/furrow systems in the Punjab to reduce costs and maximize input efficiency.
- At least 5 potentially higher yielding wheats (some 15% higher than HD2329, released in the mid-1980s) with increased yield stability will be released in the region.
- We will have a better understanding of the production constraints limiting wheat productivity gains in the eastern Subcontinent, especially helminthosporium diseases and excessive heat.
- We will expand the shuttle breeding program for fusarium resistance, yield, and quality between CIMMYT and the Yangtze River Basin region of China, resulting in 15% higher yields over locally bread germplasm.
- The potential for a yellow rust epidemic in the northern Subcontinent will be notably reduced.

Resource Allocations by TAC Activity Categories (percent of total CIMMYT budget)

Sustainable Wheat Production Systems in the Indo-Gangetic Plains and China	%
Enhancement and Breeding	.52
Production Systems Development and Management	.25
Protecting the Environment	1.06
Saving Biodiversity	.26
Policy	.26
Training	.26
Information	.26
Organization/Management	
Networks	
System-Wide Programs (Rice-Wheat Program)	1.71

Regional project # 4

Increasing Cereal Food Production in WANA

Problems Being Addressed:

- Low wheat, maize, and triticale productivity in some irrigated and rainfed environments.
- Lack of suitable germplasm and sustainable cereal-based production systems.
- Increasing pest and insect pressures.
- Low genetic diversity among wheat cultivars grown in the region.
- Increasing degradation of the natural resource base.

Project Objectives:

To enhance the stability and productivity of wheat (bread and durum), maize, and triticale production systems in WANA through the generation and transfer of system-efficient germplasm and sustainable production systems.

Anticipated Research Outputs:

- Improved cultivars that combine productivity, stability, and adaptation to prevalent biotic and abiotic stresses.
- Improved crop management practices that enhance the use efficiency of nutrients, water and other inputs.
- Integrated pest management for the control of yield-limiting pests of cereals (including weeds).
- Greater human resource capacity in the region, developed through research collaboration and training in sustainable crop management practices.

Anticipated Impacts:

- Increased cereal crop productivity in the WANA region through the transfer of system-efficient wheat, maize, and triticale germplasm and implementation of improved production systems.
- Greater food and feed self-sufficiency in the WANA region through a rise in cereal crop output.
- Reduced pressure to cultivate fragile lands as a result of increased productivity of cultivated lands, and reduced damage to the natural resource base arising from the more judicious use of inputs.

CIMMYT Programs Involved:

Wheat, Maize, Economics, Applied Biotechnology, and Natural Resources.

Partners:

ICARDA, NARSs in the region, and ARIs.

Milestones: By the year 2000...

- A shuttle breeding program will be implemented between CIMMYT-Mexico and selected locations in WANA, aimed at solving such disease problems as *Septoria tritici* in durum wheat.
- Improved cultivars for drought tolerance, especially in spring durum wheat, will be forthcoming from the CIMMYT-ICARDA Wheat Breeding Program.
- Increased adoption of triticale for feed/forage will be achieved in North Africa.
- Winter and facultative wheat germplasm improvement for such stresses as drought, heat, and cold will be accelerated, widely adapted germplasm will be identified, and at least 10 varieties with improved stress tolerance will be released in the WANA region.
- We anticipate the development of higher yielding bread wheat genotypes for the irrigated and high rainfall areas of WANA; a 10% yield advantage is the target.

Resource Allocations by TAC Activity Categories (percent of total CIMMYT budget)

Increasing Cereal Food Production in WANA	%
Enhancement and Breeding	1.58
Production Systems Development and Management	
Protecting the Environment	.73
Saving Biodiversity	.50
Policy	
Training	.64
Information	.09
Organization/Management	.18
Networks	.19

Regional Project # 5

Enhancing Maize and Wheat Production Systems in Latin America and the Caribbean

Problems Being Addressed:

- Need for diagnostic information on maize and wheat production ecologies to help better define maize and wheat system productivity/ sustainability problems (in terms of their processes, pace, incidence, causes and consequences), and to help identify areas of potential extrapolation for new technology.
- Need for high-yielding maize and wheat cultivars suited to well-defined production ecologies and that feature, as needed, appropriate grain types, acid soil tolerance, tolerance to pests (including ear worm and armyworm) and diseases, suitability to associations with beans or cassava (maize) or to grazing and stover production systems (wheat).
- Need for improved management practices that foster greater maize and wheat system productivity and sustainability, and that complement the advantages of improved germplasm; these practices may include conservation tillage, green manure cover crops, and improved crop residue management.
- Need for information and analysis on policies and institutional arrangements (including seed industries) that affect farm-level adoption of new maize and wheat varieties and management practices.

Project Objective:

To increase the productivity and sustainability of maize- and wheat-based systems in Latin America and the Caribbean.

Anticipated Research Outputs:

- Improved definition of productivity/ sustainability problems affecting maize and wheat systems — in terms of their processes, pace, incidence, causes and consequences in major production ecologies — to help design technologies and plan and target research.
- A wider array of prototype solutions to major maize and wheat system problems, featuring improved germplasm as well as improved system management; these prototypes can be tailored by NARSs, NGOs and other stakeholders to the circumstances of distinct farming systems in the region. Improved germplasm outputs will include high-yielding maize and wheat cultivars suited to well-defined production ecologies and that feature, as needed, acid soil tolerance, tolerance to pests and diseases, and other characteristics described above.
- Information on factors governing adoption of productivity-enhancing, resource-conserving practices for maize and wheat systems in the region — to help our research partners accelerate adoption through guided policy and institutional change.
- Improved understanding of on-site and off-site, near-term and longer-term, economic and environmental consequences of technical change in maize and wheat systems — to guide priority-setting in further rounds of research.

Anticipated Impacts:

- Improved maize and wheat productivity in Latin American and Caribbean ecosystems.
- Increased sustainability of production systems through improved technologies for residue management, reduced tillage, and IPM.

- Reduced pressure on tropical rainforests and other marginal lands in Latin America from farming, brought about through greater and more sustainable production of wheat and maize on lands already under cultivation.

CIMMYT Programs Involved:

Maize, Wheat, Economics, Applied Biotechnology, and Natural Resources.

Partners:

Other CGIAR Centers, NARSs in the region, and ARIs.

Milestones: By the year 2000...

- A set of publications will be developed that clearly define the productivity and sustainability challenges facing maize and wheat systems in the region, including information on the pace, incidence, processes, causes, and consequences of these problems.
- Improved maize and wheat germplasm – lines, varieties, and hybrids – will be developed and shared with regional research partners, contributing to the solution of important productivity and sustainability problems. These materials will feature, as needed, appropriate grain type, acid soil tolerance, tolerance to pests (including earworm and army worm), tolerance to important diseases in the region, as well as other characteristics.
- A regional rust laboratory will be established in the Southern Come.
- Improved crop and system management practices will be developed and tested, their performance under different conditions quantified and understood, and adaptation to defined farming systems underway – these include such practices as conservation tillage, residue management, green manures, living fences, and grazing practices.
- A set of publications will be released describing factors governing adoption of improved maize and wheat germplasm, and relevant crop and system management practices.
- An endeavor will be underway to inform the debate relative to policies and institutional arrangements that influence farmer adoption of maize and wheat germplasm and management practices.

Resource Allocations by TAC Activity Categories (percent of total CIMMYT budget)

Enhancing Maize and Wheat Production Systems in Latin America and the Caribbean

	%
Enhancement and Breeding	1.39
Production Systems Development and Management	.56
Protecting the Environment	1.24
Saving Biodiversity	.68
Policy	.25
Training	.66
Information	.37
Organization/Management	.37
Networks	.57
System-Wide Programs (Latin America Ecoregional Program)	4.35

Frontier Project # 1

Raising the Yield Potential of Wheat

Problems Being Addressed:

- Stagnating farm-level yields in high yield-potential areas.
- Increasing incidence of lodging in high-yielding, high-input environments.
- Significant year-to-year variability in yields.

Project Objectives:

To raise the yield potential and yield stability of wheat through:

- the definition and use of heterosis;
- the development of alternate plant types and physiological processes;
- the utilization of diverse and novel genotypes; and
- the development of improved crop management systems.

Anticipated Research Outputs:

- Exploitation of hybrid technology.
- Cultivars with alternate plant architectures and physiological processes, leading to a more efficient use of available nutrients, moisture, and solar radiation.
- Lodging-tolerant varieties.
- Crop management systems conducive to the realization of yield potential.

Anticipated impact(s):

- Increased productivity of wheat in high production areas and other environments.
- Staying abreast of the growing demand for wheat.
- Reduced expansion of agriculture into natural ecosystems.

CIMMYT Programs Involved:

Wheat, Applied Biotechnology, Economics, and Natural Resources.

Partners:

Other CGIAR Centers, NARSs, and ARIs.

Milestones: By the year 2000...

- A hybrid wheat program to exploit heterosis of special genetic stocks will be implemented. Some 3,000 hybrid combinations will be made and tested by then to delineate heterotic groups.
- New plant types (ideotypes) for plant architecture, canopy temperature, and other physiological processes will be defined.
- Plants with superior lodging tolerance (capable of withstanding yields of 10 tons per hectare) will be identified.
- A systematic search will be underway in landrace accessions, especially from Iran and Turkey, for genes that confer higher yields.

Resource Allocations by TAC Activity Categories (percent of total CIMMYT budget)

Raising the Yield Potential of Wheat

	%
Enhancement and Breeding	1.08
Production Systems Development and Management	
Protecting the Environment	
Saving Biodiversity	
Policy	
Training	
Information	.06
Organization/Management	.06
Networks	

Frontier Project #2

Apomixis — Equity in Access to Hybrid Vigor for Resource-Poor Farmers

Problem Being Addressed:

Small-scale farmers have limited access to seed of improved varieties, especially hybrids, and recycle their own seed, which results in heterogeneous, low-yielding crops. Once apomixis is introduced into varieties made available to farmers, it would allow the fixation of beneficial genes and the preservation of advantageous characteristics, such as heterosis, generation after generation.

Project Objectives:

- Production of apomictic maize germplasm.
- Characterization and isolation of the gene(s) controlling apomixis.
- Development of genetic engineering protocols to test apomixis expression and transfer apomixis to crops other than maize.
- Development of new breeding strategies that take advantage of apomictic varieties.
- Development of deployment strategies for apomictic varieties in small-scale farming systems.

Anticipated Research Outputs:

- Apomictic maize germplasm, distributed to breeders in NARSs.
- Markers linked to apomixis, used as screening tools in breeding programs.
- Gene constructs, including apomixis gene(s) and ovary-specific promoters.
- Transgenic apomictic wheat and maize.
- New breeding methods for producing apomictic crops.
- Strategies (recommendations) for deployment of apomictic crops in different farming systems.

Anticipated Impacts:

- Sustainable production increases in small-scale farming systems.
- Use of hybrid vigor in crops where the use of hybrids was so far not economically feasible.

CIMMYT Programs Involved:

Applied Biotechnology, Maize, Wheat, Economics, and Natural Resources.

Partners:

Other CGIAR Centers, NARSs, private sector breeding companies, and ARIs.

Milestones: By the year 2000...

- We will have enhanced knowledge of the genetic basis of apomixis in Tripsacum.
- The first apomictic maize plant(s) will be in hand.
- We will have completed the isolation and sequencing of one or more genes involved in apomixis.
- Information will be developed regarding the potential impact of apomictic varieties in developing countries.
- Draft strategies will be developed for the use and deployment of apomictic maize varieties.

Resource Allocations by TAC Activity Categories (percent of total CIMMYT budget)

Apomixis — Equity in the Access to Hybrid Vigor for Resource-Poor Farmers

	%
Enhancement and Breeding	.92
Production Systems Development and Management	.16
Protecting the Environment	
Saving Biodiversity	.16
Policy	
Training	
Information	
Organization/Management	
Networks	

Frontier Project # 3

Using Genetic Engineering to Improve Tolerance to Biotic and Abiotic Stresses in Wheat and Tropical Maize

Problem Being Addressed:

Host plant resistance/tolerance to various pathogens, pests and adverse environmental conditions is not always sufficient or easily transferable through conventional breeding schemes. Genetic engineering allows the insertion of genes from unrelated organisms, which can have novel effects in combating the stresses faced by maize and wheat, therefore enhancing their levels of resistance.

Project Objectives:

- Development of genetically engineered maize and wheat with enhanced tolerance to biotic and abiotic stresses which are specific to tropical and subtropical environments.
- Identification and acquisition of genes conferring resistance/tolerance to various biotic and abiotic stresses.
- Development of efficient transformation techniques for both maize and wheat.
- Development of breeding strategies for the efficient transfer of transgenes.
- Development of deployment strategies for transgenic maize and wheat in small-scale farming systems.
- Training of developing country scientists in the development and use of transgenics.

Anticipated Research Outputs:

- Efficient transformation methods for wheat and maize.
- Gene constructs, including stress resistance genes and high activity promoters (constitutive and inducible).
- Transgenic maize and wheat germplasm with enhanced resistance to major insect pests and pathogens, distributed to breeders in NARSs.
- Appropriate biosafety measures/regulations to test transgenic materials in greenhouse and field trials in developing countries.
- Breeding strategies, conventional and marker-assisted, to transfer transgenes to other germplasm.
- Management strategies for deployment of transgenics in various farming systems to optimize effectiveness and longevity of the genetically engineered germplasm.

Anticipated Impacts:

- Improved sustainability and reduced pesticide loading in fragile ecosystems through enhanced levels of plant resistance to insects and diseases.
- Reduction in yield losses caused by biotic and/or abiotic stresses.
- Increased longevity of resistance to pests and pathogens through the combination of genetically engineered and host-plant mechanisms.

CIMMYT Programs Involved:

Applied Biotechnology, Maize, Wheat, Economics, and Natural Resources.

Partners:

Other CGIAR Centers, NARSs, private sector breeding companies, and ARIs.

Milestones: By the year 2000...

- Genetic engineering technology for CIMMYT elite maize and wheat germplasm will be developed.
- Field trials of transgenic germplasm will be conducted in at least two developing countries other than Mexico.
- Options for training developing country scientists in the development and deployment of transgenic plants will be determined.
- Tropical maize containing one or more *Bt* genes conferring resistance to one or more tropical insect pests will be developed.
- Transgenic wheats containing fungal resistance or modified quality genes will be developed.

Resource Allocations by TAC Activity Categories (percent of total CIMMYT budget)

Using Genetic Engineering to Improve Tolerance to Biotic and Abiotic Stresses in Wheat and Tropical Maize

	%
Enhancement and Breeding	1.24
Production Systems Development and Management	
Protecting the Environment	1.48
Saving Biodiversity	.60
Policy	
Training	.16
Information	.12
Organization/Management	
Networks	

Frontier Project #4

Improving Human Nutrition by Enhancing Bio-Available Protein and Micronutrient Concentrations in Maize, Wheat, and Triticale

Problems Being Addressed:

- Deficiencies in protein of high biological value, and of iron, zinc and vitamin A in diets of poor consumers in developing countries. Deficiencies can be especially acute in women of child-bearing age and in small children shortly after weaning, when they are often transferred from breast milk to a poorly balanced carbohydrate diet.
- Previous efforts to introduce quality protein maize into areas where maize is consumed as food have generally failed.

Project Objectives:

- Develop input-efficient and productive wheat and maize varieties (or hybrids) possessing grain with quality protein (maize) or enhanced protein levels, adapted to areas where per capita maize and wheat consumption is high. To this will be added enhanced concentrations of iron, zinc and vitamin A, as needed by targeted consumer groups.
- Determine the genetic relationships between concentration of nutrients and grain yield, and overcome any negative correlations which may exist.
- Develop efficient field screening methods for selecting micronutrient-enriched grains.
- Identify molecular markers associated with high concentrations of zinc, iron and vitamin A in the three crops, and with the *opaque* 2 genes and its modifiers in maize.
- Determine the factors affecting adoption by resource-poor households of varieties with nutrient-enriched grain, and identify key constraints.

Anticipated Research Outputs:

- Improved, locally adapted maize populations and hybrids with at least double the levels of essential amino acids, lysine and tryptophan compared to normal endosperm maize.
- High-yielding, adapted wheat varieties with around 30% higher levels of protein than normal.
- High-yielding, adapted wheat and white-grained maize varieties with around 30% higher levels of iron, zinc and/or vitamin A, yet with non-toxic levels of other micronutrients.
- Information on the feasibility of developing nutrient-enhanced maize, wheat and triticale varieties.
- Identification of donor stocks for nutrient-enriched grains, and the development of markers that will allow the efficient transfer of these traits to elite germplasm.
- Identification of the factors influencing the adoption and use of nutrient-enriched grains by resource-poor families with high cereal consumption in the developing world.

Anticipated impacts:

- Improved nutrition of rural and urban poor women and children in developing countries.
- Faster growth and lower morbidity rates among recently weaned children in areas where cereals form a large part of the diet.
- Less dependence on animal protein for balanced nutrition.

CIMMYT Programs Involved:

Maize, Wheat, Economics, and Applied Biotechnology.

Partners:

Other CGIAR Centers, NARSs, ARIs, and NGOs.

Milestones: By the year 2000...

- At least 10 new tropical and subtropical inbred maize lines will be released that are resistant to ear rot and that have good general combining ability and improved protein quality.
- In collaboration with NARS in specific target countries, at least 10 hybrids and synthetic maize cultivars with stable yield and improved protein quality will be identified and released.
- We will determine, using nutrient levels in major maize food products derived from maize, the genetic relationships among micronutrient concentration and yield.
- We will identify maize genotypes with stable grain concentrations of iron and zinc that are more than two times the average for all genotypes examined.
- We will have screened at least 50 representative wheat genotypes for variability in zinc concentration.

Resource Allocations by TAC Activity Categories (percent of total CIMMYT budget)

Improving Human Nutrition by Enhancing Bio-Available Protein and Micronutrient Concentrations in Maize, Wheat, and Triticale

	%
Enhancement and Breeding	.66
Production Systems Development and Management	.24
Protecting the Environment	
Saving Biodiversity	
Policy	
Training	.07
Information	.08
Organization/Management	.07
Networks	

Frontier Project # 5

Genetic Approaches to Reducing Post-harvest Losses

Problems Being Addressed:

- Post-harvest grain losses to various pathogens, insect pests and adverse environmental conditions and the resulting food insecurity.
- The production of carcinogenic mycotoxins in maize and wheat as a result of pre- and post-harvest diseases.
- Poor management of grain storage in developing countries, which adversely affects the quality and longevity of improved maize and wheat germplasm and, therefore, food security.

Project Objectives:

- Development of genetic sources of resistance in wheat and maize to insect and disease pests found in tropical and subtropical storage systems.
- Development of efficient screening technology for characterizing grain resistance to biotic stresses.
- Development of breeding strategies using conventional and molecular techniques to incorporate resistance into agronomically elite germplasm.
- Identification and acquisition of genes conferring resistance to insect and disease pests in grain stores.
- Development of drying technology and storage techniques which are conducive to tropical and subtropical environments.
- Training of developing country scientists in storage technology for maize and wheat with a focus on improved germplasm, harvest practices, grain drying, and storage facilities.

Anticipated Research Outputs:

- Screening methods which can accelerate conventional breeding programs.
- Maize and wheat lines and varieties which have elevated levels of conventional resistance to post-harvest insect and disease pests.
- Published reports on the mechanisms and inheritance of maize and wheat resistance to insect and disease pests.
- Management protocols that preserve grain quality for extended periods of storage through improved storage technologies.
- Human resource development by equipping scientists with the tools needed for improving maize and wheat grain storage.

Anticipated Impacts:

- Reduced grain storage losses, and hence improved food security in developing countries where grain is stored for extended periods.
- Improved human and animal health through reduced levels of mycotoxin contamination and insect damage.
- Increased profits for farmers who use germplasm with improved storage properties.

CIMMYT Programs Involved:

Maize, Wheat, Applied Biotechnology, Natural Resources, and Economics.

Partners:

Other CGIAR Centers, NARSs, ARIs, and NGOs.

Milestones: By the year 2000...

- We will determine the genetic variability for resistance to two major maize storage pests among CIMMYT's elite inbred lines and landrace collections having acceptable agronomic performance.
- With breeders working on Global Project 2, we will implement a breeding program aimed at pyramiding genes for resistance to storage pests and for yield.
- Resistance to at least one major storage pest will be mapped using RFLPs.
- We will identify two options for improved on-farm storage that have attractive marginal rates of return and acceptable levels of environmental impact.

Resource Allocations by TAC Activity Categories (percent of total CIMMYT budget)

Genetic Approaches to Reducing Post-harvest Losses

	%
Enhancement and Breeding	.31
Production Systems Development and Management	.05
Protecting the Environment	.44
Saving Biodiversity	
Policy	
Training	
Information	.05
Organization/Management	
Networks	

Frontier Project # 6

Priority Setting and Technology Forecasting for Increased Research Efficiency

Problems Being Addressed:

- Inefficient allocation of scarce research resources in national programs and international research centers.
- Excessive and unnecessary duplication of research.

Project Objective:

To strengthen priority setting in research resource allocation for maize and wheat, based on constraints analysis and technology forecasting.

Anticipated Research Outputs:

- Methodologies for improved research resource allocation at the national program and the international center levels.
- Improved understanding of the constraints to increasing productivity at the farm level.
- Projections of new technological developments for wheat and maize and their likely impact.

Anticipated Impacts:

- A more rational system of research resource allocation adopted by the national programs and the international research system.
- Research resources more clearly targeted toward alleviating farm-level constraints to increasing and/or sustaining productivity growth.
- Greater congruency between technology generation and policy formulation through the use of technology projections.

CIMMYT Programs Involved:

Economics, Wheat, Maize, Applied Biotechnology, and Natural Resources.

Partners:

Other CGIAR Centers, NARSs, and ARIs.

Milestones: By the year 2000...

- An *ex ante* assessment of the impact of biotechnology on maize productivity growth will be completed, with particular emphasis on apomixis and marker-assisted selection.
- The technological prospects for unfavorable maize and wheat production environments will be assessed.
- Methods will be developed for assisting in the allocation of resources across crops and major activities with a particular crop research program.

Resource Allocations by TAC Activity Categories (percent of total CIMMYT budget)

Priority Setting and Technology Forecasting for Increased Research Efficiency

	%
Enhancement and Breeding	.30
Production Systems Development and Management	.22
Protecting the Environment	.22
Saving Biodiversity	
Policy	.36
Training	
Information	
Organization/Management	.15
Networks	

Frontier Project # 7

Learning to More Effectively Confront Problems of Resource Degradation in Maize and Wheat Systems

Problems Being Addressed:

- There are many instances where maize or wheat systems are not sustainable because the quality of resources (soil, water, nutrients, genetic diversity) devoted to these systems is threatened. In general, available research methods are not adequate for rapidly defining, understanding, and solving these problems.
- In addressing major NRM problems, scientists with different disciplinary backgrounds often find it hard to integrate their efforts. Typically lacking is a framework that outlines suitable roles in NRM for plant breeders, soils scientists, agronomists, ecologists, crop modelers, GIS experts, participatory research practitioners, social scientists, and extension workers (among others). Similarly, representatives of different collaborating institutions often find it difficult to achieve a truly fruitful partnership.
- The effectiveness of NRM often is hindered by an inability to "scale up" — to synthesize research findings across research sites (and from previous relevant research); to understand the geographical incidence of problems and the likely geographical extrapolation of possible solutions; and to understand the links among levels of system hierarchy.

Project Objectives:

To foster the development of more productive and sustainable maize and wheat systems through more effective approaches to natural resources management research, including:

- Improved methods for defining natural resource problems — to gain a better understanding of their underlying processes, their incidence and associated pace of change, their causes, and their consequences in terms of near-term and longer-term agricultural system productivity, resource quality, off-site and environmental effects.
- Improved methods for expanding the menu of technical and policy options for addressing productivity/sustainability problems — including ways to combine local knowledge with scientists' knowledge.
- Improved methods for accelerating adoption of productivity-enhancing, resource-conserving practices in maize and wheat systems by fostering participatory research, assessing constraints to adoption, and by fostering dialogue among stakeholders, including policymakers.
- Improved methods for "scaling up," including geographical extrapolation.

Anticipated Research Outputs:

- A robust and effective overarching framework for research on NRM, acceptable to a wide range of stakeholders and partners, and featuring improved research methods.
- Training materials and other publications that distill and document improved NRM research approaches and methods.
- Better collaboration among scientists from different disciplines and representatives of different research partners, and an improved understanding of how to manage research on NRM.
- More rapid development and dissemination of productivity-enhancing, resource-conserving practices for maize and wheat systems.
- Improved understanding of the consequences of resource degradation, and the effects of technical change on resource quality and system productivity, at different levels of system hierarchy.

Anticipated Impacts:

- More productive and sustainable maize and wheat systems.
- Improved rural incomes and employment, reduced poverty, and the conservation of natural resources.

CIMMYT Programs Involved:

Maize, Wheat, Economics, Applied Biotechnology, and Natural Resources.

Partners:

Other CGIAR Centers, NARSs, ARIs, NGOs, and other stakeholders.

Milestones: By the year 2000...

- A set of publications will be produced that clearly document the experience in natural resource management research in CIMMYT's regional programs – including a synthesis of lessons learned relative to research methods and management.
- A publication will be released that describes CIMMYT's corporate approach to research on sustainable systems – and the rationale behind that approach.
- Training materials will be developed based on CIMMYT's approach to research on sustainable systems and drawing on our regional experience in natural resource management research.
- CIMMYT's own internal research will be characterized by measurably closer research integration, using a wider array of research methods than at present, and featuring more effective and efficient interaction with research partners.

Resource Allocations by TAC Activity Categories (percent of total CIMMYT budget)

Learning to More Effectively Confront Problems of Resource Degradation in Maize and Wheat Systems

	%
Enhancement and Breeding	
Production Systems Development and Management	.15
Protecting the Environment	.47
Saving Biodiversity	.25
Policy	.10
Training	.15
Information	.16
Organization/Management	.15
Networks	

Special Focus Project # 1

Wheat Germplasm Development in the Newly Independent States

Problems Being Addressed:

- Lack of access to germplasm from other programs in the region.
- Lack of trained scientists, in particular in Tajikistan and Turkmenistan.
- Lack of funds and low salaries.
- Old equipment and no money for maintenance.
- No germplasm exchange with other programs because of high shipping costs.
- Lack of communication with other programs, both in and outside the former Soviet Union.
- Limited access to non-Russian literature; few scientists know English.

Project Objectives:

- To increase wheat production and contribute to food security through increased disease resistance, yield, and yield stability.
- To protect the soils from increased salinity through development of drought-tolerant wheats to reduce the needs for scarce irrigation water.

Anticipated Research Outputs:

- New cultivars identified.
- Development of segregating populations for selection of lines for rainfed and irrigated conditions.
- Network between regional breeding programs for testing and germplasm exchange.

Anticipated Impacts:

- Access to a wide range of genetically diverse wheat germplasm.
- Stronger NARSs.

CIMMYT Programs Involved:

Wheat, Economics, and Natural Resources.

Partners:

Other CGIAR Centers, NARSs in the region, ARIs, and other stakeholders.

Milestones: By the year 2000...

- A network will be established that involves NARSs, CIMMYT, and ARIs to understand the ecology, disease spectrum, soil, and plant performance in the region.
- An active and targeted training program will be implemented.
- A regional outreach program will be established in the newly independent states.

Resource Allocations by TAC Activity Categories (percent of total CIMMYT budget)

Wheat Germplasm Development in the Newly Independent States

	%
Enhancement and Breeding	
Production Systems Development and Management	
Protecting the Environment	
Saving Biodiversity	
Policy	
Training	
Information	
Organization/Management	
Networks	

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