





CIMMYT
Medium-Term Plan
2008-2010

Translating Strategic Vision to a Vibrant Work Plan

CIMMYT

CIMMYT MTP 2008-2010

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Introduction

The new vision and strategy for CIMMYT to increase its contribution to reducing poverty and hunger by 2020 was articulated in the center's strategic plan: "Seeds of Innovation" (2004), which asked that CIMMYT undertake research "*more sharply* [focused] *on reducing people's vulnerability to poverty by looking at the entire context in which poor households operate and not exclusively at maize or wheat*" [see Box 1]

As outlined in CIMMYT's Business Plan (2006-2010), the center's MTP Project portfolio addresses the needs of poor producers and consumers through eco-regional and cropping systems approaches, but within the framework of a global maize and wheat research-for-development agenda. The MTP Project portfolio reflects internal structure and delivery mechanisms within a product-oriented framework that sets out nine complementary flagship products (see below). Each Project includes a flagship product, through which CIMMYT science and innovation deliver impact across one or more eco-regions. The MTP Projects embody interdisciplinary research and the decentralization of undertakings across the locations where CIMMYT and its partners work to develop and deliver products. Each Project is an operational unit with clearly-defined goals, membership responsibilities, and leadership. The main undertakings are guided by eco-regional priority setting and impact targeting analysis, with a focus on research activities that deliver effective and sustainable impacts to beneficiaries. Many CIMMYT core products involve value-added germplasm addressing major production and use needs. The center also generates tools and methodologies to help national programs make best use of strategic germplasm in adaptive breeding research and provides training in key aspects of crop improvement. Other disciplinary activities support cropping system resource management and socio-economic analysis and advocacy.

CIMMYT flagship products

- Stress tolerant maize for enhanced food security and crop diversification
- Wheat with enhanced water productivity and appropriate quality profiles
- Rust resistant wheat
- Bio-fortified maize for improved nutrition and health
- New or improved traits through gene discovery and allele mining
- Improved tools and methodologies for genetic improvement
- Capacity-building in NARS and SME breeding programs
- Resource-conserving technologies for maize and wheat cropping systems
- Opportunities for income generation from special trait maize

Box 1 – CIMMYT in 2020:

"Building 'Seeds of Innovation' to address the Globalization Challenge"
CIMMYT acts as a catalyst and leader in a global maize and wheat innovation network that serves the poor in the developing world. Drawing on strong science and effective partnerships, CIMMYT researchers create, share, and use knowledge and technology to increase food security, improve the productivity and profitability of farming systems and sustain natural resources. This people-centered mission does not ignore the fact that CIMMYT's unique niche is as a genetic resources enhancement center for the developing world. As the CGIAR Science Council pointed out in their comments about the Business Plan and the previous rolling Medium-Term Plan (MTP): "*Overall CIMMYT has focused its research in areas where it has a clear competitive advantage. Furthermore, throughout the MTP, it emphasizes the role NARS play in the delivery of impacts from CIMMYT programs. It appears that CIMMYT is taking on the concepts of alternative suppliers and moving upstream as responsibilities are handed over to the stronger NARS. It emphasizes its role as facilitator and enabler in the overall value chain while moving away from being a 'primary provider of advanced breeding materials'. The SC encourages this shift.*"

CIMMYT value proposition[1] resides in its use of maize and wheat genetic diversity: conserving it, studying it, adding value to it, and sharing it in enhanced form with clients worldwide. The main undertakings include:

- Long-term safe conservation of world heritage of maize and wheat genetic resources for future generations, in line with formal agreements under the 2004 International Treaty on Plant Genetic Resources for Food and Agriculture.
- Understanding the rich genetic diversity of two of the most important staples worldwide.
- Exploiting the untapped value of maize and wheat genetic resources through discovery of specific, strategically important traits required for current and future generations of target beneficiaries.
- Development of strategic maize and wheat germplasm through innovative genetic enhancement.

The Center needs to ensure that its main products reach end-users and improve their livelihoods. In this regard, CIMMYT remains as the main international, public source of seed-embedded technology to reduce vulnerability and alleviate poverty, helping farmers move from subsistence to income-generating production systems. Maize and wheat cropping systems have different technology and policy concerns. The Center's socioeconomic and policy research on such systems fosters its catalytic role, improving the targeting of traits (from discovery to delivery) and of beneficiaries, and assessing the impacts on livelihoods of the Center's efforts. Beyond a focus on higher grain yields and value-added wheat and maize germplasm, CIMMYT's plays an "integrator" role in crop and natural resource management research, promoting the efficient use of water and other inputs, lower production costs, better management of biotic stresses, and enhanced system diversity and resilience.

[1] The unique added value an organization offers customers through their operations

2006 Highlights

Flagship product development and delivery

The flagship products are international public goods, align with the CGIAR priorities, and embrace a broad range of research partnerships worldwide. In most cases they constitute genetically enhanced, seed-embedded technologies for which pathways to impact on poverty and livelihoods have been mapped out.

Stress tolerant maize for enhanced food security and crop diversification: CIMMYT received the 2006 CGIAR King Baudouin Award for an innovative, ongoing series of maize-breeding projects in eastern and southern Africa that have resulted in more than 50 new cultivars that are grown on at least one million hectares. The work has produced not only plant types that tolerate drought, low soil fertility, parasitic weeds, and other common plant stresses; it has revolutionized the way in which new cultivars are developed and selected. In a fundamental change from the customary practice of testing new breeding materials under well-fertilized and well-irrigated conditions, CIMMYT researchers, national agricultural research centers, and private sector partners created a network of regional "stress breeding" sites that, for the first time, provide objective information on how well maize cultivars perform under conditions faced by poor farmers, especially drought and infertile soils. By working in partnership with local communities and by replicating the poor conditions found in farmers' fields, the approach is tailored to meet the needs of poor farmers who have not benefited from conventional breeding programs. *[System Priorities 2A, 2B, 2C]*

Wheat with enhanced water productivity and appropriate quality profiles: CIMMYT continues to develop and distribute relevant wheat germplasm products. During 2006 partners received 750 lines of advanced spring and winter wheat and spring durum wheat. A further 300 segregating populations with tolerances to various abiotic and biotic stresses were distributed, in line with the increasing emphasis on intermediate products for wheat breeders in national programs. CIMMYT researchers have also continued important efforts to develop methodologies and associated knowledge. A key area recently is research to integrate physiological trait-based approaches into conventional breeding schemes, as part of work on complex traits associated with yield and stress adaptation. CIMMYT wheat researchers are also using comprehensive environmental and phenotypic data to expand knowledge of genotype x environment interactions. This research will be catalyzed by new tools and methodologies in geographic information systems, advanced statistics, modeling, and bioinformatics [see Box 2-Wheat Phenome Atlas]. *[System Priority 2B]*

Rust resistant wheat: The Global Rust Initiative was launched with ICARDA and national partners in 2005 to tackle a real threat posed by a new, highly-virulent stem rust strain: Ug99. In trials on the Kenya Agricultural Research Institute (KARI) station at Njoro, CIMMYT and partners have recently found that more than 85% of the entries—which included widely-sown cultivars from major wheat-producing regions of the world—succumbed to Ug99, and certain wheat lines which appeared resistant to Ug99 a year ago now show susceptibility. This suggests that Ug99 represents a much greater risk to world wheat production than originally thought, and projections of potential losses for Africa, the Middle East, and South Asia run at US$ 3 billion per year, if the strain spreads to major wheat lands there. CIMMYT is scaling up efforts with partners to test new germplasm for yield, local adaptation, and stem rust resistance. There is reason for optimism, given that as much as 10% of the lines tested thus far show resistance to Ug99. In

2006, CIMMYT distributed the first stem rust resistance screening nursery, comprising some 100 resistant lines. *[System Priority 2A]*

Biofortified maize for improved nutrition and health: The main focus of this work continues to be the development of germplasm, methodologies, and knowledge associated with *B*-carotene and provitamin A concentrations. Last year CIMMYT researchers fully implemented an HPLC protocol for *B*-carotene analysis. Progress to develop and deploy quality protein maize (QPM) cultivars continues; special emphasis has been given to building partners' capacities to accomplish this. CIMMYT is supporting local seed companies with training in QPM seed production. The Western Seed Company and Freshco Ltd of Kenya have produced and marketed seed of an extra-early, drought-tolerant, open-pollinated QPM cultivar and two QPM hybrids. *[System Priority 2C]*

New alleles and genes from global crop biodiversity for priority trait improvement: During 2006 CIMMYT and partners have focused on the preservation of populations of teosinte, a wild relative of maize. A collecting mission in Mexico, led by INIFAP, has found a new teosinte population (perhaps *Zea luxurians*) that seems to have been grown since the 1930s in river beds under very wet conditions. Further research will be conducted to see whether the teosinte carries a flood adaptation trait that could be useful in the rice-maize cropping systems in Asia or in other regions of the world. In addition, CIMMYT and partners from ICTA-Guatemala and Cornell University, USA, undertook an in-situ monitoring mission for *Tripsacum* in Guatemala. The team found *T. lanceolatum, T. pilosum, T. jalapense or T. dactyloides* ssp. *hispidum, T. latifolium* or *T. maizar intermediate,* and *T. laxum*. DNA samples as well as herbarium samples will be used for further taxonomic research. Due to the threat of extinction of these species, future work will aim at rescuing the plants and transplanting them to ICTA field stations. Seed samples will later be harvested for preservation in genebanks. *[System Priority 1A]*

Improved tools and methodologies for genetic improvement: In collaboration with the University of Hohenheim, Germany, DNA-marker-aided research has shown that modern breeding techniques at CIMMYT have restored genetic diversity in CIMMYT's improved wheat germplasm and brought wheat's wild relatives back into the gene pool. By examining the DNA of the landraces of wheat grown by farmers before modern breeding and comparing it with DNA from the most popular modern cultivars and the newest breeding materials from CIMMYT, the team was able to confirm the decline in diversity in popular, current wheat varieties, while demonstrating that new wheat lines from CIMMYT had genetic diversity similar to that in the pre-Green Revolution landraces, with the improved yields, disease resistance, and other beneficial traits of the modern wheats. The research shows that the successful incorporation and re-mixing of genetic diversity from wheat's wild relatives has created wheat containing more variation than has ever been available to farmers and breeders—possibly since hexaploid wheat first appeared 8,000 years ago.

CIMMYT continued association genetics research using DNA markers and data from international, elite wheat trials. The aim is to dissect variation and map it onto the wheat genome—the first step in a major global wheat research partnership (see Box 2-Wheat Phenome Atlas for details). Grain yield, maturity, and leaf and stripe rust were analyzed across several locations. Preliminary results are very promising, with 23 significant markers found for grain yield. *[System Priority 1A, 2A, 2B]*

Box 2– Wheat Phenome Atlas

The emergence of molecular genomic technologies has created opportunities to develop new and revolutionary approaches for future plant and animal selection and breeding. The power of molecular genomics will be fully realized when used in combination with classical quantitative genetics to integrate and comparatively analyze phenotypic, pedigree, and genotypic information for important traits. Nearly half a century of world-wide research into breeding and selection by CIMMYT has resulted in a vast accumulation of knowledge and genetic resources. CIMMYT has collated extensive historical phenotypic and genealogical information on approximately 13,000 elite wheat breeding lines and seed has been conserved from all these lines. The phenotypic data were derived from more than 40 years of international trials (since 1964) and 25 years of the International Rust Nurseries (from 1950 until 1974). These trials are organized by CIMMYT and conducted by NARS partners in over 70 wheat-producing countries. Ten or more nurseries containing from 50 to 400 entries each, targeted to 6 global agro-ecological zones, are distributed each year. There are about 17 million phenotypic data points for over 80 economically important traits across the 13,000 wheat lines evaluated in more than 10,000 field trials. The full pedigrees and selection histories of all entries are known and the data cover yield and agronomic, pathological, and quality traits. A conservative estimate puts the value of reproducing these pedigree and phenotypic data at over US$500 million. This unique combination of large information resources and a comprehensive germplasm collection will allow wheat to become the first crop species in the public sector for which a new paradigm of knowledge-led plant breeding will be applied. In 2006, the University of Queensland (UQ, Australia) and CIMMYT started a small pilot project with their own limited funds to develop technology for future genetic improvement of wheat applying their accumulated interdisciplinary knowledge and skills in plant breeding, quantitative genetics, plant molecular genomics, and bioinformatics. CIMMYT and UQ are seeking additional resources to genotype all relevant lines in CIMMYT's germplasm bank, develop integrated wheat phenome maps, and release a Wheat Phenome Atlas. The latter is expected to revolutionize wheat selection and breeding, particularly through the modeling of the historical data to create predicative, simulation-based decision support systems for molecular breeding. More resources are needed for this team and new research partners to produce a Phenome Atlas Toolbox. This will comprise a publicly-available information management system, an analysis system, and all publicly available data. It should result in a much improved understanding of gene x genotype x environment interactions, of great use in breeding.

Capacity building in the breeding programs of national agricultural research systems (NARSs) and small and medium-scale enterprises (SMEs):[2] There were many capacity building activities in 2006: almost 2,000 participants took part in 8 field days and some 1,250 scientists and extension workers participated in a range of workshops, conferences, and traveling seminars (26 in total). In addition to the various training and other events already mentioned, CIMMYT places high importance on graduate students; last year 96 students conducted their thesis work under the co-supervision of CIMMYT researchers. CIMMYT is continually assessing training needs and increasing the diversity of training approaches. Towards this aim, significant progress has been made with internet-based knowledge-sharing products, including MaizeDoctor and WheatDoctor, under one of the three joint alliance project with IRRI. *[System Priority 2A, 2B, 2C]*

[2] Here national agricultural research systems is understood as the gamut of players contributing to agricultural research and development in a country: publicly-funded research and extension programs, ministries of agriculture, national universities, non-government and civil society organizations (the latter including farmer associations), and others. The term may also be understood to include small- and medium-scale enterprises (SMEs), such as local seed companies, although CIMMYT has chosen to mention the latter separately in recognition of their important role in provide farmers with access to quality seed in difficult settings and the center's commitment to support their efforts.

Resource conservation technologies for maize and wheat cropping systems: Zero- or reduced-tillage for growing wheat after rice saves water, diesel, and other inputs, and allows earlier sowing of wheat, which raises yields. The practice has been adopted by farmers in South Asia over the past six years. This is largely a result of work to test and promote zero-tillage and other resource-conserving practices by the Rice-Wheat Consortium for the Indo-Gangetic Plains [see Box 3 below with more details], which includes the national agricultural research systems of Bangladesh, India, Nepal and Pakistan; several centers of the CGIAR (with CIMMYT as the facilitator), and various advanced research institutes.

Soil infertility is a serious and widespread bottleneck to agricultural development and food security in sub-Saharan Africa. Resource-poor farmers are especially vulnerable, because their plots are traditionally the least fertile, and they lack the money or credit to purchase inorganic fertilizers. They stand to benefit the most from the various soil-fertility-improving techniques provided by the Soil Fertility Consortium for Southern Africa (SOFECSA), a regional partnership convened by CIMMYT. "Best bet" soil fertility approaches being promoted include manures (leaf litter, farm, and woodland), inorganic fertilizers, lime, and rotation and intercropping with various legumes and green manure crops (soybean, sugar bean, sun hemp, *mucuna*, pigeonpea, groundnut, and cowpea). The consortium has determined that increasing the intensity of legume cropping in maize-based systems through systematic rotations and intercrops can provide double the level of nitrogen that is typically provided by the limited use of inorganic fertilizers. *[System Priority 4D]*

Opportunities for income generation from special-trait maize: Baby corn, sweet corn, and green maize, or maize on the cob are among the most important vegetables in many locations worldwide. Moreover, green maize (fresh on the cob) is eaten parched, baked, roasted or boiled and plays an important role in filling the hunger gap after the dry season in Africa. CIMMYT is exploring options for special-trait maize, especially as a means by which maize may be value-added. Maize genetic enhancement for vegetable uses, children's food and other products (e.g. silage and bio-ethanol –see Box 5 below) that add value to the commodity chain depends on the allele diversity from farmers' fields. *[System Priority 1A, 3A]*

Box 3– The Rice-Wheat Consortium (RWC) for the Indo-Gangetic Plains: 2006 Highlights

The rice-wheat cropping systems of the Indo-Gangetic Plains are crucial for food security in South Asia. These cropping systems are difficult to manage sustainably due to complex rice ecologies and the contrasting edaphic requirements of rice and wheat. System sustainability is likewise threatened by the inefficient use of water, declining water tables, nutrient mining, and resource fatigue. Current estimates suggest that nearly 4 million hectares in India, Pakistan, Nepal and Bangladesh are sown to wheat and other crops using surface seeding or zero- or reduced tillage, largely as a result of RWC efforts to test and promote those and other resource-conserving practices. A study by CIMMYT and RWC partners in Haryana, India, and Punjab, Pakistan, has confirmed significant savings in farmers' use of diesel and tractor time through adoption of zero-tillage for wheat cultivation. The results also suggest savings in irrigation water across 3 million hectares may approach 1.18 billion m^3—equivalent to nearly two weeks of domestic water use in the USA. In financial terms, if zero-tillage is practiced on just 3 million hectares, the net income increase totals US$ 239 million per season (US$ 146 million in costs savings and an additional US$ 92 million in yield gains). National programs partners are institutionalizing RWC technology dissemination approaches which, among other things, strongly emphasize farmer involvement in innovation networks through participatory on-farm trials and diverse other means.

Box 4– Climate Change – Can Wheat Beat the Heat?

Climate change could strongly affect the global wheat crop, which accounts for 21% of food and 200 million hectares of farmland worldwide. Future climate scenarios suggest that global warming may be beneficial for the crop in some regions but could reduce productivity in zones where optimal temperatures already exist. For example, as a result of possible climate shifts, by 2050 as much as 51% of the Indo-Gangetic Plains—currently part of the high-potential, irrigated, low-rainfall global mega-environment that accounts for 15% of the world's wheat production—might be reclassified as a heat stressed, irrigated, short-season mega-environment. This shift would significantly reduce wheat yields, unless appropriate cultivars and crop management practices were offered to and adopted by South Asian farmers. To adapt and mitigate climate change effects on wheat supplies for the poor, CIMMYT researchers and partners are developing heat-tolerant wheat germplasm and cultivars for conservation agriculture. As RWC research results suggest, conservation agriculture and other resource-conserving practices are expected to help offset water shortages already threatening the region and which will intensify as global temperatures rise. The practices also provide better soil cover, moderate soil temperatures, and reduce the evaporation of irrigation water. Mitigation research promises to reduce emissions of nitrous oxide, a potent greenhouse gas generated through use of manure or nitrogen fertilizers. Results show that emissions can be halved in intensive, irrigated wheat crops with no loss of yield by applying the correct amounts of nitrogen at the right time. This can be achieved by using infrared sensors and a normalized differential vegetative index that determines the right times and correct amounts of fertilizer to apply, a practice now being tested with and adopted by farmers in the Yaqui Valley of northern Mexican, an intensive irrigated wheat zone. As described previously in this document, CIMMYT researchers are also assessing wild relatives of wheat as potential sources of genes with inhibitory effects on soil nitrification. Through existing global and regional research-for-development networks featuring wheat, this and other technology and knowledge can enable farmers to deal with the effects of climate change.

Box 5– Bio-energy: Bringing perennial traits into maize and wheat?

Converting crops to produce energy as well as food has become an important and well-funded global research goal, as petrol eum reserves fall and fuel prices rise. But the use of crop biomass—both grain and other plant parts—to produce bio-energy may compete with food and feed supplies and the alternate use of plant residues to sustain soil productivity and structure and avoid erosion. Agricultural research can mitigate these trade-offs by developing new biomass crops for marginal lands where there is less competition with food crops and developing sustainable livestock management systems that are less dependent on biomass residuals for feeds. Growing biofuel crops on lands not suitable for food production—for example, those affected by drought, salt, or temperature stresses—would substantially reduce fuel-food competition. Frontier research in genetic enhancement and crop physiology should explore the advantages of perennial biofuel crops that can generate more annualized net photosynthesis and lower input costs. Their longer life can lead to beneficial symbiotic interactions facilitating nutrient input and lower fertilizer run-off and where nutrients and organic matter can remain in the soil after harvesting. A perennial trait has been identified in wild relatives of maize and wheat.

Context

In October of 2006, based on feedback from the 5th EPMR mini-review and stakeholders, CIMMYT reduced the number of MTP Projects from 11 to 8, to improve the clarity and synergy for internal research management of its portfolio and to better align the Projects and flagship products with CGIAR system priorities (Table 1, p. 10). Specifically, former MTP Projects 5 (African livelihoods: Global solutions for maize food and income security in eastern and southern Africa) and 6 (Maize for Asia and Latin America) have been subsumed into Projects 3 (Stress tolerant maize) and 4 (Nutritional and specialty trait maize). Former MTP Project 9 (Wheat grain enriched for health and profitability) has been incorporated into Project 7 (Water productive wheat). At the time of writing, CIMMYT's Board is assessing the findings of a study on Maize in Asia. Implementation of recommendations from this study will be within the context of the existing Project structure.

For the planning period 2008-2010, CIMMYT will continue to focus on core competencies in support of delivering flagship products that align with CGIAR priorities. As such, there will be no major variation from what has been previously proposed in MTP 2007-2009. There will, however, be greater focus on Priorities 1 (Sustaining biodiversity for current and future generations); and 2 (Producing food at lower cost through genetic improvement). Associated with the focusing of CIMMYT's research agenda, a strategic staffing plan is currently under development. Specific Project highlights are summarized in the following section.

Project 1: The conservation, characterization, and utilization of maize and wheat genetic resources

Crop-related biodiversity is the founding asset of the CGIAR and the basic raw material for CIMMYT's international breeding programs. The emerging strategy of the CGIAR in the new millennium builds on this foundation, with emphasis on technology-assisted methodologies and intermediate products from the efficient identification of value-added traits and their rapid introgression into elite breeding material. Structured and well-characterized germplasm subsets, trait-specific genetic stocks (near-isogenic, introgression and substitution lines), double haploid lines, synthetic polyploidy genotypes, genetic mapping populations, enhanced gene pools, advanced lines, and diverse cultivars are becoming an increasingly critical asset for the global plant research and breeding community. Targeted development, intensive characterization, and extensive evaluation under diverse field conditions of this germplasm is increasingly seen as the rate-limiting factor for translation of outputs from the genomics and information technology revolutions into tangible products for developing country farmers. Much of the above depends in turn upon effective data management. Thus, a major new strategic focus in Project 1 is the creation of a fully-integrated, web-based support system for CIMMYT and partners involved in the conservation, utilization, evaluation, and enhancement of genetic resources, whereby all types of data can be integrated, compared, and collectively analyzed and queried by anyone anywhere.

Project 2: **Technology-assisted tools and methodologies for genetic improvement**

This Project develops and validates new tools and methodologies for more efficient and targeted manipulation of novel alleles and genes for traits prioritized by end-users in the maize and wheat improvement programs of CIMMYT and NARSs (the latter including SME breeding programs).

The ultimate goal is to enhance resilience to abiotic stresses, yield stability under biotic stress, nutritional quality and the profitability for resource-poor maize and wheat farming communities, through targeted use of genetic resources. CIMMYT and partners' molecular breeding facilities urgently need to take advantage of out-sourcing enterprises for genotyping. Conversely, the identification of new marker associations has previously been considered better achieved in advanced institutes. However, based on new tools and methodologies that allow discovery, validation, and application in breeding populations, these activities can likely be carried out by CIMMYT and partners. In addition, CIMMYT has a primary niche in developing central information resources, coordinated analysis, and the facilitation of the overall product development chain. Similarly, it is CIMMYT's role to validate, refine, and optimize outputs from advanced research institutes to ensure their robust and efficient application in plant breeding. In particular, this will involve applying quantitative knowledge-led phenotyping systems, analyzing environmental and genetic background effects, developing improved methodologies through retrospective analysis of current breeding data, and devising new selection systems based on holistic indices, on modeling and simulation, and on computational decision-support tools.

Project 3: **Stress tolerant maize**

Food security and poverty alleviation are most difficult to achieve in rainfed, stress-prone environments, where the resource-poor lack market access, rainfall is highly variable, and soils are degraded. Project 3 uses breeding to modify genes, chromosomal regions, and allelic variation to improve maize germplasm. The Project works closely with Projects 1 and 2 and the CGIAR Generation Challenge Programme.

Project 4: Nutritious and specialty trait maize

Project 4 identifies traits in demand from beneficiaries, partners and stakeholders, and incorporates these traits into maize germplasm that is usable by the wider community. CIMMYT has a comparative advantage in identifying usable traits for human nutrition, horticulture, and multiple purposes and during the period of this plan, work on assessing the market potential and benefits of specialty maize will be strengthened to provide resource-poor farmers with new income generating options.

Projects 5 and 6: Incorporated into Projects 3 and 4.

Project 7: Drought tolerant wheat with enhanced quality

Globally, almost 50% of the wheat cultivated in developing countries (50 million hectares) is sown under rainfed systems that receive less than 600 mm per annum and some of the poorest and most disadvantaged farm families live in areas of less than 350 mm per annum. Furthermore, in irrigated areas, supplementary rather than full irrigation is becoming common, exposing wheat systems to water stress. Project 7 is addressing the increasing need for water productivity and, during the period of this plan, the Project will continue to place emphasis on disaggregating drought tolerance *per se* into distinct components to apply the findings to germplasm improvement programs. In particular, work on root architecture and physiological traits, resistance to soil-borne diseases and tolerance to heat, salinity and inhospitable soils will be strengthened. Of particular note for Project 7 is the strengthened relationship with ICARDA and

implementation of joint ICARDA-CIMMYT Wheat Improvement Program (ICWIP) in the CWANA region.

Project 8: Disease resistant wheat with high productivity and quality

This Project is built on the center's long-term emphasis on research aimed at raising the genetic yield potential of wheat while maintaining disease resistance. The resultant seed-embedded technology is critical to ensuring that resource poor farmers benefit from improved wheat germplasm under conditions where diseases can potentially inflict very severe losses. A recent reminder of the threat posed by diseases is the discovery of a virulent form of stem rust (Ug99), first isolated in Kenya but now spreading eastwards and most recently found in Yemen. Diseases of wheat are an old problem; the need for germplasm and exotic sources of resistance remains and Project 8 will continue to perform a crucial role in its capacity as key member of a global network of wheat researchers. In particular, the countries of the north have a role to play in helping to combat diseases that impact on the resource poor.

Project 9: Primarily subsumed into Project 7

Project 10: Maize and wheat cropping systems

This Project undertakes systems agronomy and resource-conserving technology research with the aim to spread the principles of conservation agriculture for the benefit of smallholder maize and wheat smallholder systems. In particular, the Project will focus on the continuing development of appropriate conservation agriculture technologies that reduce tillage, provide adequate surface retention of crop residues, and stress the importance of diversified crop rotations. CIMMYT has the knowledge and practical expertise in public-private partnerships to develop, extend, and assess conservation agriculture in a wide range of different environments.

Project 11: Knowledge, targeting and strategic assessment of maize and wheat farming systems

Many resource poor farmers and consumers in developing countries depend on risky and complex maize- and wheat-based farming systems for their survival. For related crop research to sustainably reduce poverty, it must reflect the diverse production, consumption and livelihood roles of maize and wheat. This Project contributes to mission-effective maize and wheat improvement research by CIMMYT and partners. During the period of this Plan, Project 11 will emphasise the development of key methodologies such as socioeconomic and environmental characterization, impact pathway analysis, value chain mapping, and knowledge sharing.

New frontier research to address emerging global issues

Previously (MTP 2007-2009) the Science Council asked for comments addressing the point "*to see targeting in some new research explicit in the plans*." This section provides an update on some undertakings and proposed work; the latter subject to attracting additional resources.

Global warming: The role of wild species in adapting cropping systems to climate change: A third of the world's nitrogen fertilizer is applied to wheat crops whose efficiency of use is only

about 33%. The resulting nitrification of soils causes annual losses in the order of US$ 6 billion in over-use of fertilizers, as well as untold costs in environmental pollution. Artificial and biological control of nitrification can improve nitrogen recovery and nitrogen-use efficiency (NUE), and synthetic nitrification inhibitors have been used in wheat to boost NUE and reduce environmental load. However, the potential to improve the release of biological nitrification inhibitors (BNI) in wheat root exudates or to apply such a trait is unknown. Partnership research with the Japan International Research Center for Agricultural Sciences (JIRCAS) shows that *Leymus racemosus*, a distant relative of wheat, has a high capacity for producing effective BNI, and this trait has been introduced to cultivated wheat via inter-specific crosses. Preliminary results are encouraging: using recombinant luminescent *Nitrosomonas europaea* to quantify BNI released in plant-soil systems, the research team has found that *L. racemosus* releases about 20 times more BNI than wheat in an NH_4^+ enriched environment. By introducing the high-BNI release capacity of *L. racemosus* into cultivated wheat, breeders could develop cultivars whose genetic capacity to inhibit nitrification would allow more sustainable, ecologically-friendly farming in intensive cereal cropping systems, with significant economic and ecological benefits, including reduced emission of nitrous oxide which is a highly potent greenhouse gas.

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Food Safety: Linking agriculture to human health and global trade: Many millions of people (both adults and children) suffer from food-borne toxins, especially in the developing world. In the tropics, staple crops such as maize can be the source of mycotoxins, which are highly toxic metabolites produced by a number of fungi especially in drought-prone environments, unseasonably rainy environments, or high moisture during and after harvest. CIMMYT maize breeders have been working at combining biotic and abiotic stress resistance to identify stress tolerant lines or hybrids that have a reduced incidence of aflatoxin; this broader approach to reduce mycotoxin loads is proving successful.

Scab (or *Fusarium* head blight) adversely affects wheat grain quality due to both lower weight and higher mycotoxin contamination, which can cause vomiting, breathing problems, cancer, reproductive disturbance of animals, and at times death. These negative effects produce economic hardship for wheat growers due to low grain yield and poor market quality. Because of the above effects in humans, animals, and the crop, CIMMYT provides a global platform for international collaboration on *Fusarium* research by facilitating sharing of knowledge and genetically enhanced wheat germplasm as well as other breeding materials and tools. This global platform, in alliance with other research partners worldwide, capitalizes on the knowledge accumulated regarding both host plant resistance as well as genetic enhancement of the wheat crop against *Fusarium*. For example, DNA markers are being mapped and used for incorporating the distinct resistance types against the pathogen, namely to initial infection or penetration (Type I resistance); to fungal spread within plant tissues (Type II resistance); and, to mycotoxin degradation (Type III resistance). Research efforts on screening methods, coupled with the advances in genetic enhancement, should lead to novel resistance sources with genetically characterized new resistance loci.

A holistic fight against mycotoxins is envisaged, with a focus on integrated crop management (including genetic enhancement), low-cost detection technology, and a participatory assessment process to ensure food safety and to overcome potential trade barriers for the export of grains from the developing world. Such an approach should develop and implement a large-scale research-for-development program with the international human health research community, to improve human health through agricultural innovations. *[System Priority 2C]*

The CGIAR and CIMMYT

CIMMYT is an active and full partner in the Alliance of CGIAR Centers through the Challenge Programs (host center for Generation and participant in HarvestPlus, Water and Food, and Sub-Saharan Africa), inter-center initiatives and system-wide programs. The Center shares research efforts with CIAT, CIP, ICARDA, ICRAF, ICRISAT, IFPRI, IITA, ILRI, IRRI, IWMI and Bioversity. More specifically, CIMMYT has developed close linkages with IRRI and ICARDA.

CIMMYT and IRRI: The two centers continue to enhance their alliance program that includes three (3) projects:

- Crop research informatics laboratory
- Intensive production systems for Asia
- Cereal systems knowledge portal

CIMMYT and IRRI have formed a joint Board sub-committee to provide oversight to the alliance program. Similarly, CIMMYT and ICARDA have made good progress with the joint ICARDA-CIMMYT wheat improvement program for the CWANA region. Planning of research and capacity building activities for the CWANA region has included the development of a joint MTP and a Director of the joint program has been appointed.

Aligning CIMMYT's agenda to the CGIAR system priorities

CIMMYT investments are mostly addressing genetic enhancement of both maize and wheat, conservation agriculture in maize- and wheat-cropping systems, and optimizing participatory maize- and wheat-value chains. Throughout the project portfolio, capacity building is provided. Frontier research and development activities also get small resource allocation as a means for exploring new emerging issues affecting global agriculture, and ensuring impacts of CIMMYT knowledge and ensuing technology in maize and wheat farms, respectively.

Table 1. Mapping CIMMYT MTP Projects (weight in %) to CGIAR system priorities

CIMMYT 2007-2009 MTP Projects	SP1	SP2	SP3	SP4	SP5	DA	SAT	FR
P1 Conservation, characterization and targeted access to maize- and wheat-related biodiversity	40	60						
P2 Technology-assisted tools and methodologies for genetic improvement		100						
P3 Stress tolerant maize		70		10		10	10	
P4 Nutritious and specialty traits for maize	10	80	5	5				
P7 Drought tolerant wheat with enhanced quality	10	90						
P8 Disease resistant wheat with high productivity and quality	15	75				10		
P10 Maize and wheat cropping systems*		10		70		20		
P11 Knowledge, targeting, and strategic assessment of maize and wheat farming systems					70	10	20	

SP1 Sustaining biodiversity for current and future generations.
SP2 Producing food at lower costs through genetic improvement.
SP3 Creating wealth among the rural poor through high-value commodities and products.
SP4 Combining poverty alleviation and sustainable management of water, land and forestry resources.
SP5 Improving policies and facilitating institutional innovation.
DA Development activities.
SAT Stand-alone training
FR Frontier research not fitting in today's SP
* Includes CIMMYT contributions to the Rice-Wheat Consortium (RWC) research agenda

More than two-thirds of the Center's investment addresses CGIAR system priority # 2: Producing food at lower costs through genetic improvement (Table 1). This reflects the needs of maize and wheat farmers for cultivars that withstand biotic or biotic stresses, and for more nutritious and healthy food for consumers. Center resources are also allocated to the four other CGIAR system priority areas (Table 1), and a small percentage for other important areas that contribute to obtaining impacts; e.g., seed systems or stand-alone capacity building—including conservation agriculture knowledge and technology sharing, and other development activities. Finally, a small portion of CIMMYT research portfolio is dedicated to exploratory research; for example, in P1 and P2, whereby scientists test innovations in their particular areas and at their own discretion.

Center financial indicators

The primary financial and management aims of CIMMYT during the period of this MTP can be summarized as follows:

1. To complete the implementation of the outcomes of the detailed business plan that was formally adopted by the Board of Trustees in March 2006. During 2006, the rationalization of administration and the move to Project-based budgeting and reporting have been substantially implemented and will be completed in 2007. In addition, full costing of all activities has been implemented for 2007 and beyond.
2. To continue the development of a comprehensive resource mobilization strategy that is responsive to both the funding opportunities and potential risks that may arise.
3. To maintain the Center's financial reserves, which have finally reached the CGIAR mandated levels as of the end of 2006, after several years of aggressive action by management to rebuild them (capital reserves of 80 days).
4. To complete the strategic review of research infrastructure and begin implementation of a medium-long-term, sustainable capital investment plan.

CIMMYT funding overview

Detailed budget tables are set out on pages 77 to 92. Total grant revenues for the Center in 2007 are projected at US$ 34.1M, increasing to US$ 35.1M for 2008. These figures are slightly lower than forecast originally for the MTP 2007-2009, due to continued pressures on unrestricted funding, lower than expected growth in restricted funding, and conservative budgeting due to currency market volatility.

Business plan implementation

Last year's MTP narrative noted that the 11 MTP projects developed within CIMMYT's business plan would continue to be refined during the life of the MTP. This has occurred in various ways, one being the reduction in the number of Projects from 11 to 8.

CGIAR financial health indicator benchmarks

a) Long-term financial stability

During 2006, CIMMYT increased undesignated, unrestricted reserves to a level in excess of US$ 7.57M. Center reserves now equal 80 days of operating expenditures, which is within the CGIAR mandated level for working capital reserves.

b) Short-term solvency
As of the end of 2006, CIMMYT's short-term solvency amounted to 94 days, within the range mandated by the CGIAR. This indicator has improved substantially over the past four years.

The above indicators will be impacted by any capital investment decisions arising from current infrastructure reviews and will drive investments priorities during 2007. While CIMMYT's management and Board will try to minimize the impact of such investments by carefully sequencing timing and amounts, it is inevitable that large capital investments in a given year to redress past years' under-investments will impact on both cash and unrestricted reserves.

Project narratives

Project 1: *Conservation, characterization and utilization of maize and wheat genetic resources*

Crop-related biodiversity is the founding asset of the CGIAR and continues to be the basic raw material for the breeding programs of CIMMYT and its partners. The new name and output structure for Project 1 reflects an increased commitment to developing and applying new tools and methodologies for utilizing genetic resources in trait-based germplasm enhancement. *Structured sets of germplasm* are becoming an increasingly critical asset for the global plant research and breeding community. Characterization and distribution of this germplasm is a major niche for CIMMYT, as is the coordination of associated web-enabled informatics resources. *New technology-assisted methodologies* are facilitating targeted access to new beneficial alleles, genes and traits. However, intensive characterization and precise evaluation (under diverse field conditions) is now the rate-limiting factor for effective utilization of outputs from the genomics and information technology revolutions. CIMMYT has a major role to play in this area and in subsequent interdisciplinary integration of resultant outputs. *Germplasm enhancement* provides the mechanism for incorporating new added-value traits (such as pest and disease resistance), meta-traits (such as drought tolerance), and pyramided traits (such as resistance to root health complexes and multiple sources of resistance to the same disease) into acceptable genetic backgrounds that can be readily adopted by the pre-breeding programs. All Project 1 activities are directly related to CGIAR System Priority 1A and support Priorities 2A, 2B and 2C. Many of the activities in this Project are carried out in close collaboration with SGRP and the Generation and HarvestPlus Challenge Programs.

The new Project 1 structure is designed to improve the flow of the intermediate products from Project 1 to end-user breeding programs in CIMMYT (Projects 3 to 6) and NARS, including SMEs. In this context, germplasm enhancement will focus on crosses with landraces or wild species, traits that are difficult to handle until they reach homozygosity, traits that require intensive use of genomics, tissue culture, transgenics or informatics, and experimental traits that have been newly added to the priority list, such as those required for biofuel production, climate change, novel quality parameters or ideotype-led initiatives.

<u>International public goods:</u>

Genetic resources conservation, characterization, informatics and distribution

- **Conservation and characterization of genetic resources:** Germplasm accessions from global sources (including related wild species, genetic stocks and improved breeding lines) available from the genebank.
- **Informatics systems for global biodiversity:** Fully integrated, public-access, multidisciplinary germplasm information resources with powerful query and analysis tools.
- **Distribution of improved germplasm:** Globally recognized and accredited guidelines for the maintenance, regeneration, purification, distribution and documentation of germplasm regarding pests, pathogens and transgenes.

Targeted access to useful genetic variation

- **Sequence-based allele mining:** New allele mining methodologies (and outputs thereof) for using gene-based PCR markers to identify beneficial genetic variation for well studied target traits in maize and wheat improvement.

- **Dynamic germplasm subsets:** Improved interdisciplinary methodologies (and resultant web-enabled resources) for the development of end-user defined maize and wheat germplasm subsets, maximizing genetic variation for priority traits.
- **Association mapping-based gene discovery:** New added-value alleles and genes identified from germplasm subsets through marker-trait association analysis of precision multilocation phenotyping and genomewide genotyping data.

Trait-based germplasm enhancement

- **Wheat germplasm enhancement:** Beneficial genetic variation introgressed into elite wheat breeding lines focusing on client breeding program priorities in abiotic and biotic resistance, quality, and agronomic adaptation traits.
- **Maize germplasm enhancement:** Trait-based enhancement of maize genetic resources for end-user priorities in abiotic and biotic resistance, quality and agronomic adaptation traits, within geographically assigned heterotic patterns.
- **Capacity building and backstopping implementation:** Information, skills development and assistance provided to NARS, SME, and CIMMYT breeders to enable their best use of maize and wheat-related biodiversity.

Impact pathways and partnerships:

The outputs of P1 are intermediate products such as tools, methodologies, and enhanced germplasm associated with more targeted, efficient, and rapid access to and use of the most desirable genetic variation for maize and wheat breeding programs. The primary users of these intermediate products—who will also participate in their further development—includes breeders and other researchers from CIMMYT, NARS, SMEs, and ARIs. A fundamental task of P1 is to search for genetic diversity that is not readily accessible through conventional breeding approaches, using novel tools and methodologies to identify crop-related genetic diversity beneficial for improvement of specific priority traits. Facilitating a better collation of genetic variation across national and international genebanks is a critical prior role for CIMMYT in this area. Similarly, intimate and iterative linkages with advanced institutions are essential for proper orientation of their strategic research and early access to resultant outputs relevant to germplasm enhancement for stakeholders. Thus, P1 builds close alliances with all actors in the maize and wheat improvement value chain and impact pathway: national genebanks curators, breeders and trait specialists in P3-P7, and NARS and SME breeding programs. In addition, collaborations with P8 facilitate appropriate cost-benefit analysis and impact assessment of intermediate products to assist in prioritizing investments across different types of interventions and end-user trait needs. P1 has a major role to play in coordinating information networks to help ARIs, NARSs, and SMEs focus on the most important needs of resource-poor clients.

Achieving regular constructive feedback from primary end-users is fundamentally important. Conversely, information from the farmers and ultimate beneficiaries is generally indirect, and interpreted by the other projects. However, the connection between P1 and the other projects is important to strengthen these networks and make sure the right questions are being asked about end-users' needs. Particularly in terms of the priority traits, issue include the nature of the most desirable genetic backgrounds for introgression of those traits and the range of tools required for effective utilization the traits in mainstream breeding programs

Genetic resources information sharing and databases are helpful in facilitating the efficient access of ARIs, NARS, and SMEs to useful germplasm. CIMMYT has a comparative advantage in facilitating this, coordinating networks to share knowledge and skills focused around the generation of enhanced germplasm products. P1 has a role in creating and then maintaining new networks, since many of the ones set in national chains exist for different purposes.

In the Center's new vision, NARS partners—particularly in primary centers of maize or wheat diversity—and other CGIAR and advanced germplasm banks play a critical role in synergizing P1 activities in germplasm conservation and characterization. Similarly, CIMMYT's participation in the Generation and HarvestPlus Challenge Programs provides unique access to global germplasm for drought tolerance and biofortification. Partnerships with advanced institutes such as CRC-MPB (Australia), Cornell University (USA), and NIAB (UK) provide essential new technologies for targeted trait-based access to germplasm, particularly allele and gene mining technologies. General conservation and utilization activities among CIMMYT and other international centers take place under the System-wide Genetic Resource Program (SGRP) and the Global Crop Diversity Trust. CIMMYT predominantly focuses on applying various technologies for its maize and wheat germplasm collections. CIMMYT, NARS, and SME breeders also play a critical role in orientating these efforts towards the highest priority traits. P1 researchers reach up the value chain by committing to provide technical backstopping for the routine application of new tools and methodologies in CIMMYT, NARS, and SME breeding programs.

The intermediate products from P1 are likely to have an impact on the productivity, stability, and resilience of new, experimental maize and wheat varieties. Resultant impacts of new varieties on livelihoods are envisaged and, in most cases, direct impacts will first reach the CIMMYT breeding programs through P3-P7, then through NARS intimately involved with CIMMYT through globally decentralized shuttle breeding initiatives, and then to other NARS and SME breeding programs in target countries. The extent to which new genetic variation, together with the tools and methodologies to use it, is taken up by CIMMYT, NARS, and SME breeding programs will greatly influence the overall contribution of these intermediate products to the final impact of finished varieties and improved cropping systems.

Project 2: ***Technology-assisted tools and methodologies for genetic improvement***

Future gains in crop improvement will be increasingly dependent on the timely and appropriate implementation of technology-assisted tools and methodologies. The new Project 2 output structure reflects an increased commitment to the translation, validation, and facilitated application of strategic research outputs for the development of intermediate products with interdisciplinary added value. *Biotechnology-based tools and resources* are becoming a mainstay of all modern crop improvement programs. CIMMYT has a primary role in facilitating the development of a variety of biotechnology-based options for client breeding programs in NARS, SME, and CIMMYT. *Molecular breeding decision-support tools* have become the rate limiting factor for effectively integrating multidisciplinary interventions into modern breeding systems. CIMMYT has a comparative advantage in this area by virtue of the close interaction and comparative strength of its biotechnology, bioinformatics, and global maize and wheat improvement programs. *Capacity building and technical backstopping* is a fundamental priority for CIMMYT to ensure adequate uptake of outputs from Project 1 and 2, and to provide an iterative mechanism to empower end-users to orientate future efforts. All Project 2 activities are

directly related to CGIAR System Priorities 2A, 2B and 2C. Many of the activities in this Project are carried out in close collaboration with CAS-IP, GTF and the Generation and HarvestPlus Challenge Programs.

The new Project 2 structure reflects attempts to adjust the research agenda in line with the business plan, in particular improving the prioritization and impact of efforts to develop interventions that enhance the pace, scope, and value of outputs from maize and wheat improvement activities in Projects 3 to 6. In this context, Project 2 develops new tools and methodologies, as well as validating them and facilitating their application, for more efficient and targeted manipulation of new alleles and genes for traits prioritized by end-users in maize and wheat improvement programs in CIMMYT, NARS, and SMEs. Intermediate products from Project 2 ultimately enhance the crops' resilience against abiotic stresses, yield stability under biotic stresses, nutritional quality, agronomic adaptation, and profitability for resource-poor maize and wheat farming communities.

International public goods:

Development of biotechnology-based tools and transgenic resources

- **Underlying genetics of priority traits:** Increased understanding of drought tolerance, pest and disease resistance, quality traits and agronomic adaptation based on in-house marker-assisted genetic dissection and/or collaborative functional profiling analysis.
- **Trait-specific markers:** New SSR or SNP markers developed and/or validated through in-house efforts or acquired from outside sources associated with traits prioritized by end-users in NARS, SME, and CIMMYT breeding programs and background selection.
- **High-throughput marker genotyping systems:** *In silico* gene-based marker development methodologies, high-throughput single-seed-based DNA extraction system, and high-throughput SSR, SNP, and gene-based marker detection systems.
- **Rapid cycling technologies:** Optimized large-scale doubled haploid systems for use as an integrated research and breeding tool to combine marker discovery, validation, and implementation within breeding populations.
- T**ransgenics:** Efficient *Agrobacterium*-mediated transformation protocols for wheat and maize integrated with large-scale MAS introgression systems for rapid transgene functional validation and effective molecular breeding product development systems.

Molecular breeding methodologies and facilitating computational systems

- **Informatics:** Fully integrated, web-enabled data management and analysis system linking genetic resources, biotechnology, germplasm enhancement, variety development and GIS data sources for improved knowledge-led crop improvement.
- **Precision phenotyping methodologies:** More precise, higher-throughput phenotyping systems for dissecting complex traits, improving trait manipulation, and enhancing field selection.
- **Biometrics:** New tools developed for improved the understanding and ability to manipulate genotype-by-environmental interaction effects through combining advances in informatics, genomics, phenotyping, and genetics with biometrics.
- **Molecular breeding:** Efficient molecular breeding strategies and implementation systems developed and applied that effectively integrate multidisciplinary interventions for enhanced scope, cost efficiency, and impact (that is, crop improvement gains).

Capacity building and technical backstopping of technology-assisted breeding interventions

- **Capacity building – skills development:** NARS, SME, and CIMMYT staff trained in new technologies and methodologies, including genetic resources, biotechnology, computational systems, and germplasm enhancement.
- **Capacity building – backstopping implementation:** Information, skills, and technological backstopping provided to assist NARS, SME, and CIMMYT breeding programs to make best use of new tools, methodologies, and genetic resources.

Impact pathways and partnerships:

The outputs of P2 are intermediate products such as new tools and methodologies, which have direct impacts on the scope, speed and precision of crop improvement programs. This is a primary niche area for CIMMYT researchers to improve the efficiency and impact of CIMMYT, NARS, and SME breeding programs. The extent to which the potential benefits of these intermediate products are realized relies heavily upon the extent of uptake and the skills of implementers. To ensure appropriate uptake and optimum impact, P2 researchers will not only develop, validate, and refine tools and methodologies hand-in-hand with relevant breeding programs, but also assist implementation through intensive technical backstopping. CIMMYT will achieve this through proactive involvement in regional hubs, international shuttle breeding initiatives, and associated molecular breeding communities of practice. In this way, the Center will foster and synergize national programs' confidence to take a larger role in adaptive breeding. CIMMYT will increasingly emphasize its role as facilitator, enabler, and advocate in the overall value chain. Similarly, intimate and iterative linkages with advanced institutions are essential for proper orientation of their strategic research and early access to outputs relevant for germplasm enhancement. Thus, P2 builds close alliances with all up and downstream neighbors in the maize and wheat improvement value chain and impact pathway: genetic resources specialists, breeders and trait specialists in P3 to P7, and NARS and SME breeding programs. In addition, collaborations with P8 facilitate appropriate cost-benefit analysis and impact assessment of intermediate products to prioritize investments across different types of interventions and end-user trait needs. Finally, P2 has a major role in coordinating information networks to help ARIs, NARSs, and SMEs focus on key needs of resource-poor clients.

CIMMYT and partners' molecular breeding programs urgently need to evolve to a new paradigm that takes maximum advantage of out-sourcing enterprises for genotyping and other biotechnology-based services. Conversely, the identification of new marker associations has previously been considered better achieved in advanced institutes. However, based on new approaches that allow us to combine discovery, validation, and application in breeding programs, these activities can likely be carried out more rapidly and with less redundancy by CIMMYT and partners. In addition, CIMMYT has a primary niche in developing central information resources, coordinating analysis, and facilitating the overall product development chain. Similarly, it is CIMMYT's role to validate, refine and optimize outputs from advanced research institutes to ensure their robust and efficient application in plant breeding.

The intermediate products from P2 are likely to have an impact on the productivity, stability, and resilience of new, experimental maize and wheat varieties. Direct impacts will first reach the CIMMYT breeding programs through other CIMMYT Projects (#3 to #7), then NARS and SME breeding programs intimately involved with CIMMYT through globally decentralized shuttle

breeding initiatives, and then to other NARS and SME breeding programs in target countries. In the new vision of P2, advanced research institute partners play a fundamental role of predominant technology provider, although in some cases where there is no ARI provider or where CIMMYT retains the comparative advantage in developing a particular tool or methodology, the Center will take up that role. CIMMYT's founding role in the Generation Challenge Program and the Molecular Plant Breeding Cooperative Research Center provides unique access to a wide range of technology options. CIMMYT focuses predominantly on validating and refining those technologies for application in stakeholders' situations and integrating diverse technologies into efficient, new genetic improvement methodologies. CIMMYT, NARS, and SME breeders then validate and refine the methodologies.

Project 3: *Stress tolerant maize*

Achieving the Millennium Development Goals is most difficult in rainfed, stress-prone environments where communities are confronted by poor market access, erratic rainfall, and soil degradation. Tropical maize growing environments are affected by a wide range of stresses worsened by variable weather conditions, infertile and acidic soils, lack of inputs, labor shortages for other control methods, and soil degradation. In particular, the importance of finding genetic approaches which stabilize and increase crop productivity in the face of climate change and increasing water scarcity is widely acknowledged. Also, for some newly emerging or newly important biotic stresses, no sources of resistance can be found in known or improved germplasm.

This Project uses breeding methodologies, genes, chromosomal regions, and allelic variation for exploratory incorporation into elite or farmers' own maize germplasm and assessment of genotype, gene-by-genotype, and genotype-by-environment effects. It applies the insights gained to generate strategically important, stress tolerant source germplasm and to strengthen partners' capacities to use effectively new and proven tools from this Project and other undertakings, such as Projects 1 and 2 and the CGIAR Generation Challenge Program. As steward of the world's maize genetic resources, CIMMYT provides through this Project an effective access path for identifying and availing new sources of resistance. The Center's accumulated maize research and breeding materials targeting stress environments are regarded as successes. This Project builds upon them to contribute to food and income security and better use of scarce resources (water, nutrients, labor, and land), in particular as climate change increases the area and frequency of unfavorable production conditions.

International public goods:

- Stress tolerant maize with improved performance and adaptation to smallholder growing environments world-wide; they provide increased food security to resource-poor farmers, enabling them to break out of the poverty spiral and also engage in soil fertility-enhancing crop diversification strategies.
- Maize types with high levels of drought and heat tolerance to offset expected impacts of climate change in the developing world.
- As an insurance against narrowing genetic diversity and biotic constraints, new and diverse sources for host plant resistance to pre- and post-harvest diseases and pests that threaten maize production, health, and trade in significant regions of the developing world.

- Seed-embedded options for controlling *Striga*, a parasitic weed that threatens maize production throughout sub-Saharan Africa.
- Integrated into the CIMMYT-IRRI Alliance, maize germplasm suited to resource-conserving cropping systems, in particular intensive rice-maize cropping in Asia.
- Knowledge-sharing on genetic resources and selection protocols to breed maize germplasm for stress-prone environments and with improved resistance to important biotic stresses.
- Knowledge on more effective, incentive-driven impact and seed delivery pathways to increase the impact of maize genetic gains among farmers in drought-prone and outlying areas.

Impact pathways and partnerships:

A significant proportion of this Project's research is conducted through a wide range of holistic, multi-stakeholder, specially funded projects[3] that feature close collaboration with national researchers, local entrepreneurs, and institutions to develop and deliver genetic gains and know-how to beneficiaries. Summarized and world-wide, we link in this way with 150-200 partner organizations, including NARSs, sub-regional organizations, NGOs and CBOs, seed companies, universities, ARIs, IARCs, and FAO.

These multi-stakeholder projects develop and embed new traits in client and farmer-preferred maize germplasm that carries essential or valuable trait combinations defined through stakeholder priority setting, client surveys, participatory rural appraisals, and genotype-by-environment analyses. The research and delivery capacity of NARSs, local seed companies, and NGO staff is strengthened through collaborative research projects, short workshops, and MSc and PhD programs on pace-limiting issues in the impact pathway. Effective links among actors of the impact pathway are enhanced through annual planning at the country and sub-regional levels, and financial and technical support to partner activities. Such support includes:

- Backstopping to collaborative and farmer-participatory breeding projects and variety trials executed at the national and sub-regional level by NARSs, NGOs, and seed companies in Africa, Asia, Central and South America and leading to the release of stress tolerant varieties.
- Advice and training for staff of emerging and small seed companies and community-based maize seed production schemes, crucial to providing farmers with wider access to seed of new stress tolerant maize varieties.
- In collaboration with other international centers, technical input to the work of national seed services, policy-makers, and donors to harmonize regional seed regulations and promote seed sector development.
- Information on stress tolerant maize varieties targeted at partners with large client outreach, such as government and non-governmental organizations involved in seed relief, the private seed sector, and extension.

In addition to national agricultural research programs and local universities, partners for upstream activities of the Project include the Generation Challenge Program, the Universities of Hohenheim and Hanover, the Weizman Institute, Cornell, Purdue, and Texas A&M University, ICIPE, IITA, IRRI, multinational life science companies and several donor organizations.

[3] Such projects include: Africa Maize Stress Project (AMS); Drought Tolerant Maize for Africa Project (DTMA); Nepal Hill-side Research Maize Project (HRMP); Insect Resistant Maize for Africa (IRMA); Improving Livelihoods through Stress Tolerant Maize; New Maize Seed Initiative for Southern Africa (NSIMA); Stewardship of IR Maize (Striga).

Box: Role of partners and impact pathways in the Africa Maize Stress project for eastern Africa

Priority setting of research: ASARECA.

Project oversight: Steering Committee of the East and Central Africa Maize and Wheat Improvement Network (ECAMAW).

Financial support: BMZ, IFAD, the Rockefeller Foundation.

Input to the targeting of germplasm development: Representative farming communities, experts from NARSs, local seed companies, NGOs, CIMMYT staff.

Physiological and genetic studies: CIMMYT, MSc and PhD students enrolled in the Universities of Hanover, Hohenheim, Nairobi, and Texas A&M.

Socioeconomic studies: CIMMYT and NARSs staff from KIPRA, KARI, EIAR, and SARI.

Germplasm development: CIMMYT and NARSs in Ethiopia, Kenya, Uganda, and Tanzania.

Farmer-participatory varieties testing and release: NARSs, NGOs, seed companies and seed services in eastern and central African countries, representative farming communities.

Seed production: Community-based seed producers (e.g., Bakamusekamanja Womens Group) and local seed companies (e.g., Ethiopia Seed Entreprise, FICA Seed, Freshco Seed, Kenya Seed, Lagrotech, PANNAR, Seed-Co, TanSeed, Western Seed).

Seed dissemination and promotion: Local seed companies, NGOs (e.g., Catholic Relief Services) and CBOs (e.g., Bakamusekamanja Womens Group), FAO, the Millenium Development Project, USAID, and Rockefeller Foundation-supported seed dissemination projects in Ethiopia, Kenya, and Uganda.

International dissemination of germplasm: CIMMYT.

Input from and link to other germplasm projects: QPM-D and Striga-related projects in eastern Africa, NSIMA in southern Africa, CIMMYT International and IITA.

Project 4: *Nutritious and specialty trait maize*

The world's maize genetic resources contain a wealth of benefits, including new opportunities for improving nutrition, and multiple uses of maize and maize products. This Project explores new opportunities for developing genetic traits in greatest demand for beneficiaries, partners, and clients. Participants incorporate the traits into germplasm usable by breeding programs worldwide, and develops experimental germplasm for use by clients and beneficiaries and to obtain their feedback. Research also focuses on finding new traits to biofortify maize for key micronutrients (vitamin A, zinc, iron) and laying the groundwork for related breeding programs. Other traits include those associated with horticultural uses of maize (green cobs, blue corn) as a cash crop for peri-urban growers in Asia, Africa, and Latin America, or non-food uses, such as high-protein maize for poultry producers or dual purpose maize (food and fodder). The Project promotes a strong integration with CIMMYT staff in regional projects, their clients and beneficiaries, and partners in advanced institutes and Challenge Programs, capitalizing on CIMMYT's comparative advantage to identify useful traits for human nutrition and health,

horticulture, or multiple purposes in gene bank and breeding materials. The market potential and benefits of specialty maize will be assessed, and analyses of alternate suppliers and incentive-based value chains used to highlight opportunities and recommend priorities for research investments. Center breeders will continue to incorporate the quality protein trait into improved maize germplasm.

Project 4 addresses CGIAR priorities 2C (enhancing nutritional quality), 2A (maintaining and enhancing yields and yield potential of food staples), and 2B (improving tolerance to selected abiotic stresses, in collaboration with Project 3, all related to producing more and better food at lower cost through genetic improvements. Priority 1A is addressed by characterizing maize germplasm for important nutritional traits, and priority 3B is addressed in collaboration with ILRI by developing maize with improved suitability for use as feed. Project 4 is seeking resources to address priority 5B (making international and domestic markets work for the poor), by analyzing value chains in collaboration with Project 11. Project participants work with Projects 1 and 2 to apply molecular techniques that enhance the efficiency of germplasm characterization and use.

International public goods:

- Source germplasm and allelic discovery in maize genetic resources for specified high-priority traits, especially for nutritional enhancement.
- Experimental materials pyramiding proven new, important traits in adapted genetic backgrounds for evaluation and use with selected clients and beneficiaries.
- Information about inheritance and breeding methods for nutritional or specialty traits.
- Ex-ante impact assessment and analysis of the presence of alternate suppliers for assessing and targeting CIMMYT involvement in nutritional and specialty trait-specific research.
- Publications on germplasm, breeding methods, and recommended pathways (commodity chains) to maximize impact of the value-adding maize research investments chosen.

Impact pathways and partnerships:

P4 works mainly to produce two nutritional and specialty maize outputs: quality protein maize and micronutrient enriched maize. Aside from ensuring the development and incorporation of current germplasm with key nutritional traits, P4 also aims to raise awareness and appreciation of the importance of the nutritional value of commodity maize. In terms of increasing farmers' income generation potential, there is a strong link between P3 and P4: by helping to provide farmers with resources for inputs like improved seed and fertilizer, service providers will have incentives to better serve farmers. The increased purchasing capacity of farmers also has a positive, indirect impact on diet, as farm households have increased access to a more varied and nutrient-rich diet. Certain environmental constraints that limit the diet options for the poor will be addressed indirectly through the combination of the P3 and P4 efforts, as abiotic and biotic stress tolerant varieties are combined with nutritional enhancement to produce highly nutritional maize for a variety of stressed agro-ecologies.

As always capacity building is a current that runs through all the Project objectives, in relation to education and creating awareness of the importance of a diverse diet.

Agrosalud, a special project funded by the Canadian International Development Agency and convened by CIAT, offers an example of how P4 works with partners to ensure a complete and successful impact pathway. The goal of this special project is to improve the nutritional status of the rural and urban poor in target regions of Latin America by developing and deploying agronomically superior, micronutrient-dense quality protein maize (QPM). Primary target countries are El Salvador, Nicaragua, Honduras, Guatemala, Mexico, Colombia, Ecuador, and Haiti. Most of the germplasm comes directly from CIMMYT or is derived from Center products. Each country team implements a similar impact pathway, which starts from maize breeding at CIMMYT—including methodology development and applied breeding—from identification and creation of sources of variation to development of experimental hybrids and open-pollinated cultivars for evaluation by interested partners.

Beneficiaries will include maize farmers in target and spill-over countries. The main benefit will be improved productivity and stability of maize crops, through use of varieties developed and disseminated by the Project. For the poorest farmers using local varieties, adoption of the new varieties could allow them to double yields. For farmers already growing improved varieties, Project outputs will result in 10-20% production increases.

For scaling up, the Project's strongest partners are often the donors who, besides funding the work, serve an advocacy role for bio-fortified and nutritional maize and use their influence in other ways. The media are also partners in advocacy.

The variety release network is led by cultivar developers, typically public or private sector breeders collaborating with CIMMYT. A government department evaluates data and authorizes the eventual release of a variety. Extension services are often involved in the evaluation of the germplasm and in data collection, as part of assembling the information the variety release process.

For scaling out, NARS researchers traditionally work through extension programs, where those are linked to NGOs, farmer associations, and farmers, or directly with NGOs and farmer associations, where extension is weak or non-existent. It is the same in the case of links to the private companies. The Project may also have direct connections to the private sector and will foster NARSs-private company linkages.

Project 7: *Drought tolerant wheat with enhanced quality*

Approximately 50 million hectares—close to 50% of all wheat cultivated in developing countries—is sown under rainfed systems that receive less than 600 mm of rainfall annually. Some of the poorest and most disadvantaged wheat farmers live in rainfed areas of less than 350 mm annual rainfall and their livelihoods often depend solely on income from wheat production, with wheat straw or fodder contributing to farm animal sustenance. In rainfed areas, water availability is limited and unpredictable, and indications are that climate change is making this variability more extreme. Water productivity is an increasingly important trait for wheat cultivars for irrigated areas. Recognizing water productivity and drought tolerance as priorities for wheat,

CIMMYT has worked to disaggregate drought tolerance *per se* in wheat into distinct components and to apply those findings to germplasm improvement. Ongoing research is gaining a better understanding of traits with major effects on water productivity in dryland wheat areas. These include root architecture and physiological traits, resistance to soil-borne pests and diseases, tolerance to heat and saline, zinc deficient, and boron toxic soils. The combination of improved germplasm, the Center and partners' expertise in drought physiology, soil-borne diseases, and agronomy, and the availability of markers for various traits place CIMMYT in a unique position to develop water-productive wheat with resistance to the important stresses for use by partners throughout the developing world.

International public goods

Spring and winter bread, and spring durum wheat germplasm

- Wheat germplasm with increased water productivity, adaptation and performance stability, multiple resistances to soil-borne and foliar diseases, and appropriate end-user quality, distributed through international nursery trials for sharing and evaluation by NARS partners.
- Segregating populations distributed, targeted to NARS-specific germplasm requirements and to locations where hot spot screening is needed.
- Expanded validation and use of high-throughput, marker-assisted selection for soil-borne pathogen resistance, durable quantitative resistance to foliar pathogens, and improved market-oriented and nutritional quality, using publicly available markers.

Germplasm characterized for abiotic and biotic stress adaptive traits

- Germplasm developed through targeted shuttle breeding with partners for specific traits (soil-borne pathogens, micro-nutrient screening, Hessian fly, rusts).
- Data and information through the International Wheat Improvement Network.
- New sources of genetic material and associated knowledge for water-use-efficient germplasm.

Selection methodologies to improve wheat for drought stressed environments

- Effective breeding methodologies for germplasm improvement for variable locations significantly affected by genotype-by-environment interactions.
- Refined application of physiological tools such as canopy temperature depression, stem carbohydrate remobilization, real-time spectral reflectance in applied breeding at CIMMYT and by NARS colleagues.
- Validation of international crop information systems (ICIS) data management applications, and expanded use of automated planting, harvesting and seed packeting technologies, including barcode unique identity tracking.

Regional capacity building; breeding, pathology, quality and physiology

- The capacity of NARS researchers in wheat physiology, industrial quality, and food safety, and improvement for biotic and abiotic stress resistance/tolerance will continue to be enhanced and upgraded through visits of scientists and training.

Impact pathways and partnerships:

P7 research targets traits that convey resistance/tolerance in wheat cultivars to biotic and abiotic stresses in rainfed areas. The four chief ones are drought tolerance, heat tolerance, cold tolerance, and resistance to soil-borne pathogens. Resulting germplasm must also preserve a range of quality traits to meet users' needs. P7 works closely with P1 to address the lack of genetic variability or molecular tools that will allow efficient breeding for the above. By understanding morphological traits and physiological traits associated with water productivity, participants aim to improve the productivity of rainfed wheat systems and to enhance grain quality. Together with building the capacity of NARSs and other partners, this research will help reduce the vulnerability of wheat farmers in marginal conditions due to yield variation. The Project is also linked to P11 (resilience) and P10 (conservation agriculture).

CIMMYT and ICARDA are committed to improving the welfare of poor people and to alleviating poverty in CWANA by increasing the production, productivity and nutritional quality of wheat. The joint ICARDA-CIMMYT Wheat Improvement Program for CWANA (ICWIP) is a good example of a strategic alignment between a global commodity center (CIMMYT) and an eco-regional center (ICARDA) working on the same commodity (wheat). Given its high per capita wheat consumption and status as the center of origin and diversity for the wheat, CWANA represents one of the most important regions of CIMMYT's global mandate for wheat improvement. The new joint program has improved services to NARSs and, ultimately, wheat producers. This has come partly through economies of scale and optimal use of resources and greater efficiency and effectiveness of research, taking advantage of synergies/complementarities in the Centers' programs.

Another example of a global network to develop, test, and distribute germplasm is the TURKEY/CIMMYT/ICARDA Winter Wheat Program in Turkey (Figure 1). Participants receive germplasm from a diverse array of public and private sector programs. From Turkey, the breeding materials go to most other winter wheat growing countries. Collaborators in these countries evaluate the materials and send the results to IWIN, where the data are compiled and distributed to partners to help guide further research and variety testing.

The Generation Challenge Program Consortium applies molecular biology to global stocks of wheat genetic resources in support of CIMMYT's work to create a new generation of water-productive wheat. The CIMMYT programs currently develop some 1,000 lines annually of spring bread wheat, facultative and winter bread wheat, spring durum wheat, and spring triticale for international distribution. This generally requires 3 to 5 years, which is substantially quicker than most other wheat breeding programs worldwide because shuttle breeding in Mexico allows two generations per year. Around half of these lines are targeted for regions where water stress occurs, particularly the Asian Subcontinent, CWANA, and the southern cone of South America.

Grain quality is a paramount concern for farmers, processors, and consumers. High-value and value-added traits include improved nutritional quality, better milling and processing qualities, safer food products, and improved straw and forage quality for animal feed and fodder. Wheat breeding has always focused on bread-making quality, but increasing attention is now being given

to wheat's use in products such as noodles, chapattis, semolina, and pasta. This Project focuses on traits that add value to grain by improving its quality, increasing its nutritional value, or enhancing the safety of wheat-based foods. CIMMYT germplasm must meet the quality demands of a range of clients, markets, and beneficiaries.

The ultimate beneficiaries will continue to be smallholder farmers, who will receive suitable, improved bread wheat, durum wheat, and triticale cultivars. Building upon the foundation of modern wheat cultivars, new releases can be expected to deliver 10% more yield than older varieties, be more tolerant to variable climate conditions, and produce more straw (an important component for animal fodder, home cooking fuel, and roofing material). Broad adaptation in cultivars buffers farmers' risks in low- or variable rainfall settings, while allowing SMEs and progressive farmers to produce and market seed of relevant cultivars economically.

Project 8: ***Disease resistant wheat with high productivity and quality***

Until the advent of science-based agriculture, world wheat harvests were held hostage by rapidly evolving fungal pathogens, among the most damaging of which were the rusts (stem, leaf and stripe), other foliar diseases and fusarium head blight. Modern breeding, combined with the free international exchange of experimental wheat lines, resulted in developing and wide dispersion of genetically enhanced wheat germplasm able to resist the rusts and other diseases for several decades. Durable resistance to common wheat diseases provides farmers with confidence that they will reap reasonable harvests, despite evolving pathogen populations, and without the need to use expensive chemical inputs. But because more virulent pathotypes or strains of a pathogen will likely overcome the crop's resistance at some point and to ensure that production increases stay abreast of population growth, CIMMYT emphasizes research aimed at raising the genetic yield potential of wheat while maintaining its disease resistance. This results in enhanced, seed-embedded technology that gives superior performance in farmers' fields. The foundation is improved wheat germplasm and related knowledge built together by CIMMYT and partners; this combination has had demonstrable impact in farmers' fields.

<u>International public goods:</u>

Genetically diverse wheat germplasm with enhanced consumer and market oriented quality, high yield potential, resistant to biotic stresses, and buffered to tolerate climatic change and variability.

- Disease resistant cultivars with high yield potential for farmers in wheat producing agro-ecologies where adequate or supplementary irrigation is used.
- Basis of yield potential expanded, addressing important associated traits such as resistance to lodging, spike "sink" capacity, stay-green, and heat tolerance.
- Potential "durable", polygenic sources of resistance from the bread and durum wheat genomes, as well as related wild species, for main wheat diseases.

The basis of durable disease resistance characterized and genetic diversity enhanced to reduce genetic vulnerability in farmers' fields.

- Knowledge of the basis for durable resistance to the main pathogens of wheat.
- Knowledge of rust epidemiology to assist in the fight against a global stem rust pandemic.
- New sources of resistance to wheat pathogens confirmed.

Global networks to monitor distribution, evolution and migration of pathogens for an early warning of threats.

- A global wheat research network: public-private-NGO partnerships among international and national agricultural research and development organizations.
- CIMMYT's improved germplasm is dispatched, through nurseries targeted to specific agro-ecological environments, to a cadre of wheat researchers participating in the International Wheat Improvement Network.

Regional capacity for genetically enhancing wheat against pathogens and pests.

- The enhanced laboratory and field capacity of KARI (Kenya) and EIAR (Ethiopia) to conduct research on rust, in particular stem rust.
- The development and application of high-throughput doubled haploid, single seed descent or microspore systems to speed up the development of fixed lines, to rapidly respond to partners' emergency needs.

Impact pathways and partnerships:

P8 works with intensive, fully or supplementally irrigated agro-ecosystems. The Project's goals are addressed through understanding physiological traits such as those related with yield and heat tolerance, while keeping in mind the issue of quality: low mycotoxin contents and traits that result in good storage possibilities for the grain are the main examples. Often together with NARSs, CIMMYT will select germplasm in disease hot-spots in China, Ecuador, Ethiopia, India, Iran, Kazakhstan, Kenya, Mexico, Nepal, Pakistan, Turkey, and Uruguay to protect farmers' yields from rust and other diseases of wheat. CIMMYT breeders generate some 500 lines annually with broadened, often more durable disease resistance, focusing on leaf, stem, and yellow rust, fusarium head blight and crown rots, and *Helminthosporium* and *Septoria* spp.

CIMMYT breeders and pathologists will apply representative yet intensive screening pressures through shuttle breeding schemes to identify high-yielding, stable, broadly adapted, disease resistant germplasm suitable to the needs of resource-poor farmers. Together with more than 80 country partners in the International Wheat Improvement Network, Center staff will also monitor the vulnerability of currently-sown wheat cultivars to emerging disease risks such as the new virulent Ug99 stem rust strain from Uganda.

These issues are addressed while maintaining end-user grain quality.

Worldwide, over 100 new wheat varieties containing CIMMYT germplasm are released each year. Time to variety release and registration after receiving experimental germplasm varies considerably by country, from as little as 3 years to as much as 10-12 years. Lack of effective

seed production also limits farmers' use of new varieties: wheat is a self-pollinated crop, so farmers can re-sow seed from one year to the next without substantially altering the identity or performance of a variety, and this constitutes a disincentive for commercial seed production.

This Project will identify new traits and incorporate them into elite germplasm accessible to resource-poor farmers. Its impacts will include improved food security and livelihoods. CIMMYT germplasm must meet the quality demands of a range of clients, markets, and beneficiaries. For the poorest of the poor, biofortification of wheat cultivars through increased micro-nutrient content will be pursued. CIMMYT and partners will also work to provide value-added traits that enable farmers to meet industry standards. Relevant traits include improved micronutrient and protein content and improved quality for specialized food products. Through resistance breeding, CIMMYT and partners will also work proactively to address food health issues associated with contamination from *Fusarium* mycotoxins.

P8 has strategic alliances to other CIMMYT projects on topics such as the inefficient use of nitrogen fertilizers and enhanced use of conservation agricultural practices. Activities in P8 are integrated and contribute to the Global Rust and the Global Fusarium initiatives. Problems of non-sustainable cropping systems and improved systems, like fully irrigated raised bed cropping, are addressed together with P10. This Project's outputs directly address the enhanced genetic variability and the molecular tools that will improve breeding efficiency (with P1 and P2). Project participants also contribute to capacity building in NARSs.

The ultimate beneficiaries will be farmers, including smallholders, who will receive improved cultivars. Through the increased, durable resistance of their crops, their yields are protected and household vulnerability to famine and extreme poverty is reduced.

Project 10: ***Maize and wheat cropping systems***

Through partnerships with NARSs, agri-business, and other CGIAR centers, this Project undertakes systems agronomy and resource-conserving technology research with an ultimate vision of widespread sustainable smallholder wheat and maize systems based on the principles of conservation agriculture (CA). The aim is to improve rural incomes and livelihoods through sustainable management of agro-ecosystem productivity and diversity, while minimizing unfavorable environmental impacts. The Project will focus on the development of appropriate practices tending to reduce tillage, provide adequate surface retention of crop residues, and underline importance of diversified crop rotations to reverse soil degradation. For small- and medium-scale farmers, the Project will seek more efficient and sustainable use of water and other inputs, lower production costs, better management of biotic stresses, and enhanced system diversity and production. As resource-conserving practices are adopted, research will promote an integrated evaluation of the effects of long-term conservation agriculture under diverse agro-ecological conditions, both rainfed and irrigated. Studies will focus on such factors as pest, weed, and disease dynamics; the effects of crop rotations and green manure cover crops; residue management and threshold levels of residue cover; soil nutrient dynamics and nutrient

management; water management; soil structure dynamics; impacts on greenhouse gas emissions; adaptive research/policy issues; impacts on household livelihoods, local/regional economies, and food security; and varieties adapted to CA systems.

International public goods:

- Technological components for conservation agriculture systems that are appropriate for small- and medium-scale maize and wheat systems that generate additional food and/or income, that facilitate system diversification and improve soil health and productivity, and thereby contribute to sustainable production.
- Knowledge of the effects of conservation agriculture systems and practices on land, labor, and water productivity; on soil organic matter and soil physical, chemical, and biological fertility; on pest and disease dynamics; and on farm household incomes and livelihoods.
- The strengthened capacity of partners (NGOs, NARS, farmer groups, public and private sector entities, and policy-makers) in conservation agriculture research-for-development; the formation and management of farmer-focused innovation systems; the scaling out of conservation agriculture principles and technologies; and the development of local, regional, and national policies that promote sustainable agricultural practices.

Impact pathways and partnerships:

In collaboration with ICARDA in CWANA, CIAT in Southern Africa and NARS and NGO's in Afghanistan, Azerbaijan, Bangladesh, Bolivia, China, Ethiopia, India, Iran, Kazakhstan, Malawi, Mexico, Morocco, Mozambique, Nepal, Pakistan, Paraguay, Turkey, Tajikistan Uzbekistan, Zambia and Zimbabwe, CIMMYT has conducted primary research relating to the design and implementation of on-farm conservation agriculture practices. This has resulted among other things in the development of new technologies for soil conservation and increased water productivity, while reducing labor requirements and production costs. Research and appropriate implement development have been participatory, with farmers, extension workers and NARSs assessing their requirements and defining appropriate intervention points to facilitate wider adoption. Access to and development of appropriate planting equipment have been primary focuses, often relying on the exchange of agricultural engineering technologies across continents. The specific approaches used depended on the degree of crop production intensity. Under rainfed environments, efforts have focused on the adoption of minimum and zero-tillage mostly on the flat, with residue retention. In more intensive irrigated agriculture, conservation agriculture is coupled with establishment of (semi-)permanent raised-bed planting as a first step toward CA. Significant efforts have been made by CIMMYT researchers to demonstrate the advantages of conservation agriculture and raised-bed planting to farmers, extension agents, researchers and policy-makers. Efforts have been made to involve small- and medium-sized enterprises for machinery manufacture or modification and to supply inputs. Experience has shown that even smallholder farmers see benefits in this technology, in some cases hiring local agricultural mechanization entrepreneurs to sow and harvest. Beneficiaries include farmers, who save natural and economic resources while ensuring more sustainable farming, and communities that depend on the improved biophysical and economical sustainability of agricultural production. The many P10 partners include:

- Farmers and farmer organizations, who are direct beneficiaries and active elements in setting CIMMYT's research and agenda, and in knowledge-sharing through their feedback.
- Private enterprises, including seed producers and machinery manufacturers.
- NARSs and NGOs, who serve as principle contacts for adapting, implementing, and spreading technologies (e.g., CGIAR Challenge Program for Water and Food, and the project Yellow River Rainfed Conservation Agriculture).
- National and local policy-makers, who cooperate and create enabling institutional environments.
- Regional agricultural R&D organizations (e.g., Rice-Wheat Consortium for the Indo-Gangetic Plains).
- International agricultural R&D organizations (e.g., CG Centers such as ICARDA and IRRI, and FAO).
- Advanced institutions (universities), which collaborate with CIMMYT on basic research of technology design and the evaluation of economic and biophysical effects of these technologies.

Project 11: ***Knowledge, targeting, and strategic assessment of maize and wheat farming systems***

Most poor farmers and consumers in developing countries depend on risky and complex maize- or wheat-based farming systems for their survival. For related crop research to have rapid, lasting impacts on poverty reduction, it is essential to consider the diverse production, consumption, and livelihood roles of wheat and maize, which go far beyond household and national food security to include cash income from sales of grain and speciality products, the reduction of vulnerability through stable grain yields, the stimulus of animal production through the provision of fodder and feed, the creation of bioenergy from low cost feedstocks, and the improvement of human health through nutritionally-enhanced grain. In addition, there are a range of secondary, indirect benefits not widely recognized: for example, the intensification of maize and wheat fosters on-farm diversification and local rural non-farm economy growth.

Through strategic assessments of wheat and maize systems and knowledge sharing, this Project will contribute to mission-effective maize and wheat improvement research by CIMMYT and NARS. As the "easy" research gains have been achieved and as the international community places greater emphasis on sustainable poverty reduction, sustainable management of resources, and other MDG goals, the choice and efficient delivery of maize and wheat traits and management technologies to small farmers requires more careful analysis of options. In many developing regions, the dominant role of wheat and maize on small farms is changing from staple for home consumption to cash crop for domestic sales and export, both in well-watered and drought-prone environments. The technological and knowledge needs of resource-poor farmers are evolving rapidly as a result of changing trade regimes, the withdrawal of state services, the transformation of food systems, the reduction of the agricultural research budgets, and pervasive market and institutional failures.

Despite the diversity of maize and wheat systems, relatively homogenous mega-environments, farming systems and research domains can be defined to guide priority setting and targeting and supporting spatial knowledge bases assembled. The synthesis of ex post and ex ante impact

assessments, conducted in the normal course of research, identifies key lessons for research targeting and operations. The Project develops key methodologies (e.g., socioeconomic and environmental characterization, impact pathway assessment, value chain mapping, knowledge sharing). Science knowledge sharing platforms are being developed under the IRRI-CIMMYT Alliance.

International public goods:
The Project produces international public goods in the following areas:

- Spatial knowledge bases and strategic assessments to support priority setting, targeting, and scaling up for CIMMYT and partners.
- Syntheses of ex post and ex ante impact assessments.
- Better understanding of producer incentives and institutional drivers of maize and wheat diversity.
- Analyses of maize and wheat value chains to improve marketing efficiency and producer and consumer benefits.
- Knowledge and associated knowledge sharing mechanisms for maize and wheat science that provide direct benefits and also support capacity building at CIMMYT.

Impact pathways and partnerships:
The principal users of Project products and services are research managers and scientists for the design and appraisal of agricultural research and development. The knowledge outputs of the Project take the form of web products, reports, papers, and databases developed by CIMMYT and partners, especially NARS socioeconomics and senior research managers and agri-businesses in developing countries. Sometimes the knowledge flows through other CIMMYT Projects, sometimes directly to NARS partners. Ultimately, improved NARS understanding, research methods and targeting lead to improved livelihoods and poverty reduction.

Consider the specific impact pathway of the publication *Wheat* (or *Maize*) *Facts and Futures*. After assembling, analyzing and interpreting data assembled jointly with NARSs, including seed companies where appropriate, the Project provides maize and wheat status and scenario information to NARSs actors. The short-term outcome will be improved understanding, on the part of national research managers and policy makers, of current and probable future commodity markets and technologies. The medium-term expectation is improved focus and effectiveness of national crop improvement programs (this will occur more rapidly in strong NARSs such as India; more slowly in less well-resourced NARSs), and thus better cultivars and faster adoption by poor farmers. In the long-term, significant producer and consumer impacts could be expected: improved livelihoods, reduced vulnerability, and reduced poverty among marginalized farmers, diversification towards cash crop production, job creation in the rural non-farm economy, and increased food consumption by poor consumers. The farm household benefits will tend to be aligned with CIMMYT flagship products.

There are several assumptions that link these steps: the feasibility of assembling relevant data for the analysis; the availability and credibility of the results; the relevance to national science policy decisions; the effectiveness of crop improvement, seed distribution, and knowledge extension activities; the correspondence with farmers' goals; and the on-farm cost-effectiveness of a specific technology.

The impact pathways depend on a variety of functional internal and external partnerships that can be mapped as networks. In regard to internal partnerships, the collaboration with CIMMYT Projects underpins the delivery of most outputs, which in turn supports the networks of those respective Projects. The internal network of CIMMYT social scientists also fosters the dissemination of Project knowledge outputs, including methodologies, guidelines, and knowledge bases.

Regarding external partnerships, the Project collaborates strategically with the CGIAR Science Council Standing Panel on Impact Assessment (SPIA) on impact assessment approaches and methods. Project scientists partner with other CGIAR centers to complement expertise in multidisciplinary and micro-economic analyses of maize, wheat, and conservation agriculture: notably IFPRI, ICARDA, CIAT and ILRI in relation to targeting, environmental characterization, climate change, knowledge bases and impact assessment; IPGRI in relation to crop diversity; CIAT, IFPRI and ILRI for value addition and grain and stover quality; and the IRRI-CIMMYT Alliance as well as many other centers for the knowledge sharing and the Cereal Systems Knowledge Portal. In relation to Challenge Programs, the Project provides analyses of strategies for reaching end users and ex ante impact assessment for HarvestPlus, and with the System-wide Livestock Program in relation to the analysis of emerging maize fodder. The development of data and knowledge bases requires cooperation in sharing data on cultivar adoption, financial and economic benefits, impact pathways, and innovation systems, including NARSs from Mexico, Morocco, Turkey, Ethiopia, Kenya, India, China and Bangladesh.

Universities and NARSs support impact assessments and crop diversity studies. Joint activities with universities, NARSs, FAO, and NGOs are planned on value chain analysis. Active collaboration on the Cereal Systems Knowledge Portal is ongoing with IRRI, as well as a wide range of NARSs, universities, and other public and private sector organizations. Project staff conduct joint research with advanced universities and in the field with universities in developing countries.

MTP 2008-2010 Log-frames

Project 1: Conservation, characterization and utilization of maize and wheat genetic resources

	Outputs	Intended users	Outcomes	Impacts
Output 1	Genetic resources conservation, characterization, informatics and distribution	Maize and wheat international research and breeding community, and SGRP	Improved efficiency of maize and wheat ex situ conservation and distribution	Increasingly targeted access of maize and wheat germplasm users leading to enhanced access and improved efficiency of utilization
2008	Fully integrated, public-access, multidisciplinary germplasm information resource with powerful query and analysis tools, linked to a web-based registry of global maize and wheat genetic resources	CIMMYT, NARSs, SME, IARC and ARI researchers and breeders worldwide	Global access to and analysis of CIMMYT's entire historical data reserves	Increased use of CIMMYT genetic resources and improved germplasm for research and breeding worldwide
2008	Increasingly targeted and tailored distribution of genetic resources and strategic germplasm to stakeholders worldwide	Global maize and wheat research and breeding community	Enhanced efficiency of maize and wheat germplasm utilization	Increase use of CIMMYT genetic resources and improved germplasm for research and breeding worldwide
2009	Phenotypic and genotypic characterization of the GCP mini-composite germplasm subsets for maize and wheat available through an on-line ICIS-based resource	CIMMYT, IARCs, NARSs, ARI, SME researchers and breeders	Improved efficiency of access to new genetic variation for improving important agronomic traits, particularly yield stability under abiotic stresses	Improved uptake and increased impact of utilization of genetic resources in breeding programs worldwide
2009	Identification of important gaps in maize and wheat collections, and formulation of a 5-year strategic plan for future acquisition of novel germplasm	Global maize and wheat research and breeding community	Reduction in germplasm requests that are declined or inappropriately fulfilled due to lack of the necessary genetic variation	Improved efficiency of maize and wheat germplasm utilization in research and breeding programs worldwide
2009	Logistical and statistical improvements through process and genetic modeling for efficient maintenance and regeneration of maize and wheat genetic resources	Maize and wheat genebank curators worldwide	Increased efficiency of conservation of maize and wheat genetic resources	Improved long-term sustainability of maize and wheat germplasm collections
2009	Standard operating procedures for genebank operation, germplasm data curation and quality assurance, and germplasm distribution developed in coordination with SGRP, including pathogen and transgene detection systems	CIMMYT, IARCs, NARSs, and ARI genebank curators	Increased quality and efficiency of CIMMYT germplasm distribution through transparent definition of procedures and protocols	Enhanced public confidence in seed health and contamination risk management for global recipients of seed shipments from CIMMYT-Mexico
2010	Creation of an active community of practice of maize and wheat genebanks, germplasm enhancers, and germplasm users	CIMMYT, IARCs, NARS and ARI plant genetic resource collections, recipients of germplasm and SGRP	Rapid and widespread uptake of genebank operation best practices and response to end-user feedback	Increased quality and efficiency of maize and wheat germplasm conservation, distribution, and utilization
2010	An on-line portal for all genebank and germplasm data	Global maize and wheat research and breeding community	Global access to and analysis of CIMMYT's entire germplasm-related historical data reserves	Increased targeted utilization of CIMMYT genetic resources and improved germplasm for research and breeding worldwide

	Outputs	Intended users	Outcomes	Impacts
Output 2	Targeted access to useful genetic variation	Global maize and wheat research and breeding community	Enhanced efficiency of maize and wheat germplasm utilization	Improved uptake and increased impact of utilization of genetic resources in breeding programs worldwide
2008	Establishment of representative germplasm subsets from global maize and wheat collections based on passport, pedigree, genotype, ecoregional adaptation and/or type of germplasm data	CIMMYT, ICARDA, IITA, NARS and SME breeding programs and the GCP research community	Greater depth and breadth of genetic resources utilization in regional maize and wheat breeding programs	Increased use of germplasm in the improvement of important agronomic traits, particularly yield stability under abiotic stresses
2008	New sources of genetic variation and/or molecular markers for existing sources of variation improve important agronomic traits identified in diverse maize and wheat germplasm using association mapping	CIMMYT, ICARDA, IITA, NARS and ARI researchers and breeders	Novel alleles and genes affecting pest and disease resistance, drought tolerance, or quality traits identified in diverse maize and wheat genotypes	Increased scope and efficiency of use of genetic resources in maize and wheat breeding programs worldwide
2008	Identification and characterization of new candidate alleles influencing grain quality in maize	CIMMYT, IITA, and ARI researchers and breeders	New allelic variation of molecular breeding of grain quality in maize	Proof-of-concept value of allele mining strategies for fueling future plant breeding gains in grain quality
2009	Germplasm subsets from CIMMYT maize or wheat collections relevant to target mega-environments and/or specific priority traits identified	CIMMYT, ICARDA, IITA, NARS and ARI researchers and breeders	New methodologies for selecting trait-specific germplasm subsets, most important gaps and areas of redundancy in current collections identified	Improved efficiency of targeted access to global maize and wheat genetic resources and identification of the most genetically unique material
2009	New sources of genetic variation for improvement of new value-added traits in diverse maize germplasm using association mapping	CIMMYT, ICARDA, IITA, and ARI researchers and breeders	Novel alleles and genes affecting value-added traits in maize	Increased scope and efficiency of use of genetic resources in maize breeding programs worldwide
2009	New sources of genetic variation for improvement of agronomic traits identified in diverse maize or wheat germplasm using sequence-based allele mining and gene discovery technologies	CIMMYT, ICARDA, IITA, NARS and ARI researchers and breeders	Novel alleles and genes affecting pest and disease resistance, reproductive traits, drought tolerance, or quality traits identified in diverse maize or wheat germplasm	Proof-of-concept of the value of allele mining to foster plant breeding gains for various complex traits
2010	Web-enabled, dynamic germplasm sub-set selector available with a range of analytical tools for real-time targeted selection of maize and wheat genetic resources using all passport, phenotype, pedigree and genotype data	Germplasm bank collection managers worldwide, irrespective of crop species	New methodologies for selecting trait-specific germplasm subsets, most important gaps and areas of redundancy in current collections identified	Improved efficiency of targeted access to global maize and wheat genetic resources and identification of the most genetically unique material
2010	Validated methodology for linking from trait hot-spots in mini-composite subsets to the main germplasm collection	Germplasm bank collection managers worldwide, irrespective of crop species	New methodologies for using germplasm stratifications to effectively target access to the entire collection	Improved efficiency of targeted access to global maize and wheat genetic resources
2010	Validated, multidisciplinary methodologies for trait-based allele mining and gene discovery	Germplasm bank collection managers worldwide, irrespective of crop species	New methodologies for genomics-based target access to genetic resources	Increased scope and efficiency of use of genetic resources in maize and wheat molecular breeding programs worldwide

	Outputs	Intended users	Outcomes	Impacts
Output 3	Trait-based germplasm enhancement and facilitating community support	CIMMYT, ICARDA, IITA, NARS and SME maize and wheat breeding programs	Improved efficiency of utilization of novel sources of genetic variation for improvement of agronomic traits	Enhanced progress in the improvement of agronomic traits in maize and wheat breeding programs worldwide
2008	Introgression of new sources of disease resistance and drought tolerance from secondary wheat gene pools into primary gene pools of wheat germplasm through artificial re-synthesis	Global wheat improvement communities	New re-synthesized wheat lines available for crossing with elite wheat breeding lines	Enhanced improvement of agronomic traits due to increased utilization of wild species in wheat breeding worldwide
2008	Improvement of eco-regionally targeted strategic germplasm pools	Global maize improvement communities	30 enhanced maize pools refined with introgressed Latin American landrace germplasm	Increase scope and efficiency of utilizing landraces in maize breeding worldwide
2009	Optimized methodologies for evaluation and germplasm enhancement using transgenic sources of drought tolerance in wheat	CIMMYT and partner national wheat breeding programs	Wheat breeding lines with improved drought tolerance due to transgene introgression	Increased scope and efficiency of using transgenic lines in wheat breeding
2009	Marker-assisted improvement of eco-regionally targeted strategic maize germplasm pools	CIMMYT and partner national maize breeding programs	Increased efficiency of maize germplasm enhancement activities	Increased scope and efficiency of utilizing landraces in maize breeding worldwide
2009	Comprehensive evaluation of cost and time efficiency, and rate of genetic gain achieved through double haploid germplasm enhancement strategies in maize and wheat	CIMMYT and partner national maize and wheat breeding programs	Increased speed, efficiency or scope of genetic gain, including more efficient development and integration of MAS	Dramatic increases in the efficiency of maize and/or wheat breeding systems
2010	Validated methodology for selecting parental genotypes for generation of re-synthesized wheat lines with beneficial impacts on disease resistance and drought tolerance breeding programs	CIMMYT and partner national wheat breeding programs	More efficient breeding systems for utilizing re-sysnthesized wheat lines	Increased scope and efficiency of utilizing wild species in wheat breeding worldwide
2010	Genomics-based methodology for defining heterotic patterns among strategic maize germplasm	CIMMYT and partner national maize breeding programs	Improved efficiency of hybrid maize breeding	Increased heterosis achieved with less breeding effort
2010	National, regional and international researchers and breeders trained in germplasm conservation, characterization, data management and/or utilization	CIMMYT, ICARDA, IITA, NARS, ARI breeding programs	Up to 100 researchers and breeders trained during the life of this MTP in the latest innovations in germplasm management, novel technology-assisted germplasm enhancement tools and methodologies	Increased capacity of CGIAR centers and NARS partners to achieve rapid progress in maize and wheat germplasm enhancement

Project 2: Technology-assisted tools and methodologies for genetic improvement

	Outputs	Intended users	Outcomes	Impacts
Output 1	Biotechnology-based tools and transgenic resources	CIMMYT, SME and NARSs researchers and breeders	New technology-based tools for use in CIMMYT, ICARDA, IITA, NARSs and SME breeding programs	Improved efficiency, speed and precision of maize and wheat breeding systems
2008	Increased understanding of the genetic basis, epistasis and genotype-by-environment interaction of complex target agronomic traits	Global maize and wheat genetics research and breeding community	Proof-of-concept regarding the power and value of comparative, simulation and modeling analyses of diverse datasets that have not previously been brought together	Increased ability to design knowledge-led breeding systems accounting for epistasis and genotype-by-environment interaction
2008	Validated DNA markers for existing sources of disease resistance, drought tolerance and grain quality traits in maize or wheat available	CIMMYT, ICARDA, IITA, NARS and SME researchers and breeders	Robust markers for High-throughput low cost molecular breeding applications in CIMMYT and partner breeding programs	Improved efficiency, speed and precision of maize and wheat molecular breeding systems
2008	LIMS system established for High-throughput genotyping in maize and wheat, and linked to ICIS for automated data curation	Molecular breeders and genomics researchers worldwide	Reduced sample tracking time and errors plus increased data management efficiency	Increased efficiency of molecular breeding programs
2009	High-throughput low cost multiplex MAS system for large-scale introgression of resistances to rusts in wheat available	CIMMYT, ICARDA and NARSs wheat breeders	Increased speed and decreased cost of rust resistance molecular breeding	More efficient development of elite wheat breeding lines with rust resistance including combinations of genes not previously possible
2009	DNA markers identified for new sources of pest and disease resistance, drought tolerance or grain quality in maize through large-scale selective genotyping	CIMMYT, SME and NARSs researchers and breeders	Dramatically increased efficiency of identifying marker-trait associations for important agronomic traits	Improved scope and impact of MAS in maize
2009	New maize and wheat transgenic lines with improved agronomic traits available	Molecular breeders and genomics researchers worldwide	New sources of disease resistance, drought tolerance or grain quality for maize or wheat molecular breeding	New options for the development of maize and wheat cultivars with improved resilience, stability and profitability
2010	Low density genome-wide genotyping system for maize and wheat molecular breeding available	CIMMYT, ICARDA, IITA, NARS and SME researchers and breeders	High-throughput low cost genotyping system available for molecular breeding applications in CIMMYT and partner breeding programs	Improved efficiency, speed and precision of maize and wheat molecular breeding systems
2010	Methodologies for large-scale double haploid production in maize and wheat available	Global maize and wheat genetics research and breeding community	Improved pace, genetic gain and cost of maize and wheat molecular breeding programs	Improved efficiency of maize and wheat breeding systems including progress towards goals not previous possible
Output 2	Molecular breeding methodologies and facilitating computational systems	CIMMYT, ICARDA, IITA, NARS and SME maize and wheat breeders	Increased efficiency of maize and wheat improvement, particularly for priority traits	Maize and wheat cultivars with improved resilience, stability and profitability
2008	Integration of germplasm enhancement, breeding, genomics and international nursery data into a web-enabled, ICIS-based resource for maize	Global maize genetics research and breeding community	Ability to compare and analyze data from across the entire genetic resources, germplasm enhancement and breeding continuum	More efficient knowledge-led germplasm utilization and breeding systems

	Outputs	Intended users	Outcomes	Impacts
2008	Statistical models for assessing association of phenotypic traits with molecular marker data in subsets of breeding lines available	CIMMYT, ICARDA, IITA and NARS maize and wheat geneticists and breeders	Proof-of-concept ability to carry out association mapping in subsets of breeding lines	Increased efficiency of identification and validation of marker-trait associations
2008	Simulation models of molecular breeding strategies for maize and wheat available	Global maize and wheat breeding community	Reduced number of cycles, population size or phenotyping required to achieve the desired rate of genetic gain	Improved efficiency of maize and wheat molecular breeding systems
2009	Integration of germplasm enhancement, breeding, genomics and international nursery data into a web-enabled, ICIS-based resource for wheat	Global wheat genetics research and breeding community	Ability to compare and analyze data from across the entire genetic resources, germplasm enhancement and breeding continuum	More efficient knowledge-led germplasm utilization and breeding systems
2009	Precision phenotyping methodologies for drought tolerance in maize and wheat available	CIMMYT, ICARDA, IITA, NARSs, SME and ARI researchers and breeders	Improved ability to evaluate material during mapping studies or screen material in breeding programs	Increased accuracy of marker development activities and selective power of conventional breeding programs
2009	Genotype-by-environment interaction for abiotic and biotic stress tolerance in crop breeding programs characterized and classified	CIMMYT, ICARDA IITA, NARS, SME and ARI researchers and breeders	Improved ability to identify underlying genes for complex biotic and abiotic stress tolerances and model their interaction with the environment	Increased ability to design knowledge-led breeding systems accounting for epistasis and genotype-by-environment interaction
2010	Integrated methodologies validated for foreground and background molecular breeding	Global maize and wheat research and breeding community	Dramatically increased impact of genomics tools in maize and wheat breeding systems	Improved efficiency of maize and wheat molecular breeding systems
2010	A fully integrated decision-support system available for the design and implementation of molecular breeding of wheat and maize	CIMMYT, ICARDA, IITA, NARSs and SME breeders	Improved efficiency, speed and precision of trait-targeted breeding programs through linking genetic, economic, crop growth and whole plant physiology modeling analyses	Improved efficiency, pace and success of maize and wheat breeding product development
Output 3	Capacity building and backstopping implementation of technology-assisted breeding interventions	CIMMYT, ICARDA, IITA, NARSs and SME researchers and breeders	Newly identified genetic resources, latest innovations in germplasm management, novel technology-assisted germplasm enhancement tools and methodologies routinely adopted by CIMMYT, NARSs and SME breeding programs	Increased pace, quantity and value of market preferred cultivars that reduce farmer risks and vulnerabilities, improve farming household livelihoods and health, and conserve natural resources
2008	High-throughput DNA extraction facilities established at four key maize and wheat breeding locations	National and international partner maize and wheat breeding programs	Increased autonomy of breeding programs to engage in molecular breeding activities	Improved efficiency of maize and wheat molecular breeding systems in regional hubs in Africa, Asia and Latin America
2008	Coordinated out-sourcing system for genome-wide genotyping available for maize	National and international partner maize breeding programs	Increased autonomy of maize breeding programs to engage in molecular breeding activities	Improved scale and cost efficiency of maize molecular breeding systems in national and international programs worldwide

	Outputs	Intended users	Outcomes	Impacts
2009	Training in new technology-assisted breeding methodologies through biotech hubs in Africa and Asia	NARSs, SME and CIMMYT researchers and breeders	Modern breeding best practices adopted in national and international programs worldwide. Enhanced quality and efficiency of research and breeding programs	Increased flow of more targeted maize and wheat germplasm with greater impact.
2009	Molecular breeding communities of practice established around biotech hubs in Africa and Asia	NARS, SME, IITA, ICARDA and CIMMYT maize and wheat breeding programs	Cooperatively designed and developed maize or wheat seed-based technologies tailored for use in each target mega-environment	More rapid and efficient development of market preferred cultivars with improved agronomic performance
2009	A comprehensive research data management system across all disciplines	Researchers in IRRI and CIMMYT and their NARSs partners	Efficiency and focus of research improved by access to sound informatics practices and relevant, high quality information and data from previous research	Increase in research and breeding advances through effective analysis of fully integrated data across all disciplines
2010	Virtual consultancy service available for biometrics, computational biology, breeding informatics and simulation	Researchers in IRRI and CIMMYT and their NARSs partners	Latest innovations in computational sciences adopted by CIMMYT and partners	Global access to current information technology that facilitates data management and product delivery
2010	Service, support and training unit established in biotech hubs in Africa and Asia	National and international partner maize and wheat breeding programs	Latest innovations in technology-assisted plant breeding adopted by CIMMYT and partners	Improved efficiency of maize and wheat breeding programs worldwide
2010	On-line training resources available for all aspects of molecular breeding	National and international maize and wheat breeding programs worldwide	Latest innovations in technology-assisted plant breeding freely available to anyone	Improved efficiency of tropical breeding programs worldwide

Project 3: Stress tolerant maize

Time Frame	Outputs	Intended User	Outcome	Impact
Output 1	Drought tolerant (DT) maize to enhance food and income security, reduce use of scarce irrigation water and adjust to climate change	Breeders in NARS, private seed companies and at IITA, formal and community-based seed producers, NGOs and CBOs, decision makers, scientific community at large	Use of increasingly drought tolerant, diverse maize germplasm; more effective development, and dissemination of drought tolerant maize cultivars to farmers world-wide	Increased food and income security for resource-poor farm families, decreased vulnerability to recurrent droughts and climate change, decreased need for food aid and irrigation water
Output Target 2008-2010	Annual provision of >10 elite new DT maize genotypes adapted to eastern and southern African maize mega-environments	Breeders in NARS and private seed companies	Continued increase of drought tolerance in maize varieties made available to farmers in eastern and southern Africa	Reduced maize yield losses in drought-affected maize growing environments in Africa
Output Target 2008	New phenotyping protocols for crop water status defined for maize	Breeders and scientific community world-wide	Inclusion of additional selection criteria in maize drought breeding results in greater breeding progress	
Output Target 2008	Morpho-phenological diversity of southern Africa maize landraces documented for abiotic stress tolerance	Breeders in SSA, scientific community world-wide	More effective use of maize genetic resources in stress breeding projects for southern Africa	
Output Target 2008	Use of DT maize by seed producers in Africa assessed and bottlenecks for variety deployment defined	NARS, seed companies, decision makers	More rapid scale-up of seed production of drought tolerant maize	
Output Target 2008	Asian-adapted germplasm (at least 40 lines) with genes for drought tolerance introgressed from elite CIMMYT sources distributed to national programs in Southeast Asia for advanced testing	NARS and private seed companies in India, Southern PRC, Indonesia, Philippines, Thailand, and Vietnam	Drought tolerant maize varieties made available to farmers in East and Southeast Asia	Productivity increases in Asia maize growing environments limited by drought and scarcity of irrigation water
Output Target 2009	Global characterization of elite maize inbreds from CIMMYT and IITA for drought tolerance and genetic diversity	Breeders and scientific community world-wide	Accelerated breeding gains for drought tolerance	
Output Target 2009	Double-haploid technique used to extract inbreds from drought tolerant source populations	Breeders and scientific community world-wide	Accelerated breeding progress for drought tolerance	
Output Target 2010	Transgenic sources of drought tolerance incorporated into drought tolerant CIMMYT maize germplasm	Breeders in SSA, scientific community world-wide	First information on the complementarity of transgenic and conventional maize drought tolerance	
Output 2	Maize germplasm tolerant to acidic and low fertility soils to enhance productivity among resource-constrained farmers and reduce encroachment of maize production into more fragile environments	Breeders in NARS, private seed companies and at IITA, formal and community-based seed producers, NGOs and CBOs, decision makers, scientific community at large	Maize productivity increases on acidic and low fertility soils	Reduced encroachment of maize production into fragile environments such as tropical forests

Time Frame	Outputs	Intended User	Outcome	Impact
Output Target 2008-2010	Annual provision of >4 elite, new low-pH tolerant maize genotypes adapted to South American maize mega-environments	Breeders in NARS and private seed companies	Continued increases in the low-pH tolerance of maize varieties available to farmers in South America	Maize productivity increases on acidic soils in South America
Output Target 2008-2010	Annual provision of >4 elite new, low-N tolerant maize genotypes	Breeders in NARS and private seed companies	Continued increases in the low-N tolerance of maize varieties available to farmers	Maize productivity increases on low fertility soils in Africa, Asia and Latin America
Output Target 2008	Inheritance of callose content in tropical maize documented and manual developed	Breeders and scientific community world-wide	Accelerated breeding progress for soil acidity tolerance	
Output Target 2009	Evaluation of best acid soil tolerant maize germplasm from South America for use in Asia	NARS and private seed companies in Asia	Accelerated breeding progress for acid soil tolerance in Asia	
Output Target 2010	Acid soil tolerant screening sites established and incorporated in breeding network for Asia	NARS and private seed companies in Asia	Accelerated breeding progress for soil acidity tolerance in Asia	
Output 3	*Striga* resistant maize to restore maize production in affected areas in sub-Saharan Africa	Breeders in NARS, private seed companies and at IITA, formal and community-based seed producers, NGOs and CBOs, decision makers, scientific community at large	Maize varieties become available which are not affected by *Striga*; reduction of *Striga* seed banks in soils	Restoration of maize production on resource-poor farmers' fields affected by *Striga* sp. (parasitic weeds)
Output Target 2008	A minimum of 25 *Striga* resistant (IR) hybrids and OPVs for evaluation by partners	Breeders in NARS, private seed companies and at IITA	Access to a suite of elite germplasm adapted to all major agro-ecologies in Africa	
Output Target 2008	Through collaboration with NARS, local seed companies and AATF, adapted *Striga* resistant (IR) maize cultivars meet release requirements in a minimum of four eastern and southern African countries	Resource-poor farmers in *Striga*-affected areas in eastern and southern Africa	*Striga* resistant maize cultivars become available in an increasing number of eastern and southern African countries	
Output Target 2009	Adoption and benefit-sharing assessment conducted for *Striga*-resistant (IR) maize showing benefit sharing among farmers, public and private sector	Decision makers	Conditions that improve benefits to farmers of proprietary technology better understood	
Output Target 2010	New Mutator-induced sources of *Striga* resistance identified and mapped	Breeders in NARS and private seed companies in sub-Saharan Africa; IITA	Wider genetic basis for *Striga* resistance in maize, preventing emergence of resistance in *Striga*	
Output 4	Disease and insect resistant maize to reduce pre-and postharvest losses	Breeders in NARS, private seed companies and at IITA, formal and community-based seed producers, NGOs and CBOs, decision makers, scientific community at large	Maize varieties with in-built resistance to new or intractable high priority disease and insect pests become available to farmers in tropical environments	Reduced pre- and postharvest losses due to new or high-impact biotic stresses

Time Frame	Outputs	Intended User	Outcome	Impact
Annual Output Target 2008-2010	Annual provision of >10 elite new tropical maize genotypes with host plant resistance to highly virulent diseases, stem borers or post-harvest pests	Breeders in NARS and private seed companies	More diverse and improved conventional resistance to disease and insect pests in released maize varieties	
Output Target 2008	In collaboration with trait providers and KARI, *Bt* hybrids with transgenic resistance to *Busseola fusca* tested in biosafety greenhouse facilities	Scientific community, decision makers	Knowledge about the effectiveness of new transgenic *Bt* traits against *Busseola fusca* in eastern Africa	
Output Target 2009	In collaboration with trait providers and KARI, *Bt* hybrids with transgenic resistance against *Busseola fusca* tested in open quarantine facilities	Scientific community, decision makers	Knowledge about effectiveness of new transgenic *Bt* traits against *Busseaola fusca* in eastern Africa	
Output Target 2009	Sources for banded leaf and sheet blight resistance identified and shared with breeders in Asian countries	NARS and private seed companies in Asia	Accelerated breeding progress for resistance to banded leaf and sheet blight in Asia	
Output Target 2010	Molecular markers for leaf diseases important to sub-Saharan Africa identified and applied in marker-assisted breeding projects	Breeders in Africa and the scientific community world-wide	More effective selection for background traits (leaf diseases) in germplasm being improved for intractable traits, such as drought tolerance	
Output Target 2010	Option for market segmenting between humanitarian and commercial use of transgenic *Bt* maize seed explored	Decision makers, seed companies	Humanitarian access to *Bt* events in markets with commercial interests for transgenic *Bt* maize seed	
Output 5	Mycotoxin resistant maize for increased food safety	Breeders in NARS, private seed companies and at IITA, formal and community-based seed producers, NGOs and CBOs, decision makers, the scientific community at large	Maize varieties with reduced mycotoxin contamination become available to farmers in tropical environments	Increase food safety and trade opportunities
Output Target 2008	Mycotoxin resistant germplasm sources documented on CIMMYT's webpage	Breeders in NARS and private seed companies	Increased awareness and use of available genetic variation	
Output Target 2009	GIS-based prediction of maize production areas affected by aflatoxin contamination	Decision makers	More effective targeting of resistance breeding strategies	
Output Target 2010	Resistance breeding strategy to decrease mycotoxin contamination of maize implemented in Africa and Asia, based on newly available funding	NARS and IARC	Maize varieties with reduced mycotoxin contamination become available to farmers in Africa and Asia	
Output 6	Strengthened impact pathways for stress tolerant maize	NARS, seed companies, NGOs and CBOs	Increased effectiveness of NARS, seed companies, NGOs, CBOs in developing, releasing, targeting and disseminating stress tolerant maize cultivars	Sustainable maize productivity increases among resource-poor maize farmers in stress-prone environments

Time Frame	Outputs	Intended User	Outcome	Impact
Annual Output Target 2008-2010	Stress breeding skills of 25 NARS and private sector scientists improved through workshops, visiting scientist fellowships and graduate research projects	Scientists from NARS and private seed companies	Increased effectiveness of NARS and SMEs in developing stress tolerant maize cultivars	
Annual Output Target 2008-2010	Backstopping of 15 NARS in Africa, Asia and Latin America through collaborative country-specific maize breeding and dissemination projects targeted for stressed environments	In-country multi-stakeholder teams including NARS, seed entrepreneurs, NGOs, CBOs and farming communities	Agreed and coordinated public-private strategies that increase the access of farmers in stress-prone environment to improved maize seed	
Output Target 2008	In collaboration with IITA, a minimum of 100 technicians in sub-Saharan Africa trained in implementing stress breeding and farmer-participatory maize variety trials	Technicians from NARS and seed companies in sub-Saharan Africa	Reduced time to the release of new stress tolerant maize varieties	
Output Target 2009	15 small-scale seed entrepreneurs trained in practical skills relevant to increasing maize seed production and dissemination in stressed environments	Small-scale seed entrepreneurs and leaders of community-based seed production schemes	Increased success rate among emerging seed entrepreneurs and reduced time to the availability of seed of new stress tolerant maize varieties to farmers	

Project 4: Nutritious and specialty maize

Time Frame	Outputs	Intended User	Outcome	Impact
Output 1	Micronutrient-enriched maize for improved nutrition, health and agricultural productivity.	Researchers in NARS, private companies, IARC and ARIS	Nutritious maize germplasm is used and incorporated in breeding and research programs, resulting in biofortifled cultivars being availed to maize farmers and consumers.	Improved vitamin A, Fe, and Zn nutrition in selected countries
Annual Output Target 2008-2010	At least 5 new advanced or elite genotypes with enhanced pro-vitamin A, Zn or Fe concentration	Researchers in NARS, private companies, IARC and ARIs	Greatly expanding genetic base of micronutrient-enhanced germplasm	
Output Target 2009	In collaboration with ARI partners, chromosome regions associated with carotenoids mapped, and gene expression studies of enzymes involved in the carotenoid synthesis pathway documented	Researchers in NARS, private companies, IARC and ARIs	Increased breeding efficiency and effectiveness for enhanced pro-vitamin A concentrations in maize	
Output Target 2008	Effectiveness of various inbred maize lines as donors (sources) of enhanced pro-vitamin A for maize breeding documented	Researchers in NARS, private companies, IARC and ARIs	Increased breeding efficiency and effectiveness for enhanced pro-vitamin A concentrations in maize	
Output Target 2008	Utility of NIRS laboratory method for rapid analysis of pro-vitamin A in maize documented	Researchers in NARS, private companies, IARC and ARIs	More cost-effective breeding for high pro-vitamin A	
Output Target 2008	Consumer preferences for yellow maize documented for Africa (literature review) and measured and analyzed in Kenya	Researchers in NARS, private companies, IARC and ARIs	Improved targeting of maize varieties biofortified with pro-vitamin A carotenoids	
Output Target 2009	Effectiveness documented of recurrent selection for enhancing pro-vitamin A concentration in maize	Researchers in NARS, private companies and IARC	Decisions about future breeding strategies and likelihood of success	
Output Target 2009	Simple, in-vitro laboratory methods validated for analysis of bioavailability of pro-vitamin A in maize and manual developed	Public and private laboratories	Enhanced breeder effectiveness at improving nutrition through pro-vitamin A breeding	
Output Target 2010	In collaboration with NARS, germplasm with enhanced pro-vitamin A content evaluated in variety release trials in a minimum of four African and Latin American countries	Seed producers and NGOs in target countries	Varieties with enhanced levels of pro-vitamin A become available to farmers in pilot countries	
Output 2	Quality protein maize (QPM) for improved agricultural productivity and health.	Researchers in NARS, private companies, IARC and ARIs	Nutritious maize germplasm is used and incorporated in breeding and research programs, resulting in biofortified cultivars being availed to maize farmers and consumers	Reduced risk of protein malnutrition in groups heavily dependent upon maize, especially women and children members; increased income opportunities for smallholder pork and chicken producers

Time Frame	Outputs	Intended User	Outcome	Impact
Annual Output Target 2008-2010	At least 15 new, elite QPM genotypes available	Researchers in NARS, private companies, IARCs and ARIs	Sustained development of high yielding, agronomically excellent QPM cultivars	
Output Target 2008	QPM conversion of the popular Ethiopian hybrid 'BH660' and at least one other farmer-grown cultivar in Africa available and tested in direct comparison with the original non-QPM versions	Ethiopian researchers, seed industry and farmers	Accelerated adoption and impacts of QPM germplasm	
Output Target 2008	New, simplified laboratory methods for analysis of tryptophan in maize grain validated and adopted by partners in at least four countries	Public and private laboratories	More cost-effective breeding and quality control of QPM germplasm	
Output Target 2008	Impact assessment of QPM in target areas of four eastern African countries	NARS, seed companies, agribusinesses, nutrition and public health specialists, food aid programs	Improved targeting of QPM	
Output Target 2009	Simplified quality assurance strategy to monitor the quality of QPM cultivars developed, validated with partners in at least three countries with commercial QPM cultivars, and documented	NARS, seed companies, agribusinesses	Accelerated commercialization and impact of QPM	
Output Target 2010	Use of molecular markers implemented for the *Opaque-2* gene and selected modifiers	Breeders, scientific community	More effective maintenance of QPM characteristics in new breeding projects and more effective conversion of high-value germplasm to QPM	
Output 3	Dual-purpose or specialty maize for improved livelihoods and income generation	Researchers in NARS, private companies, IARC and ARIs	Maize with value-added traits or uses is incorporated in breeding and research programs, resulting in cultivars with increased income-generating potential being availed to maize farmers and markets.	Increased incomes and market competitiveness improve adopters' livelihoods
Output Target 2008	In collaboration with ILRI and NARS, documentation of farmer perceptions regarding the best, high-stover quality maize genotypes and of the influence of fodder traits on cultivar choice in Ethiopia and Tanzania	Researchers in NARS, IARC; and policy makers	Decisions about the future development and promotion of food/stover dual-purpose maize for maximum livelihood impacts	
Output Target 2008	Stover quality assessed for at least 50 genotypes in Africa, and prediction formulae developed for rapid screening of maize stover quality	Researchers in NARS, private companies, IARC and ARIs	Simple, rapid, inexpensive selection methods will facilitate breeding efforts	

Time Frame	Outputs	Intended User	Outcome	Impact
Output Target 2009	Ex-ante impact assessment and prioritization of investments in biofuel or specialty maize	Researchers in NARS and IARC; policy-makers; donors	Initiation of focused genetic enhancement projects with high impact potential and benefits to resource-poor farmers	
Output Target 2009	High-throughput laboratory methods for assessment of specialty/nutritional traits (e.g. anthocyanins, oil, starch) validated and documented	Researchers in NARS, private companies, IARC and ARIs	Facilitated genetic improvement for emerging, high-value traits	
Output Target 2010	A minimum of three focused, genetic enhancement projects initiated on specialty maize with high impact potential and benefits to resource-poor farmers, supported by new funding	Researchers in NARS, private companies, IARC and ARIs	New opportunities for income generation by smallholder farmers	
Output 4	Strengthened impact pathways for nutritional and specialty trait maize	NARS and private seed company breeders	Increased effectiveness of NARS, seed companies, NGOs, CBOs in developing, releasing, targeting and disseminating nutritional or specialty maize cultivars	Impact on nutrition and income of resource-poor farm families
Annual Output Target 2008-2010	Backstopping of 10 NARS in Africa, Asia and Latin America through collaborative country-specific maize breeding and dissemination projects addressing nutritionally enhanced or specialty maize	In-country multi-stakeholder teams including NARS, seed entrepreneurs, NGOs, CBOs and farming communities	Agreed and coordinated public-private strategies that increase farmers' access in stress-prone environments to improved maize seed	
Annual Output Target 2008-2010	Skills of 25 scientists, technicians and students improved in breeding, participatory research, or reaching end users through workshops, visiting scientist fellowships and graduate research projects	Scientists from NARS and private seed companies	Increased effectiveness of NARS and SMEs in developing stress tolerant maize cultivars	

Project 7. Drought tolerant wheat with enhanced quality

	Outputs	Intended User	Outcome	Impact
Output 1	Spring bread and durum wheat and triticale with increased drought and heat tolerance, multiple resistance against soil-borne stresses and pathogens and foliar diseases, and appropriate end-use quality.	NARS, IARC ARI, NGOs, SME breeding and seed companies.	Measurable increases in productivity, water-use efficiency and genetic diversity in farmers' fields. Reduced losses from diseases and increased stability of grain yield.	Increased national food security. Reduced vulnerability of farm families whose livelihoods depend on income from wheat-based farming systems. Improved agricultural productivity and profitability, better quality of wheat products and more sustainable utilization of natural resources. Risk of disease epidemics reduced.
2008	Advanced spring bread and durum wheat and triticale lines with tolerance to abiotic stresses (drought, heat) and multiple disease resistance (rusts, *Septoria*, *Fusarium*, soil-borne disease complexes) and better end-use quality distributed through the Semi-Arid Wheat Screening Nursery (150), Semi-Arid Wheat Yield Trial (40), International Durum Screening Nursery (120) and International Triticale Screening Nursery (50).		Valuable lines used in breeding programs. Data from International Wheat Improvement Network available to cooperators.	Improved and genetically diverse wheat germplasm used by breeders. Faster development of improved cultivars. Participation in global and regional wheat improvement networks increases. Global monitoring and pre-emptive screening against new diseases and new virulences before major epidemics occur.
2008	At least 100 advanced wheat lines tested by partners in multilocation yield trials.	Breeding programs, farmers	Candidate lines characterized for relevant traits. Lines and data used for wheat improvement. Candidate cultivars evaluated by farmers through participatory varietal selection. Lines submitted for national cultivar registration trials.	Germplasm and information sharing and analysis lead to faster deployment of improved cultivars and increased productivity.
2008	At least 5 cultivars released and 60 new lines used in NARS crossing programs.	Farmers, seed production enterprises, breeding programs	Cultivars released and adopted by farmers for areas affected by erratic rainfall.. Seed available for formal and informal collaboration.	Farmers and consumers benefit from new wheat cultivars. The enhanced drought and heat tolerance of these cultivars buffer cropping systems against possible negative effects from climate change.
2009	Advanced spring bread and durum wheat and triticale lines with tolerance to abiotic stresses, multiple disease resistance and better end-use quality, distributed through the SAWSN (150), SAWYT (40), IDSN (120) and ITSN (50).	NARS, IARC ARI, NGOs, SME breeding and seed companies.	Valuable lines used in breeding programs. Data from International Wheat Improvement Network available to cooperators.	Improved and genetically diverse wheat germplasm used by breeders. Faster development of improved cultivars. Participation in global and regional wheat improvement networks increases. Global monitoring and pre-emptive screening against new diseases and new virulences.

	Outputs	Intended User	Outcome	Impact
2009	At least 100 advanced wheat lines tested by partners in multilocation yield trials.	Breeding programs, farmers	Candidate lines characterized for relevant traits. Lines and data used for wheat improvement. Candidate cultivars evaluated by farmers through participatory varietal selection. Lines submitted for national cultivar registration trials.	Germplasm and information sharing and analysis lead to faster deployment of improved cultivars and increased productivity.
2009	At least 5 cultivars released and 60 new lines used in NARS crossing programs.	Farmers, seed production enterprises, breeding programs	Cultivars released and adopted by farmer for areas affected by erratic rainfall. Seed available for formal and informal collaboration.	Farmers and consumers benefit from new wheat cultivars. The enhanced drought and heat tolerance of these cultivars buffer systems against possible negative effects from climate change.
2009	Parental lines with desirable quality for diverse end uses identified and deployed.	NARS, IARC ARI, NGOs, SME breeding and seed companies.	New lines with better quality properties available to wheat breeders.	Cultivars with improved end-use quality and better marketability; farmers have higher income.
2009	New sources (5) of resistance to nematodes and root rots identified per year, and 30 lines resistant to soil-borne diseases distributed through the Root Disease Screening Nursery.		Use by partners and stakeholders, leading to increased productivity and sustainability.	Rainfed wheat farmers benefit from an increased and more stable production, despite the effects of climate change.
2010	Advanced spring bread and durum wheat and triticale lines with tolerance to abiotic stresses, multiple disease resistance, and better end-use quality, distributed through the SAWSN (150), SAWYT (40) and IDSN (120).		Valuable lines used in breeding programs. Data from International Wheat Improvement Network available to cooperators.	Improved and genetically diverse wheat germplasm used by breeders. Faster development of improved cultivars. Participation in global and regional wheat improvement networks increases. Global monitoring and pre-emptive screening against new diseases and new virulences.
2010	At least 100 advanced wheat lines tested by partners in multilocation yield trials.	Breeding programs, farmers	Candidate lines characterized for relevant traits. Lines and data used for wheat improvement. Candidate cultivars evaluated by farmers through participatory varietal selection. Lines submitted for national cultivar registration trials.	Germplasm and information sharing and analysis lead to faster deployment of improved cultivars and increased productivity.
2010	At least 5 cultivars released and 60 new lines used in NARS crossing programs.	Farmers, seed production enterprises, breeding programs	Cultivars released and adopted by farmer for areas affected by erratic rainfall. Seed available for formal and informal collaboration.	Farmers and consumers benefit from new wheat cultivars. The enhanced drought and heat tolerance of these cultivars buffer systems against possible negative effects from climate change.

	Outputs	Intended User	Outcome	Impact
2010	Distribution of F4 and F5 segregating populations targeted at five eco-regions or farming systems with required market-oriented end-use quality.	NARS in five regions or wheat farming systems	Enhanced efficiency to exploit wide genetic variability by partners.	Better adapted and market-oriented cultivars with more genetic diversity in farmers' fields.
Output 2	Determine the scientific basis of stress adaptive traits, with emphasis on drought, heat and resistance to diseases to develop more efficient selection methodologies.	NARS, IARC, ARI, SME	New valuable diversity identified and incorporated into breeding lines.	Livelihood of farmers living in marginal areas enhanced through more drought tolerant and stress resistant cultivars. Measurable increase in productivity, genetic diversity in farmers' fields.
2008	Main physiological traits associated with drought adaptation in diverse wheat genetic resources identified.		Enhanced knowledge and applied tools. Increased selection efficiency. Physiological trait-based breeding for heat tolerance implemented. Wheat germplasm with improved drought tolerance based on novel gene combinations.	Better drought and heat tolerant cultivars delivered faster to farmers
2008	QTL identified for water-use and N-use efficiency in durum populations.		Increased efficiency to select for drought and heat tolerance associated traits.	Better drought tolerant and input efficient cultivars delivered faster to farmers.
2008	Improved phenotypic screening methods identified for soil borne pathogen resistance.		Enhanced knowledge and applied tools. Increased selection efficiency.	Germplasm developed with multiple levels of tolerance to water-limited conditions.
2009	Routine application of optimized molecular markers (for soil cyst nematodes, boron tolerance, cereal rust resistance, fusarium head blight, protein quality) and physiological markers (for canopy temperature, spectral indices) by CIMMYT or NARS.	NARS and CIMMYT breeders	Enhanced selection and characterization efficiency in breeding improved germplasm	Germplasm developed more quickly and efficiently, with better adaptation and end-use acceptance characteristics.
2009	Available trait data routinely provided with international nurseries to NARS and SME partners.		Users of CIMMYT germplasm make better decisions about the appropriate, immediate use of co-developed germplasm.	Breeding programs utilize germplasm more thoroughly, resulting in better cultivars reaching farmers more quickly.
2009	MAS applied for drought and heat adaptive traits in bread wheat mapping populations, with emphasis on canopy temperature and stem carbohydrates.		Knowledge on genetics of heat and drought tolerance; increased breeding efficiency.	More drought or heat tolerant cultivars available to farmers; farmers' production less vulnerable to abiotic stresses.
2009	Improved understanding of soil borne pathogen frequency, diversity and economic importance for three countries.		Knowledge of biotic components that affect tolerance to drought stress and input use efficiency.	Germplasm possessing multiple traits associated with resistance to drought and marginal environments.

	Outputs	Intended User	Outcome	Impact
2010	Genetic stocks and rye evaluated for stress related traits (drought, physiological traits, zinc efficiency, disease resistance) by CIMMYT and partners.		Wheat genetic stocks, mostly with introgressions from wheat wild relatives, in improved backgrounds, evaluated for drought relevant traits.	Available genetic variability is better utilized with impact in farmers' fields.
2010	Identification of new genetic variability for physiological traits associated with heat and climate change adaptation in wheat germplasm.		Physiological trait-based breeding for heat tolerance implemented.	Greater efficiency in breeding using fundamental molecular pathways and processes is achieved.
2010	Efficiency of doubled haploids versus shuttle selection schemes compared.		Enhanced breeding efficiency.	Validation and recommendation of an optimal breeding strategy for CIMMYT and NARS partners.
2010	Genotype by tillage interactions understood and extended to selection methodologies, to develop germplasm adapted to conservation agriculture systems.		Wheat cultivars adapted to zero-tillageage systems.	Cultivars that can fully exploit the benefits of conservation agriculture with higher yield and reduced production costs, leading to increased incomes for farmers.
Output 3	Increased capacity of partners to face the challenges of climate change in relation to wheat improvement in drought and heat stressed, variable environments.	NARS, SME	NARS and partner staff trained. Increased effectiveness of partners and CIMMYT research.	Partner's research-for-development capacity strengthened to improve the livelihoods of people depending on income from rainfed wheat systems.
2008	International training on soil borne pathogens in North Africa conducted and network of researchers in SBP formed.		Better capacity of North African partners to monitor, assess and investigate SBP production limitations.	Improved information and knowledge sharing and networking.
2008	Multidisciplinary program for visiting scientists focused on drought tolerance.		Strengthened pool of wheat scientists.	Increased research effectiveness of CIMMYT and its partners in key regions and NARS.
2009	Multidisciplinary program for visiting scientists focused on heat tolerance			
2010	Multidisciplinary program for visiting scientists focused on climate change.			
2010	Regional testing networking of NARS wheat lines facilitated.		Better utilization of NARS bred wheat lines for similar agro-ecologies. Pre-emptive disease screening for new diseases and their virulence.	More genetic diversity in farmer's fields, with better adaptation to prevalent abiotic and biotic stresses, more stable and higher productivity.

Project 8: Disease resistant wheat with high productivity and quality

	Outputs	Intended user	Outcome	Impact
Output 1	Genetically diverse wheat germplasm with enhanced consumer and market oriented quality, high yield potential, resistant to biotic stresses and buffered to tolerate climatic change	Farmers, household consumers, food processors, NARS, IARC ARI, NGO, SME, other private sector	Measurable increase in productivity and genetic diversity in farmers' fields. Reduced losses from diseases and increased stability of grain yield. Enhanced input efficiency.	Increased national food security. Reduced vulnerability of farm families whose livelihoods depends on income from wheat based farming systems. Improved agricultural productivity, better quality of wheat products and more sustainable utilization of natural resources. Risk of disease epidemics reduced.
2008	Advanced spring, durum wheat and triticale germplasm and segregating populations for irrigated environments with durable disease resistance, input-use efficiency, high and stable yield, and required end-use quality, distributed through the Elite Selection Wheat Yield Trial (40), International Bread Wheat Screening Nursery (150), International Durum Yield Nursery (40) and International Triticale Yield Nursery (40).	NARS, IARC ARI, NGO, SME, other private sector	Sustained growth in wheat productivity by release of new and diverse wheat germplasm distributed through international nurseries and used by NARS breeding programs.	Improved and genetically diverse wheat germplasm used by breeders. Faster development of improved cultivars. Participation in global and regional wheat improvement networks increases. Global monitoring and pre-emptive screening against new diseases and their virulence before major epidemics occur.
2008	At least 150 advanced wheat lines tested by partners in multilocation yield trials.		Advanced lines characterized for relevant traits. Lines and data used for global wheat improvement. Candidate cultivars evaluated by farmers through participatory varietal selection.	Germplasm and information sharing and analysis lead to faster deployment of improved cultivars and increased productivity.
2008	Candidate lines (20) submitted for national cultivar registration trials; new lines (100) used in partners' crossing programs.		Cultivars released and adopted by farmer for areas affected by variable input potential and high disease pressure; partners' breeding programs strengthened.	Farmers and consumers benefit from new wheat cultivars. Enhanced drought and heat tolerance of these cultivars buffers against possible negative effects from climate change.
2008	Advanced lines resistant to stem rust distributed in the International Stem Rust Resistance Screening Nursery (150).	Global wheat breeding community, Global Rust Initiative	Diverse sources of spring and winter bread wheat germplasm, with information on genes for resistance to Ug99, made available to NARS for either direct release or use in their breeding programs	Development of cultivars resistant to Ug99 reduces the risk of a global stem rust pandemic and associated food insecurity and economic losses.

	Outputs	Intended user	Outcome	Impact
2009	Advanced spring, durum wheat and triticale germplasm and segregating populations for irrigated environments with durable disease resistance, input-use efficiency, high and stable yields, and required end-use quality, distributed through the ESWYT (40), IBWSN (150), HTWYT (30), the IDYN (40), ITYN (40) and High Temperature Wheat Yield Trial (30).	NARS, IARC ARI, NGO, SME, private sector	Sustained growth in wheat productivity by release of new and diverse wheat germplasm distributed through international nurseries and used by NARS-own breeding programs.	Improved and genetically diverse wheat germplasm used by breeders. Faster development of improved cultivars. Participation in global and regional wheat improvement networks increases. Global monitoring and pre-emptive screening against new diseases and their virulence before major epidemics occur.
2009	At least 150 advanced wheat lines tested by partners in multilocation yield trials.		Advanced lines characterized for relevant traits. Lines and data used for global wheat improvement. Candidate cultivars evaluated by farmers through participatory varietal selection.	Germplasm and information sharing and analysis lead to faster deployment of improved cultivars and increased productivity.
2009	Candidate lines (20) submitted for national cultivar registration trials, and 100 new lines used in partner-own crossing programs.		Cultivars released and adopted by farmers for areas affected by variable input potential and high disease pressure, and partner breeding programs strengthened.	Farmers and consumers benefit from new wheat cultivars. Enhanced drought and heat tolerance of these cultivars buffer against possible negative effects from climate change.
2009	Advanced lines resistant to stem rust distributed in the International Stem Rust Resistance Screening Nursery (150).	Global wheat breeding community, Global Rust Initiative	Diverse sources of spring and winter bread wheat germplasm with information on resistance genes against Ug99 made available to NARS for either direct release or for use in their breeding programs	Development of cultivars resistant to Ug99 will reduce the risk of a global stem rust pandemic and associated damage to economies and food security.
2009	100 bread wheat lines adapted to Sichuan and Yunnan Provinces of China enhanced with durable resistance to yellow rust and evaluated for yield potential	Sichuan and Yunnan AAS, CAAS	Sustained productivity growth in Sichuan and Yunnan Provinces through the release of high-yielding spring bread wheat cultivars with durable resistance to yellow rust	Livelihood of farmers improved through increased food security and income.
2009	At least 40 new heat tolerant, early-maturing lines with resistance to *Helminthosporium* leaf blight and leaf rust identified and developed for the Eastern Gangetic Plains	Nepal, Bangladesh, BAU-India, CIMMYT breeders	Genetic stocks with combined resistance to these stresses, as well as with yield stability, made available for further genetic diversification	Reduced vulnerability of farmers through enhanced wheat productivity and stability for tolerance to the effects of climate change and diseases.
2009	Wheat germplasm resistant to fusarium head scab through MAS and hot-spot shuttle breeding with China, Korea, Japan and the Southern Cone	GFI, USWBSI, China, INIA-Uruguay	Increased availability of wheat germplasm resistant to scab	Reduced toxin content in wheat results in improved health of wheat consumers.

	Outputs	Intended user	Outcome	Impact
2009	Large quantities of seed available of 5 to 10 wheat genotypes resistant to Ug99 stem rust and adapted to target countries.	Farmers and seed producers in Kenya and Ethiopia	Mitigating the threat from the Ug99 stem rust race, to safeguard food security and livelihoods in Africa, Middle East and Asia	Reduced vulnerability of farmers in target areas; increased food and economic security through reduced risk of a global stem rust pandemic.
2010	Advanced spring, durum wheat and triticale germplasm and segregating populations for irrigated environments with durable disease resistance, input-use efficiency, high and stable yields, and required end-use quality, distributed through the ESWYT (40), IBWSN (150), HTWYT (30), the IDYN (40), and HTWYT (30).	NARS, IARC ARI, NGO, SME, other private sector	Sustained growth in wheat productivity through release of new and diverse wheat germplasm distributed through international nurseries and used by NARS breeding programs.	Improved and genetically diverse wheat germplasm used by breeders. Faster development of improved cultivars. Participation in global and regional wheat improvement networks increases. Global monitoring and pre-emptive screening against new diseases and their virulence before major epidemics occur.
2010	At least 150 advanced wheat lines tested by partners in multilocation yield trials.		Advanced lines characterized for relevant traits. Lines and data used for global wheat improvement. Candidate cultivars evaluated by farmers through participatory varietal selection.	Germplasm and information sharing and analysis lead to faster deployment of improved cultivars and increased productivity.
2010	Candidate lines (20) submitted for national cultivar registration trials, and 100 new lines used in partner-own crossing programs.		Cultivars released and adopted by farmer for areas affected by variable input potential and high disease pressure, and partner breeding programs strengthened.	Farmers and consumers benefit from new wheat cultivars. Enhanced drought and heat tolerance of these cultivars buffer against possible negative effects from climate change.
2010	Advanced lines (40) with low vomitoxin identified and distributed to partners in countries where consumers are vulnerable.	Global wheat breeding community, Global Fusarium Initiative	Parental germplasm developed that protects human and animal health from toxins caused by *Fusarium* pathogens.	Reduced vulnerability of farmers and consumers; wheat grain of higher nutritional and economic value.
2010	Advanced lines resistant to stem rust distributed in the International Stem Rust Resistance Screening Nursery (150).	Global wheat breeding community, Global Rust Initiative	Diverse sources of spring and winter bread wheat germplasm, with information on genes for resistance to Ug99, made available to NARS for either direct release or for use in their breeding program	Development of cultivars resistant to Ug99 will reduce the risk of a global stem rust pandemic and associated economic and food security effects.
2010	Adapted wheat cultivars from Africa and Asia and elite genotypes enhanced with diverse and durable sources of resistance to the Ug99 stem rust pathogen.	Farmers and seed producers	High acceptance of stem rust resistant cultivars by farmers, with resistance to Ug99 introgressed into widely grown cultivars	Reduced vulnerability of farmers in target areas; increased food security through reduced risk of a global stem rust pandemic.

	Outputs	Intended user	Outcome	Impact
Output 2	Basis of durable disease resistance characterized and genetic diversity enhanced to reduce genetic vulnerability in farmers' fields.	NARS, ARI	Germplasm developed with better resistance to pathogens	Germplasm developed in partnership through global alliances between CIMMYT, North and South.
2008	Knowledge on the epidemiological dynamics of stem rust in East Africa.	Global Rust Initiative	Breeding efficiencies employed to rapidly develop wheat germplasm for use by GRI partners worldwide.	More durable and diverse rust resistance deployed, particular to areas where rapid pathogen evolution occurs.
2008	New race-specific rust resistance genes in bread and durum wheat (40) advanced lines. Studies of the genetic basis of durable resistance to the three rusts in bread and durum wheat.	NARS, ARI, Global Rust Initiative	Better understanding of genetic resistance to three rust diseases of wheat. Enhanced genetic diversity for rust resistance in farmers' fields.	Increased national and regional food security; reduced vulnerability of farmers and increased farm income.
2008	Identification of genomic regions (QTL) in bread and durum wheat populations for fine mapping of rust resistance genes and marker development.		Increased selection efficiency; wheat germplasm with durable resistance to rust.	Increased national and regional food security; reduced vulnerability of farmers and increased farm income.
2009	Basis of adult plant resistance to leaf rust in durum wheat determined and APR durum germplasm (40) distributed to partners.		Better understanding of the genetic basis of durable rust resistance in durum wheat, allowing more rapid and efficient germplasm development.	Parental germplasm developed and used extensively by CIMMYT and partners.
2009	Identification of resistance-related genes to scab and development of DNA markers.	NARS; Cooperators in Global Fusarium Initiative	Increased selection efficiency and availability of scab resistant germplasm.	Reduced toxin content in wheat results in improved health of wheat consumers.
Output 3	Global networks to monitor distribution, evolution and migration of pathogens for an early warning of threats.	NARS, Policy Makers, NGO, IARC, ARI	Responsibility for	Farmers less vulnerable to losses from pathogen epidemics, thereby increasing their productivity, food security, wealth and health.
2008	Early warning networks to alert and to reduce losses from new races of rust pathogens of wheat.		Risks from wheat rust pathogens are reduced. Enhanced information on diversity in rust populations.	Increased regional and national food security;
2009	International *Fusarium* Nursery (FHB and CR resistance and informative genetic stocks) grown in FHB/crown rot hotspots	GFI, NARS, USWBSI,	Knowledge of the nature and distribution of FHB and crown rot causing Fusarium species (including knowledge of new means of describing pathogenic Fusarium-chemotype, DNA based lineages, etc.)	Reduced toxin content in wheat products results in improved health of wheat consumers

	Outputs	Intended user	Outcome	Impact
2009	Species and chemotype of pathogen isolates (FHB/crown rot) regionally determined.		Nature and distribution of FHB and crown rot causing *Fusarium* species determined	Reduced losses from *Fusarium* species and healthier wheat products
Output 4	Germplasm developed with enhanced genetic variability for increased iron, zinc and protein concentration, reduced susceptibility to mycotoxin contamination, and/or improved value-added, end-use quality	Resource poor consumers and farmers; processors; NARS	Wheat germplasm with acceptable nutritional and end-user traits identified and used	Improved and safer nutrition from grain consumption for rural and urban poor. Enhanced wheat grain market opportunities for farmers
2008	Germplasm characterized for value-added, market-oriented quality, nutritional value and food safety traits	CIMMYT and NARS breeders, processors, consumers	Enhanced breeding efficiency through well characterized parental germplasm	More tasty and healthy food reaching rural and urban consumers
2008	Wheat genetic resources screened for iron and zinc concentration	NARS, ARI and CIMMYT breeders	Enhanced genetic variability for biofortified grain improvement	Genetic diversity contributes to nutritional security
2008	Micronutrient bioavailability determined for biofortified processed grain products	Processors, consumers	Optimized processing methods defined to retain nutritional value of biofortified grain	Improved health of wheat consumers
2009	Germplasm development (300) for biofortified, enhanced iron or zinc concentration	NARS and CIMMYT breeders	Biofortified germplasm development	Improved wheat germplasm contributes to improved farmer and consumer livelihoods
2010	Farmer participatory evaluation of biofortified wheat germplasm	Farmers in India and Pakistan	Improved wheat cultivars reach farmers	Enhanced food and nutritional security
2010	High through-put NIR screening for iron, zinc and protein grain concentration established and fully functioning	NARS, ARI and CIMMYT breeders	Enhanced genetic variability for biofortified grain improvement	Genetic diversity contributes to nutritional security

Project 10: Maize and wheat cropping systems

	Outputs	Intended users	Outcome	Impact
Output 1	Strategic systems knowledge of cereal-soil dynamics and management developed to exploit genotype x system interactions (G x S) and enhance resource and input-use efficiency for sustainable maize- and wheat-based cropping systems.	NARS researchers supporting breeding and crop management	Enhanced understanding of G x S and resource- and input-use efficiency underlying conservation agriculture (CA), and improved design of applied research programs in developing countries (including both breeding and crop management research) to better exploit genetic and management options for increasing system productivity and mitigating the effects of climate change.	Through better technologies and knowledge, reduction of poverty and producer risk, enhancement of agricultural resources and contributions to the mitigation of and adaptation to climate change
Output Target 2008	Published synthesis of G x S in maize and wheat systems	NARS researchers supporting breeding and crop management	Better understanding of G x S and implications for trial design	Increased productivity and reduced poverty
	Paper on long-run impacts of CA technologies on water infiltration and soil water balance in contrasting environments	NARS researchers supporting breeding and crop management	Better understanding of water dynamics and management in CA systems	Increased productivity and stabilized yields; i.e., reduced production risk
	Report on assessment of low-cost, reliable methodologies to measure soil physical, chemical and biological properties	NARS researchers supporting breeding and crop management	Greater volume of soil quality data through lower cost methods to improve knowledge of soil-cereal relationships and to better define research domains	Enhanced resources and data to support climate change mitigation/adaptation practices
Output Target 2009	Published manual on simple tests to evaluate biological activity in the soil	NARS researchers supporting breeding and crop management	Greater volume of data on biological activity	Enhanced soil resource management
	Synthesis of the long-run effects of CA on soil biological activity in contrasting environments	NARS researchers supporting breeding and crop management	Greater volume of data on biological activity of soils under cereal CA systems	Enhanced soil resource management
	Documented effects of residue in different amounts on the biophysical and socioeconomic components of CA systems, especially with respect to crop-livestock competition	NARS researchers supporting breeding and crop management	Better knowledge of sustainable residue management practices	Maintained soil resources and more productive mixed maize or wheat farming systems
Output Target 2010	Synthesis of the long-run impact of CA on soil organic matter (soil carbon) and plant nutrient availability in contrasting soil types and environments	NARS researchers supporting breeding and crop management	Better knowledge of input-use efficiency	Increased input-use efficiency and climate change mitigation and adaptation
	Strategies developed for the efficient management of nitrogen in CA systems, including issues of fertilizer placement and immobilization, crop rotations and residue amounts.	NARS researchers supporting breeding and crop management	Improved knowledge of fertilizer use practices under CA systems	Increased nutrient use efficiency and reduced greenhouse gases

	Outputs	Intended users	Outcome	Impact
	Publication on the effects of CA on greenhouse gas emissions under different environments	NARS researchers supporting breeding and crop management	Knowledge of CA systems, greenhouse gases, and climate change	Reduced greenhouse gases; climate change mitigation
Output 2	Coordinated innovation and learning platforms established in key farming systems to engage NARS technology developers and associated stakeholders (notably researchers, farmers, policy makers) and develop widely applicable technologies, identify policies to increase system productivity and sustainability, including improved efficiency of use of water, nutrients, and labor, and soil quality management	NARS scientists and policy makers from different disciplines, initially in risky maize-based systems in southern Africa; intensive maize and wheat systems in Asia (rice-wheat, rice-maize, cotton-wheat and maize-wheat); and degraded maize- and wheat-based systems in Mexico	Greater knowledge and capacity in NARS to manage innovation systems and develop sustainable maize and wheat-based farming systems through participatory system-oriented research.	Poverty reduced, livelihoods improved, soil and water conserved, fuel use reduced, soil organic carbon loss slowed or reversed, functioning mechanisms for the mitigation of and adaptation to climate change in the domains surrounding hubs
Output Target 2008	Functioning networks of international and national researchers, farmers, public and private extension agents, private companies and local policy makers established and involved in developing functional CA systems in at least 10 contrasting communities each in southern Africa, India and China	NARS scientists and policy makers from different disciplines	Increased rate of technology development	Increased productivity and resilience, reduced poverty
	Strategic assessment of rice-maize systems in Asia	NARS associated with the rice-maize intensification under the IRRI-CIMMYT Alliance	Efficient targeting of rice maize intensification research across Asia	Sustainable intensification with enhanced resource management and reduced poverty
	Analysis of input use efficiency in CA systems across different environments	NARS scientists and policy makers from different disciplines	Better knowledge of input use efficiency	Increased productivity, reduced costs and reduced poverty
	Case studies on the impacts of CA on physical and economic system productivity and livelihoods of early adopters of CA technologies in southern Africa, India and China	NARS scientists and policy makers from different disciplines	Better knowledge of determinants of CA system productivity across environments	Increased system productivity from adapted CA systems for different environments
Output Target 2009	Report on technology and policy options for increased water-use efficiency through CA systems across different environments	NARS scientists and policy makers from different disciplines	Better knowledge of technologies for water-use efficiency	Increased productivity and yield stability, and thus reduced poverty
	Case studies published on the adoption and impact of CA on the productivity and livelihoods of smallholder adopters in South Asia	NARS scientists and policy makers from different disciplines	Better knowledge of adoption, adaptation and impacts of CA systems	Increased system productivity from adapted CA systems for different environments, reduced poverty, improved resource management

	Outputs	Intended users	Outcome	Impact
	Synthesis of the impacts of CA on smallholder labor requirements and use in Africa, Asia and Latin America	NARS scientists and policy makers from different disciplines	Better knowledge of the adoption, adaptation and impacts of CA systems	Increased returns to labor and reduced poverty
	Documented options for technologies to improve rice-maize system productivity in selected locations across Asia	NARS associated with the rice-maize intensification under the IRRI-CIMMYT Alliance	Knowledge of plausible, productivity-enhancing technologies for rice-maize intensification across Asia	Sustainable intensification with enhanced resource management and reduced poverty
Output Target 2010	Documented options for residue management and soil carbon and nitrogen options to mitigate and adapt to climate change in different environments	NARS scientists and policy makers	Better knowledge of climate change mitigation and adaptation options	Climate change mitigation or adaptation in maize and wheat farming systems in developing countries
	Knowledge of integrated rice-maize intensification models in selected locations across Asia	NARS associated with the rice-maize intensification under the IRRI-CIMMYT Alliance	Knowledge of integrated, productivity-enhancing technologies for rice-maize intensification across Asia	Sustainable intensification with enhanced resource management and reduced poverty
	Report of analysis of similarities and differences in policy impacts on the adoption and profitability of CA in selected communities in three continents	NARS policy makers from different disciplines	Better knowledge of policy drivers	Wider adoption of CA technologies leading to poverty reduction, enhanced resources and mitigation of climate change
	Report on the impact of adoption of CA technologies on the uptake of improved varieties in Africa, Asia and Latin America	NARS scientists and policy makers	Better knowledge of germplasm - CA system interactions and impacts	Increased impacts of improved maize and wheat germplasm

Project 11. Knowledge, targeting, and strategic assessment of maize and wheat farming systems

	Outputs	Intended users	Outcomes	Impacts
Output 1	Strategic information and data for targeting priority setting	CIMMYT and System-wide Program researchers and managers, NARSs, policy makers, donors	Better knowledge of impact pathways and enhanced targeting of research and policy for maize and wheat systems, especially for poor farmers	Increased effectiveness of maize and wheat system, research-for-development for improvement of rural livelihoods, food security and reduced poverty
Output Targets. 2008	• Populated spatial knowledge bases for selected hotspots including drought areas; and improved temporal and spatial characterization of maize of wheat environments. • Mapping and diagnosis of impact pathways for one maize and one wheat Project. • Established system to monitor impacts in two countries in East Africa. • Documented opportunities for high-value utilization of maize in Mexico and South Asia.	CIMMYT researchers and managers, NARSs, CGIAR managers, investors.	Better understanding of the environments and role of drought tolerant germplasm in risk management in marginal areas. Enriched policy dialogue on instruments to enhance impact pathways for maize and wheat improvement and management practices	More effective maize and wheat breeding for drought tolerance. Improved policies a nd institutions for impact and innovation pathways for maize and wheat research. More effective targeting of germplasm and technologies to specific environments and improved efficiency of breeding programs.
Output Targets. 2009	• Enriched spatial knowledge bases in two further priority regions/hotspots. • Specification of impact pathways for two genetic resources Projects. • Appraisals of climate change impact on maize and wheat farming systems initiated. • Valuation of intermediate products from genetic improvements and advancements developed with respect to maize. Assessments of maize seed systems in eastern and southern Africa; synthesis of markets and diversity.	Managers and researchers in NARSs, CIMMYT, CGIAR and associated partners, agricultural policy makers and donors. NARS (including extension), university and CGIAR researchers, policy makers in ministries of agriculture and water resources, CGIAR Challenge Programs	Better understanding of the environments and impact pathways for maize. Lessons from ex post and ex ante assessments. Estimates of gene valuation to guide the utilization of genetic diversity; knowledge of the interactions between seed markets and diversity	More efficient and effective Project monitoring and evaluation. Improved priority setting for germplasm enhancement including, intermediate genetically enhanced materials More efficient utilization of ex situ and in situ maize and wheat genetic diversity (including considerations of seed markets in the latter case).
Output Targets. 2010	• Two documented ex post and ex ante impact assessments in two eastern African countries • Past impacts assessed and strategic investment pathways identified for drought tolerant maize in eastern and southern Africa • Functioning wheat atlas			

	Outputs	Intended users	Outcomes	Impacts
Output 2	Functional understanding of value chains and innovations systems in selected regions	CIMMYT researchers, private sector, policy makers, partners (including NGOs), CGIAR centers.	Greater effectiveness of crop improvement and crop management research, including high protein and micro-nutrient enriched maize and wheat cultivars, and improved value-added chains in selected maize and wheat farming systems.	Increased farmer income and accelerated adoption of improved cultivars, and increased employment through value chain and innovation system effectiveness
Output Targets. 2008	• Documented value chains for poor wheat and maize areas in South Asia. . • Identified means to increase impacts of micronutrient-enriched wheat cultivars on micro-nutrient deficiencies in South Asia and of QPM on maize/poultry value chains in India. • Low-cost field methodology developed and tested to assess potential benefits of QPM in selected poor regions of Central America. • Synthesis of literature on wheat quality with particular reference to China.	CIMMMYT researchers, NARSs, CGIAR centers, private sector, small enterprise and market development sectors, NGOs	Greater understanding of constraints and opportunities within the value and nutrient chains. Identification of service providers to make value chains work better.	Improved functioning of value chains leading to increased financial capital for value chain actors, especially smallholder farmers.
Output Targets. 2009	• Analysis of wheat chain in Tunisia • Documentation of the impacts of macro- and meso-policies on the maize sector in Mexico • Synthesis of approaches and methods of innovation systems for maize and wheat farming systems	CIMMMYT researchers, NARSs, CGIAR centers, private sector, small enterprise and market development sectors, NGOs	Identification of potential health and other. livelihood benefits from improved functioning of wheat value and nutrient chains	
Output Targets. 2010	• Documented value chains for marginal maize systems in Asia and sub-Saharan Africa			
Output 3	Strengthened partners involved in research and sustainable development for maize and wheat based cropping systems, in alliance with other CGIAR centers.	NARS (including extension), NGOs, CGIAR researchers, policy makers, universities, agri-business.	Strengthened professional capacity to improve maize- and wheat-based farming systems. Accessibility and impact of knowledge and technology developed by CIMMYT and partners enhanced.	Partners' capacity strengthened to conduct appropriate research-for-development to improve livelihoods and reduce poverty.
Output Targets. 2008	• Core of Cereal Systems Knowledge Program (CSKP), Cereal Knowledge Bank populated and operational.	NARS, NGOs, universities, investors, policy makers	Improved access to CIMMYT data and information and greater capacity of partners. Improved communication	Increased research effectiveness of CIMMYT and its partners especially in the key regions.

	Outputs	Intended users	Outcomes	Impacts
	• Country knowledge banks in South and South-East Asia expanded (maize and wheat content) and strengthened. • Functional knowledge sharing based on promotion of CSKP through in-country workshops and courses.		between scientists through CKB including rice, wheat and maize.	Improved information and knowledge sharing and networking.
Output Targets. 2009	• Country knowledge bank model adapted by the key collaborating NARS in Africa. • Global community of CKB users supported by the enhancement of its features and utilities (e.g. portal application). • Impact assessment of capacity building 2004-2008.	NARS, NGOs, universities, investors, policy makers.	Strengthened and expanded pool of scientists in wheat, maize systems, livelihoods and poverty reduction.	Increased research effectiveness of CIMMYT and its partners especially in the key regions. Improved information and knowledge sharing and networking.
Output Targets. 2010	• Distance learning (e-courses) program in collaboration with universities and other CGIAR centers functioning • Country knowledge bank model adapted by the key collaborating NARS in Latin America • Global community of CKB users continued exchange on content and adjustment of portal	NARESs, universities.	Strengthened and diversified study curricula of partner universities. Diversified possibilities for continuous professional development.	Extended knowledge of new generation of cereal breeders.

Eco-regional Program. Rice-Wheat Consortium (RWC) for the Indo-Gangetic Plains.

Goal	Conserve natural resources, improve livelihoods, and alleviate poverty through sustainable increases in the productivity of rice-wheat systems in South Asia			
Purpose	Strengthen existing linkages and partnerships with NARSs, IARCs, ARIs and local private enterprises working to develop and deploy more efficient, productive and sustainable technologies for the diverse rice-wheat production systems of the Indo-Gangetic Plains, thereby fostering the production of more food at lower costs, improving the livelihoods of those involved in agriculture, and overall reducing poverty			
	Outputs	Intended users	Outcomes	Impact
Output 1. Develop technologies and policies to improve water productivity, soil health and enhanced diversity of the rice-wheat systems				
Output Targets 2008	• Multi-crop zero-tillage seed drills and bed planters developed, tested and refined in the eastern Gangetic plains. • N management practices using GreenSeeker technology refined for field application. • Legumes and winter maize in the eastern Gangetic plains introduced. • Diversification practices that promote sustainability developed. • Rice crop establishment practices for direct seeded rice refined. • GPS surveys, geo-referenced databases for RCTs adoption sites.	Farmers in South Asia, private seed sector, NARSs, other research centers.	More diversified systems in the eastern Gangetic plains. Maize seed systems available. More pulses and fodder produced. Farmers adopt new machines for seeding into loose residues. The efficiency of use of water and other inputs improved. Reliable in-season forecasting of wheat and rice yields.	Zero-tillage drill manufacturing units cross 150, and appear in the eastern sector for enhanced adoption of conservation agriculture for improved livelihoods, human and animal health and quality of the environment.
Annual Output Targets 2009	• New drills for seeding into loose residue placed in the hands of the farmers to test in eastern IGP, Karnataka and AP. • Rice crop establishment practices developed, co-culturing of rice with green manure crops established, intercrops, dual purpose wheat, maize and legumes promoted. • N-response curve in farmers' fields validated in new areas.	Farmers in South Asia, private sector, NARSs, other research centers.	Area of zero-tillage or reduced- till, laser leveling, dual purpose wheat, QPM and direct-seeded rice expands in parts of IGP. Farmers adopt new machines for seeding into loose residues. Soil surface cover becomes increasingly popular for saving irrigation water.	Diversified rice-wheat systems produce more at lower costs and generate new sources of income and employment. Knowledge and experiences shared among stakeholders. Farmers shift to double zero-tillage systems on a sizeable area in rice-wheat cropping systems.
Annual Output Targets 2010	• New drills for seeding into loose residue available to large number of farmers. • Additional diversification crops tested. • N-management tests by extension workers and farmers.	Farmers in South Asia, private sector, NARSs, other research centers.	Area of zero- or reduced- tillage, laser leveling, dual purpose wheat, QPM and direct-seeded rice expands in parts of IGP. Farmers adopt new machines for seeding into loose residues. Soil surface covers become increasingly popular for saving irrigation water	Diversified rice-wheat systems. produce more at less costs and generate new sources of income and employment. Knowledge and experiences shared among stakeholders. Farmers shift to double zero-tillage systems on a sizeable area in rice-wheat cropping systems.

Output 2. Accelerate adoption of resource-conserving technologies (RCTs). All stakeholders involved in accelerating the pace of development and adoption of RCTs using farmer participatory approaches in the IGP				
Output Targets 2008	• RCT options and diversification practices refined and promoted in the eastern IGP and Central India. • Weeds in direct-seeded rice cropping for eastern IGP managed.	NARSs, CGIAR researchers, farmer associations	Farmers gain understanding of benefits of RCTs and weed management for direct-seeded rice. Underutilized lands at selected sites benefit from technology targeting.	Greater acceptance of direct-seeded rice practices doing away with puddle, transplanted rice.
Annual Output Targets 2009	• RCTs for risk-prone areas (flood or drought) of the eastern IGP fine-tuned for scaling up to other risk-prone areas. • Agronomic and crop management practices to address climate change are adapted for the eastern IGP.	NARSs, farmers, CGIAR and other researchers	Rental services of new customized machines for RCTs become increasingly popular in the IGP. Seed village concept for QPM maize and grain legumes takes root in the East and Northwest. Better understanding of global conservation agriculture practices in a changing world.	Stakeholders adopt a knowledge-sharing and networking culture. More innovative cropping systems practiced in the IGP to address climate change effects.
Annual Output Targets 2010	• RCTs for risk-prone areas (flood or drought) of Central India maize systems fine-tuned for scaling up to other risk-prone areas. • Agronomic and crop management practices to address climate change are adapted for Central India.	NARSs, farmers, CGIAR and other researchers		
Output 3. Prudent management of the RWC by strengthening the capacity of partners to conduct research for sustainable intensification and diversification of rice-wheat systems and make information on RCTs available to users				
Annual Output Targets 2008	Spatial knowledge database for bio physical and socio economic indicators created. Technology knowledge sharing mechanisms tested.	NARS, CGIAR scientists and policy makers/planners	Improved targeting of RWC research. Knowledge shared among stakeholders. Information disseminated through publications, training materials, website, Radio, TV and press. RCT farmers and manufacturers directory created on the web for on-line surveys, interviews for impact assessment.	Line departments in NARSs focus local developmental plans on the new RCTs in specific locations in the eastern IGP and Central India.
Annual Output Targets 2009	GIS, remote sensing and socioeconomic techniques tested for targeting RCTs in different rice eco-systems in the IGP. Technology and market knowledge assembled.	NARS, CGIAR scientists and policy makers/planners	Knowledge shared among stakeholders. Information disseminated through publications, training materials, website, radio, TV and press. RCT farmers and manufacturers directory created on the web for on-line surveys, interviews for impact assessment.	Line departments in NARSs base their local developmental plans on the new RCTs and begin to use techniques for enhancing productivity in risk-prone areas.
Annual Output Targets 2010	Web-based knowledge sharing portal extended to identify and control problems (e.g., weeds).	NARS, CGIAR scientists		Research and extension staff use up-to-date technology knowledge and local departments base their development plans on the new RCTs and begin to use techniques for enhancing productivity in risk-prone areas.

Annex

Progress Report on Implementation of Recommendations, 5th CIMMYT EPMR

Dates of EPMR Report Presentation and Discussion:	March 2005
Science Council:	April 2005
Executive Council:	May 2005
CGIAR Annual General Meeting:	December 2005

Status of Implementation of 5th EPMR recommendations.

Recommendation	Center response	Milestones	Progress achieved	Target date to Complete	March 2007 update
1) The Panel recommends that management and program directors undertake a much more rigorous process to define goals for the new strategy that provide a framework within which to organize projects and activities and against which progress in meeting the goals can be measured. In addition to strengthening the implementation of the new strategy, the process will enable program directors as a team to identify a set of goals that are congruent across the Center.	CIMMT agrees with the recommendation and plans to implement the required actions with immediate effect. The Center, in its *Seeds of Innovation* document, already planned for such a set of goals and milestones to be developed during 2005 and for there to be a Center-led review of the implementation by late 2006. *Seeds of Innovation* is a vision document for the new strategy that is being implemented and will be complemented, as originally planned, by a supplemental plan document entitled *From vision to implementation*.	Recommendation to be addressed through development of business plan for the period 2006-2010 by January '06.	Business plan formally adopted, Jan '06.	N/A	
2) The Panel recommends that CIMMYT develop a business strategic plan that will support the successful implementation of the new strategy in the face of a dynamic financial environment.	CIMMYT agrees with the recommendation and sees the value in a business style strategic plan document. As with recommendation 1, the Center will begin implementation of this recommendation with immediate effect. A business strategic plan that brings into full operation the *Seeds of Innovation* vision will clearly and explicitly state program goals, milestones, deliverables, focus and balance. The document will also show clear linkages between the setting of institutional and program goals, resource mobilization and program budgets.	Business plan for the period 2006-2010 developed and adopted by January '06.	Achieved.	N/A	
3) To facilitate the establishment of a multidisciplinary approach to conducting ex ante impact studies, the Panel recommends that increased integration through time allocation be secured between ITA staff and non-social scientists in the other programs.	CIMMYT agrees with the recommendation and notes that a multi-disciplinary approach to research, embracing biophysical and social scientists, is emphasized in *Seeds of Innovation*.	Two workshops to be held: impacts framework (May '05); and targeting (August '06) Annual work plan meetings to specifically address this recommendation.	Fully implemented through workshops, thematic meetings and annual work plan meeting; the latter held in Jan '06.	N/A	
4) The Panel recommends that ITA, in cooperation with the eco-regional programs, collect data on the variables that explain the heterogeneity of the	CIMMYT agrees with the recommendation and considers this approach to be part of a planned wider research effort to assemble and analyze information on	Spatial meta knowledge of impact pathways to be developed for 2 macro-systems: i) mixed maize farming	In progress for 2006 work plan	Dec '06	Impact pathways assembled and being published for rice-wheat farming

Recommendation	Center response	Milestones	Progress achieved	Target date to Complete	March 2007 update
existing production functions and thus, of yields (both potential and actual) that express differences attributable to productivity gaps within the same agroecological region, due to constraints that limit the adoption of improved technology.	factors determining pathways for technology adoption, livelihood impacts and poverty reduction in major maize- and wheat-based farming systems of developing countries.	systems in sub-Saharan Africa; and ii) rice-wheat farming systems across Pakistan and Bangladesh.			systems across India, Pakistan and Bangladesh. Research on livelihoods impacts of SG2000 technologies in Ethiopia and Uganda and in Mexico, on-going.
5) The Panel recommends that ITA initiate macroeconomic studies by 2006 in close cooperation with IFPRI and other CGIAR Centers. The highest priority should be assigned to sub-Saharan African countries.	CIMMYT agrees with the recommendation insofar as it refers to analyzing sectoral and rural development policy determinants of maize- and wheat-based farming systems improvement and to identify and advocate appropriate policy and institutional responses.	Discussions and meetings to be held with IFPRI during '05 (May-June)	Meetings held, and very productive dialogue on-going. Continuing cooperation a part of the '06 work plan including finalization of joint book *Maize policies in Asia* and joint work to monitor macro-economic indicators, identify pathways, and foster agricultural policy dialogue on maize in east and southern Africa.	N/A	
6) The panel recommends that maize research in CIMMYT identify the high priority Marginal Maize Production Areas (MMPAs) in each mega-environment. Based on such MMPAs, a seed delivery system for improved cultivars should be developed jointly with partners as a vehicle to make CIMMYT's upstream maize research results available to resource-poor farmers.	CIMMYT accepts the recommendation to focus on low-yielding areas caused by abiotic, biotic and socioeconomic constraints. CIMMYT has a comparative advantage in the development of germplasm for low to very low yielding environments to which much of our germplasm development efforts in sub-Saharan Africa have been directed. We agree that seed delivery systems require further development and, towards this aim, CIMMYT has recently hired a seed systems specialist for our Africa Livelihoods Program.	MMPAs verified during '05 Recruit maize molecular breeder to focus on low yielding environments with emphasis on the following traits: quality; and, host plant resistance using non-transgenic approaches.	Achieved Maize molecular breeder recruited, Feb '06.	N/A N/A	
7) The Panel recommends that maize breeding and research efforts in the following areas be intensified:					
a) Grain quality characteristics of high priority to end users in MMPAs, combined	CIMMYT agrees with this recommendation, but notes the need for additional, sustainable resources to	Discussions and joint project proposals with IITA initiated by June '06.	Joint project proposals under development; additional funding	Dec '07.	Mega-project on mycotoxins under development.

Recommendation	Center response	Milestones	Progress achieved	Target date to Complete	March 2007 update
with more systematic research and breeding to reduce mycotoxin contamination on the grain;	ensure that new initiatives have a medium-to-longer-term outlook. In the meantime, CIMMYT will explore opportunities for collaborative work in this area with IITA.	Joint project on mycotoxins to be funded by Dec '07.	sources yet to be identified.		
b) *Testing and evaluation of breeding materials directly in the MMPAs, for identification of the best material for release;*	CIMMYT notes this recommendation and observes that it is routine procedure for experimental materials to be tested in their target environments. CIMMYT has made very significant progress in MMPAs using farmer-participatory "Mother-baby" trials (> 1M ha in southern Africa sown with improved maize using this approach) and acknowledges the recommendation as being a strong endorsement of this approach.	A routine and on-going aspect of our work.	N/A		
c) *Non-transgenic host plant insect resistance research to speed up the process of integration of the highly resistant CIMMYT germplasm into new cultivars;*	CIMMYT notes this recommendation. The Center has invested in host plant resistance work for at least 30 years and considerable progress has been made, but transgenic approaches to insect resistance are increasingly providing significant gains. We will continue to work on an integrated pest management strategy that is reflected in a number of on-going projects.	N/A			
d) *Application of fast track breeding techniques (doubled haploid, MAS, NIR techniques) in all maize breeding activities in CIMMYT;*	CIMMYT partially agrees with this recommendation as the value of these technologies should be assessed on a case-by-case basis. CIMMYT has routinely been using MAS for traits where MAS is more cost-effective than field-based techniques. Recently, CIMMYT has commenced the use of NIR for assessing stover quality in maize and we expect to expand this work. The use of double haploids in maize is a relatively new technique and its utility for marginal and low input environments is yet to be proven. As for our response to 8a) CIMMYT notes the need for additional resources	MAS to be adopted when several traits may be selected at once and double haploids and NIR to be implemented if and when additional resources may be found. Capacity to be developed in partnership with ARI' during the period July'06-June '07.	A maize molecular breeding position has been filled; the incumbent commenced April '06.	Further review in June '07.	Achieved. Several MAS projects implemented (GLS, MSV, QPM, pro-vitamin A). Doubled haploids initiated and inducer lines developed with University of Hohenheim. New NIR purchased.

Recommendation	Center response	Milestones	Progress achieved	Target date to Complete	March 2007 update
	of a medium-to-long-term nature to implement areas of research of strategic importance.				
e) *Acquisition, storage and management of maize breeding data to eliminate the current back-log.*	CIMMYT agrees with this recommendation and notes that decisions have already been made to allocate more resources to the acquisition, storage and management of maize breeding data within CIMMYT during the next two years.	Additional funds to be allocated in the '05 budget	165K of additional funding allocated for '05. Further efforts underway through the joint program (CRIL) with IRRI.	Dec '06	All data available in MGB (26,000 accessions) also migrated to CropFinder and web-enabled (http://sas.cimmyt.org/CropFinder) This includes more than 2.3M data points related to maize germplasm.
8) The Panel recommends that:					
a) *Crop management research in (the) TES (Program) in the regions be strengthened by allocating NRM (Crop and Resource Management) staff time from other programs, particularly IAP, to TES;*	CIMMYT agrees with the recommendation and notes that there are at least two avenues to be pursued: a) additional financial resources are needed for the TES Program; and b) increasing the overall staffing and cross-program assignments of crop and resource management scientists generally.	Reallocation and/or additional staff time as and when extra resources become available.	Additional resources not yet available.	Further review by Dec '06	The grouping of crop and resource management researchers in MTP 10 from Jan'07 will facilitate cross-commodity assignments.
b) *CIMMYT, TES in particular, seek collaboration with other CGIAR Centers in the region, including shared appointments of agronomists and other natural resources specialists;*	CIMMYT agrees in principle with the recommendation. We will follow up on some initial discussions that have already been held with three other centers and also on emerging collaboration among centers within the Water and Food Challenge Program.	Development of at least one joint program by June '06.	The IRRI-CIMMYT alliance program on intensive cropping systems for Asia has developed a work plan and is in the process of recruiting a program leader.	Program leader appointed by Dec '06	Achieved. The IPSA program has a joint IRRI-CIMMYT leader.
c) The Crop and Resource Management Group, TES and other eco-regional programs enhance strategic research on natural resource management, particularly for improved water and nutrient use efficiency.	CIMMYT agrees with the recommendation. Already there is an increased emphasis on more strategic research through two recent appointments and we plan to enhance this approach in future projects.	Recruitment of additional staff by June '05	Achieved	N/A	

Recommendation	Center response	Milestones	Progress achieved	Target date to Complete	March 2007 update
9) The Panel recommends that the IAP breeding teams work closely with crop management and social science groups to develop cultivars that are suitable for conservation agriculture, use water efficiently and are resistant to storage losses.	CIMMYT notes the recommendation and observes that activities in the RWC have embraced genotype by management (conservation agriculture) interactions for some time. The plant breeding programs in both maize and wheat, in recent years, have aimed at the development of germplasm with an emphasis on input use efficiency (water) and resistance to storage losses (maize) and the development of materials suited to conservation agriculture. The breeding programs in Mexico run a parallel selection program under conservation agriculture and conventional conditions.	N/A			
10) The Panel recommends that IAP undertake long term experiments to evaluate cropping system sustainability with the results being fully utilized for strategic research as well as for demonstration purposes.	CIMMYT agrees with the recommendation insofar as it relates to long-term trials conducted on CIMMYT's experiment stations in Mexico and notes that trials over the past 10 years in Mexico have provided an excellent platform for strategic research and demonstration. In regional locations, CIMMYT collaborates with research partners to effectively design, manage and use long-term crop management trials.	N/A			
11) The Panel recommends that IAP increase its research in maize cropping systems and their development.	CIMMYT agrees with the recommendation and we expect to focus attention on the maize producing regions of Asia where demand is increasing at the fastest rate.	Increased research activity in this area by June '06	The IRRI-CIMMYT alliance program on intensive cropping systems for Asia has developed a work plan and is recruiting a program leader.	Program leader appointed by Dec '06	Achieved
12) The Panel recommends that the data acquisition, data management and gene bank user interface be upgraded in the CIMMYT gene bank for both wheat and maize as a matter of urgency.	CIMMYT agrees with the recommendation and notes that significant steps are already underway through several different system-wide initiatives to develop a range of integrated modules to fully computerize data acquisition, genebank management, germplasm evaluation and database query across both crops.	Allocation of additional funding to the genebank in '05 and attendant work plan	CRISCO work plan implemented in '05; IRRI-CIMMYT joint program for research informatics established with a program leader (G McLaren, IRRI).	Dec '06	Wheat International Nursery System (WINS) is fully operational and a module of ICIS has been developed for wheat germplasm inventory management.

Recommendation	Center response	Milestones	Progress achieved	Target date to Complete	March 2007 update
					Maize Genebank (MGB) management system is fully operational.
13) *The Panel* recommends *that:*					
a) *Training coordinator position be relocated to an independent Unit reporting directly to the DDG-R;*	CIMMYT notes the recommendation. As set forth in the CIMMYT strategy, training and capacity building activities are an integral part of the knowledge management and sharing activities of the ITA Program. These activities are closely related to broader ITA thrusts on the orientation of CIMMYT and its partners to livelihoods and poverty reduction; support to the use of best practices; priority setting and impact assessment; and, advocacy of effective policies to foster impact on the ground.	CIMMYT has retained the training coordinator within the ITA unit for a number of strategic reasons.	N/A		
b) *The Training Unit working together with program directors develop a priority setting tool, both thematic and geographical. The resulting priorities should then be used to allocate resource to the programs;*	CIMMYT agrees in principle with the recommendation for training purposes and will implement a priority setting tool as part of the enrichment of the Resource Allocation Tool developed during strategic planning, noting that priorities for capacity building need to be determined within and across programs.	Development of capacity building strategy during '05. Targeting workshop for CIMMYT researchers to be held August '05 to develop mechanisms for priority setting and targeting of training.	Capacity building strategy developed and workshop held.	N/A	
c) *CIMMYT develop innovative alternative funding schemes for training*	CIMMYT agrees in principle with the recommendation and is actively exploring a variety of options internally and with external stakeholders, including private sector support. Fellowship programs, both internally and externally funded, will be implemented to facilitate capacity building.	Alternate funding mechanisms to be actively pursued in 2005; further review of funding of training by Dec '06.	Some funding support from the private sector for training has been provided.	Dec '06	Some private sector support for fellowships achieved. Discussions on-going with one company on development of Maize Doctor.
14) To help ensure that CIMMYT builds and sustains high functioning Boards, the Panel recommends the establishment of a governance committee with responsibility for a range of activities essential to Board	The Board is committed to fulfilling its role to the highest possible standards, and will reduce its size to no more than seven appointed members, while maintaining the appropriate mix of skills, and will enhance the roles of the Audit and Finance and Administration Committees as	New governance model (policies and procedures) for the CIMMYT Board to be in place by March '06	CIMMYT Board workshop on governance held, March '05; Schedule for the reduction of Board size (currently 8 appointed members) implemented; Executive	March '07	Completed

Recommendation	Center response	Milestones	Progress achieved	Target date to Complete	March 2007 update
effectiveness, including defining more clearly the role of the board, developing a more strategic process for identifying and recruiting board members, assessing board performance on a formal basis, evaluating the performance of members before re-election, recommending improvements to board practice, such as meeting design and preparation, information flow and communication, and developing an orientation and ongoing education program for members to enhance their performance	agents of the Board. Rather than create a separate governance committee, CIMMYT will engage a specialist consultant to help the Board and its committees clarify their roles and put in place a more strategic process for identifying and recruiting Board members, assessing Board performance and evaluating the performance of members before re-election. The consultant will advise on designing and preparing meetings, information flow, and communications, and will work with the Board to develop an orientation and ongoing education program for trustees. Finally, the consultant will review (annually at first) the Board's effectiveness. In the future, the Board as a whole will explicitly address governance functions, in lieu of a committee.		Committee of the Board established and functioning; Audit and Finance and Administration Committee functions separated; formal Board self-assessment procedures implemented; improved practices for meetings and out-of-session handling of business matters implemented.		
15) The Panel recommends that a dedicated staff person in the DG's office be identified to serve as the Board Secretary. This position should have sufficient status within the organization, clear responsibility and also adequate time to provide support and coordination for the board.	CIMMYT agrees with the recommendation and has already (effective March 2005) implemented this recommendation.	N/A			
16) The Panel recommends that management review the staff survey results in detail with special attention to staff morale, communication of policies, clarity of goals, performance recognition, and staff evaluation, and take appropriate corrective action as a matter of urgency.	CIMMYT agrees with the recommendation. Clearly, CIMMYT is in a period of transition and it is inevitable that staff morale has been affected over the past 2 years and with the staff downsizings. CIMMYT will work extremely hard to ensure that all staff have clarity on the future and an important aspect of this will be a new One Staff policy that is already agreed in principle by the Board. Consistent with recommendations 1) and 2)	Staff morale "indicator" improved as of June '06; staff work plans clearly communicated by Jan '05; revised HR policy (OneStaff) implemented by Dec '06.	With the development of the business plan for CIMMYT, all staff have a clear sense of direction of the Center. The launch of the plan in January '06 during a very successful 'science week' and attendant research planning meetings has added further coherence to our agenda including the role of staff as	Dec '07	Indications- not yet quantified- that staff morale is improving.

Recommendation	Center response	Milestones	Progress achieved	Target date to Complete	March 2007 update
	we fully expect that communication of roles and responsibilities to staff, with attendant policies and procedures, will greatly assist staff function and morale.		we move forward. All staff appraisals in Jan-Feb '05 included plans of work for '05; similarly for '06, with an emphasis on merit-based recognition (salary increases) of performance. Range of institutional improvements implemented to assist in development of the social health of the Center, including clarification of some key personnel policies; improved communication (open fora, monthly meetings with staff committees, weekly newsletter). The Center's improved financial health and overall performance ("A" for World Bank 2005 indicators) have helped improve staff morale.		
17) The Panel recommends that management give priority to reforming financial management at the Center, including budget, staffing and related systems, with highest priority given to the development of a computerized financial management system that provides real on-time financial information to users; and urgently develop (in consultation with program staff) a transparent resource allocation process consistent with needs of the matrix management system.	CIMMYT agrees with the recommendation. We have already commenced the implementation of the following systems which are the initial building blocks for the development of a more comprehensive financial management system: • An integrated human resource information system (HRIS); the first phase of this project will be implemented by the end of March '05 and the complete staff database will be finalized by the end of June '05. • CIAT's project manager application. We plan to have an effective project management system in place during the 3rd quarter of '05.	Integrated human resources information system functional by June '05 Project Manager system implemented by Dec '05 New financial management information system in place by June '06	A complete staff database (IRS, NRS) has been finalized as of June '05 Project Manager system not implemented; instead, Axapta, a Microsoft product which has project management capabilities is being implemented and will be tested during June '06 with the aim for it to become the basis of our financial system in the second half of '06.	Dec '06	Achieved

Recommendation	Center response	Milestones	Progress achieved	Target date to Complete	March 2007 update
	The issues surrounding the development and implementation of a completely new financial management information system are being currently reviewed and we are evaluating options of moving to a shared service with another CGIAR Center as a first priority.				
18) The Panel recommends that management carefully examine the correctness of the net assets (equity) balance for 2004 attributable to the increase in 2003 (of approximately US$ 2.0 million) from fixed assets write-off and revaluation.	CIMMYT notes the recommendation and has reviewed it with our external auditors who have confirmed that while the detail that was presented in the 2003 financial statements was less than clear, the treatment is correct. The disclosure issue has been clarified in the 2004 financial statements and the relative balances of CIMMYT's net asset categories are correctly stated.	N/A			
19) The Panel recommends that the Board and management develop a set of financial indicators for measuring the Center financial performance and health. The indicators should supplement those developed by the CGIAR System in close consultation with CGIAR Secretariat and Center Finance Directors.	CIMMYT agrees with the recommendation. We have discussed and agreed upon a set of financial indicators at the March '05 Board meeting. These indicators are based on those developed by the CGIAR.	N/A			
20) The Panel recommends that a full cost recovery/pricing system for support services be implemented to recover the full costs from projects and users of services. This will reduce the pressure on unrestricted funding and make it available for other high priority activities at the Center, including building the working capital to the required level.	CIMMYT agrees with the recommendation and has already implemented changes within the '05 budget that will lead to full cost recovery from projects and users of services. It is expected that through a combination of restructuring of our internal costing practices and improved project costing when submitting proposals to donors, we will be able to substantially improve our performance in this area.	Implementation of project costing template by Jan '06 Full recovery of indirect costs by Jan '09, as scheduled in the business plan with an intermediate target of 50% recovery by Jan '07	Achieved 52% of total indirect costs were recovered in '05. The main focus to date has been on attribution of depreciation costs and charging out ICT costs. For '06, all field station costs in Mexico have been fully apportioned to users of the facilities.	Dec '08	
21) The Panel recommends that Board and management:					

Recommendation	Center response	Milestones	Progress achieved	Target date to Complete	March 2007 update
a) *Make substantial efforts and allocate adequate time for the careful review of the external audit (at headquarters and regional operations), management letters and the audited financial statements with the notes;*	CIMMYT agrees that the external audit function is crucial to the fiduciary oversight of the Center by the Board and asserts that its Audit Committee takes its roles in relation to the External Auditors seriously. The CIMMYT Board Audit Committee and full Board will continue to commit substantial time and effort for the careful review of external audit reports for headquarters and regional offices. The Committee annually receives audit plans, and will review the external audit scope to reflect management's and the Board's assessment of risks, taking into account the changing nature of the Center's programs at headquarters and in the regions. The Audit Committee will develop and implement a formal plan for assessment of the External Auditors prior to renewal or selection of new auditors.	BOT Audit Committee to develop an agenda for audit at CIMMYT including the development of an MTP, by Nov '05 BOT Audit Committee to use CGIAR best practice in the (re)appointment of external auditors, commencing March '06	Achieved- Internal audit MTP 2006-08 approved by the BOT. Achieved.	N/A	
b) *Carefully review the annual audit plans and scope of external audit for headquarters and regional operations;*					
c) *Formally assess annually the performance of the external auditors before deciding on their re-appointment.*					
22) The Panel recommends that Board and management review the scope of internal audit work and the capabilities of the senior internal auditor and make the required changes to strengthen this important function.	The CIMMYT Board and Management agree that CIMMYT must have a strong internal audit function. The scope and capabilities of the internal audit function will continue to be under review and all necessary and appropriate actions will be taken.	Review of internal auditor in '05	In addition to the development of an internal audit MTP, CIMMYT has been actively involved in the recruitment and placement of the CGIAR IAU Associate Director for the Americas who is now based at CIMMYT with approx. 25% of his time dedicated to CIMMYT-specific audit issues.	N/A	

Budget Tables

Table 1. Allocation of Project Costs by Priority Area and Priorities, 2008 (in $millions)

	Priority Area 1	Priority Area 2			Priority Area 3	Priority Area 4	Priority Area 5			Non-Priority Area		
Project	1A	2A	2B	2C	3A	4D	5A	5B	5C	Development Activities	Stand-alone Training	Total
Project 01 - Conservation, characterization and utilization of maize and wheat genetic resources	1.160	0.725	0.725	0.290								2.900
Project 02 - Technology-assisted tools and methodologies for genetic improvement		1.260	2.100	0.840								4.200
Project 03 - Stress tolerant maize			6.300	1.050		1.050				1.050	1.050	10.500
Project 04 - Nutritious and specialty trait maize	0.350	0.875	0.525	1.400	0.175	0.175						3.500
Project 07 - Drought tolerant wheat with enhanced quality	0.310	0.620	1.860	0.310								3.100
Project 08 - Disease resistant wheat with high productivity and quality	0.855	0.855	2.280	1.140						0.570		5.700
Project 10 - Maize and wheat cropping systems		0.250				1.750				0.500		2.500
Project 11 - Knowledge, targeting and strategic assessment of maizeand wheat farming systems							1.080	0.540	0.270	0.270	0.540	2.700
Total	2.675	4.585	13.790	5.030	0.175	2.975	1.080	0.540	0.270	2.390	1.590	35.100

Table 2. Allocation of Project Costs to CGIAR Priorities, 2007-2010 (in $millions)

Projects Priorities	Estimated 2007	Proposal 2008	Plan 1 2009	Plan 2 2010
Project 01 - Conservation, characterization and utilization of maize and wheat genetic resources				
1A	1.546	1.160	1.200	1.240
2A	0.967	0.725	0.750	0.775
2B	0.966	0.725	0.750	0.775
2C	0.387	0.290	0.300	0.310
Project Total	3.866	2.900	3.000	3.100
Project 02 - Technology-assisted tools and methodologies for genetic improvement				
2A	1.199	1.260	1.290	1.320
2B	1.998	2.100	2.150	2.200
2C	0.798	0.840	0.860	0.880
Project Total	3.995	4.200	4.300	4.400
Project 03 - Stress tolerant maize				
2B	5.944	6.300	6.360	6.540
2C	0.991	1.050	1.060	1.090
4D	0.991	1.050	1.060	1.090
Development Activities	0.991	1.050	1.060	1.090
Stand-alone Training	0.991	1.050	1.060	1.090
Project Total	9.908	10.500	10.600	10.900
Project 04 - Nutritious and specialty trait maize				
1A	0.312	0.350	0.370	0.380
2A	0.781	0.875	0.925	0.950
2B	0.468	0.525	0.555	0.570
2C	1.249	1.400	1.480	1.520
3A	0.156	0.175	0.185	0.190
4D	0.156	0.175	0.185	0.190
Project Total	3.122	3.500	3.700	3.800

Table 2. cont'd

Projects Priorities	Estimated 2007	Proposal 2008	Plan 1 2009	Plan 2 2010
Project 07 - Drought tolerant wheat with enhanced quality				
1A	0.230	0.310	0.320	0.330
2A	0.460	0.620	0.640	0.660
2B	1.382	1.860	1.920	1.980
2C	0.230	0.310	0.320	0.330
Project Total	2.302	3.100	3.200	3.300
Project 08 - Disease resistant wheat with high productivity and quality				
1A	0.816	0.855	0.870	0.900
2A	0.816	0.855	0.870	0.900
2B	2.175	2.280	2.320	2.400
2C	1.088	1.140	1.160	1.200
Development Activities	0.544	0.570	0.580	0.600
Project Total	5.439	5.700	5.800	6.000
Project 10 - Maize and wheat cropping systems				
2A	0.339	0.250	0.270	0.280
4D	2.372	1.750	1.890	1.960
Development Activities	0.678	0.500	0.540	0.560
Project Total	3.389	2.500	2.700	2.800
Project 11 - Knowledge, targeting and strategic assessment of maize and wheat farming systems				
5A	0.817	1.080	1.120	1.160
5B	0.408	0.540	0.560	0.580
5C	0.204	0.270	0.280	0.290
Development Activities	0.204	0.270	0.280	0.290
Stand-alone Training	0.408	0.540	0.560	0.580
Project Total	2.041	2.700	2.800	2.900
Total	34.062	35.100	36.100	37.200

Table 3. Summary of Project Costs, 2007-2010 (in $millions)

Project	Estimated 2007	Proposal 2008	Plan 1 2009	Plan 2 2010
Project 01 - Conservation, characterization and utilization of maize and wheat genetic resources	3.866	2.900	3.000	3.100
Project 02 - Technology-assisted tools and methodologies for genetic improvement	3.995	4.200	4.300	4.400
Project 03 - Stress tolerant maize	9.908	10.500	10.600	10.900
Project 04 - Nutritious and specialty trait maize	3.122	3.500	3.700	3.800
Project 07 - Drought tolerant wheat with enhanced quality	2.302	3.100	3.200	3.300
Project 08 - Disease resistant wheat with high productivity and quality	5.439	5.700	5.800	6.000
Project 10 - Maize and wheat cropping systems	3.389	2.500	2.700	2.800
Project 11 - Knowledge, targeting and strategic assessment of maize and wheat farming systems	2.041	2.700	2.800	2.900
Total	34.062	35.100	36.100	37.200

Table 4. Summary of Priority Costs, 2007-2010 (in $millions)

Priorities	Estimated 2007	Proposal 2008	Plan 1 2009	Plan 2 2010
1A	2.904	2.675	2.760	2.850
2A	4.562	4.585	4.745	4.885
2B	12.933	13.790	14.055	14.465
2C	4.743	5.030	5.180	5.330
3A	0.156	0.175	0.185	0.190
4D	3.519	2.975	3.135	3.240
5A	0.817	1.080	1.120	1.160
5B	0.408	0.540	0.560	0.580
5C	0.204	0.270	0.280	0.290
Development Activities	2.417	2.390	2.460	2.540
Stand-alone Training	1.399	1.590	1.620	1.670
Total	34.062	35.100	36.100	37.200

Table 5. Investments by Undertaking, Activity and Sector, 2006-2010 (in $millions)

	Actual	Estimated	Proposal	Plan 1	Plan 2
	2006	2007	2008	2009	2010
Increasing Productivity	21.336	20.435	21.060	21.660	22.320
Germplasm Enhancement & Breeding	14.224	13.623	14.040	14.440	14.880
Production Systems Development & Management	7.112	6.812	7.020	7.220	7.440
Cropping systems	7.112	6.812	7.020	7.220	7.440
Livestock systems	0.000	0.000	0.000	0.000	0.000
Tree systems	0.000	0.000	0.000	0.000	0.000
Fish systems	0.000	0.000	0.000	0.000	0.000
Protecting the Environment	1.778	1.703	1.755	1.805	1.860
Saving Biodiversity	1.778	1.703	1.755	1.805	1.860
Improving Policies	1.778	1.703	1.755	1.805	1.860
Strengthening NARS	8.890	8.518	8.775	9.025	9.300
Training and Professional Development	3.556	3.406	3.510	3.610	3.720
Documentation, Publications, Info. Dissemination	1.778	1.703	1.755	1.805	1.860
Organization & Management Couselling	0.000	0.000	0.000	0.000	0.000
Networks	3.556	3.409	3.510	3.610	3.720
Total	35.560	34.062	35.100	36.100	37.200

Table 6. Project Investments by Developing Region, 2006-2010 (in $millions)

Project	Region	Actual 2006	Estimated 2007	Proposal 2008	Plan 1 2009	Plan 2 2010
Project 01 - Conservation, characterization and utilization of maize and wheat genetic resources	Asia	0.912	0.773	0.580	0.600	0.620
	CWANA	1.368	1.160	0.870	0.900	0.930
	LAC	1.368	1.160	0.870	0.900	0.930
	SSA	0.912	0.773	0.580	0.600	0.620
Total Project		4.560	3.866	2.900	3.000	3.100
Project 02 - Technology-assisted tools and methodologies for genetic improvement	Asia	0.508	0.999	1.050	1.075	1.100
	CWANA	0.506	0.998	1.050	1.075	1.100
	LAC	0.508	0.999	1.050	1.075	1.100
	SSA	0.508	0.999	1.050	1.075	1.100
Total Project		2.030	3.995	4.200	4.300	4.400
Project 03 - Stress tolerant maize	Asia	0.672	0.991	1.050	1.060	1.090
	CWANA	0.000	0.000	0.000	0.000	0.000
	LAC	0.672	0.991	1.050	1.060	1.090
	SSA	5.380	7.926	8.400	8.480	8.720
Total Project		6.724	9.908	10.500	10.600	10.900
Project 04 - Nutritious and specialty trait maize	Asia	1.725	1.249	1.400	1.480	1.520
	CWANA	0.216	0.155	0.175	0.185	0.190
	LAC	1.294	0.937	1.050	1.110	1.140
	SSA	1.078	0.781	0.875	0.925	0.950
Total Project		4.313	3.122	3.500	3.700	3.800
Project 07 - Drought tolerant wheat with enhanced quality	Asia	2.107	0.921	1.240	1.280	1.320
	CWANA	2.107	0.921	1.240	1.280	1.320
	LAC	0.527	0.230	0.310	0.320	0.330
	SSA	0.527	0.230	0.310	0.320	0.330
Total Project		5.268	2.302	3.100	3.200	3.300
Project 08 - Disease resistant wheat with high productivity and quality	Asia	2.492	2.176	2.280	2.320	2.400
	CWANA	2.492	2.175	2.280	2.320	2.400
	LAC	0.623	0.544	0.570	0.580	0.600
	SSA	0.623	0.544	0.570	0.580	0.600
Total Project		6.230	5.439	5.700	5.800	6.000
Project 10 - Maize and wheat cropping systems	Asia	1.211	1.017	0.750	0.810	0.840
	CWANA	1.211	1.017	0.750	0.810	0.840
	LAC	0.404	0.338	0.250	0.270	0.280
	SSA	1.211	1.017	0.750	0.810	0.840
Total Project		4.037	3.389	2.500	2.700	2.800
Project 11 - Knowledge, targeting and strategic assessment of maize and wheat farming systems	Asia	0.600	0.510	0.675	0.700	0.725
	CWANA	0.598	0.511	0.675	0.700	0.725
	LAC	0.600	0.510	0.675	0.700	0.725
	SSA	0.600	0.510	0.675	0.700	0.725
Total Project		2.398	2.041	2.700	2.800	2.900
Total		35.560	34.062	35.100	36.100	37.200

Table 7. Summary of Investments by Developing Region, 2006-2010 (in $millions)

Region	Actual 2006	Estimated 2007	Proposal 2008	Plan 1 2009	Plan 2 2010
SSA	10.839	12.780	13.210	13.490	13.885
Asia	10.227	8.636	9.025	9.325	9.615
LAC	5.996	5.709	5.825	6.015	6.195
CWANA	8.498	6.937	7.040	7.270	7.505
Total	35.560	34.062	35.100	36.100	37.200

Table 8. Expenditure by Object, 2006-2010 (in $millions)

Object of Expenditure	Actual 2006	Estimated 2007	Proposal 2008	Plan 1 2009	Plan 2 2010
Personnel	16.596	16.566	16.800	16.900	17.100
Supplies and services	10.352	8.696	9.200	9.500	9.800
Collaboration/ Partnerships	5.588	5.700	5.800	6.100	6.400
Operational Travel	2.035	2.000	2.100	2.300	2.600
Depreciation	0.989	1.100	1.200	1.300	1.300
Total	35.560	34.062	35.100	36.100	37.200

Table 9. Member and Non-Member Unrestricted and Restricted Grants, 2006-2008 (in $millions)

Member	Actual 2006	Estimated 2007	Proposal 2008
Unrestricted Grants			
Australia	0.568	0.565	0.570
Canada	1.044	1.034	1.030
China	0.120	0.120	0.120
Denmark	0.481	0.670	0.670
France	0.152	0.158	0.160
Germany	0.430	0.447	0.450
India	0.113	0.112	0.110
Japan	1.045	0.800	0.800
Korea, Republic of	0.050	0.050	0.050
Netherlands	0.795	0.000	0.000
Norway	0.318	0.325	0.330
Philippines	0.008	0.007	0.010
Sweden	0.324	0.357	0.360
Switzerland	0.489	0.488	0.490
Thailand	0.010	0.010	0.010
United Kingdom	1.672	1.765	1.770
United States	4.048	3.036	3.040
World Bank	3.204	2.000	2.000
Subtotal	14.871	11.944	11.970
Total Unrestricted	14.871	11.944	11.970
Restricted Grants			
ADB	0.209	0.250	0.042
Australia	0.499	0.317	0.236
Canada	1.617	0.859	0.600
Denmark	0.023	0.000	0.000
European Commission	0.014	1.654	1.501
FAO	0.041	0.040	0.000
Germany	0.740	0.953	0.473
IDB	0.010	0.000	0.000
IFAD	0.678	0.445	0.150
India	0.294	0.408	0.200
Iran	0.060	0.109	0.000
Italy	0.031	0.038	0.000
Japan	1.321	1.200	1.224
Korea, Republic of	0.087	0.105	0.090
Mexico	0.000	0.000	0.100
OPEC Fund	0.064	0.000	0.200
Peru	0.036	0.040	0.070
Rockefeller Foundation	1.556	1.270	0.303
South Africa	0.060	0.035	0.070
Spain	0.323	0.272	0.302
Sweden	0.011	0.000	0.000
Switzerland	0.857	1.011	0.799
Syngenta Foundation	0.395	0.380	0.298
Turkey	0.165	0.068	0.080
United Kingdom	0.430	0.126	0.150
United States	2.033	1.661	0.748
World Bank	0.300	0.150	0.118
Subtotal	11.854	11.391	7.754

Table 9. Cont'd

Member	Actual 2006	Estimated 2007	Proposal 2008
Non-member			
Agrovegetal	0.079	0.134	0.106
BASF, Germany	0.042	0.150	0.000
Bill and Melinda Gates Foundation	0.190	5.284	7.000
Busch Agri Research	0.015	0.000	0.000
CIAT	0.018	0.000	0.000
CONACYT, Mexico	0.111	0.188	0.000
Cornell University	0.068	0.000	0.000
CRC for Molecular Plant Breeding, Australia	0.420	0.000	0.024
FENALCE	0.208	0.201	0.126
Fundacion Guanajuato Produce A.C.	0.059	0.014	0.000
Fundacion Sonora	0.038	0.060	0.020
Generation/CP	1.156	0.680	0.900
Global Diversity Fund	0.092	0.000	0.000
GRDC	0.982	0.885	0.792
HarvestPlus/CP	1.026	1.037	0.500
ICAMEX	0.063	0.014	0.000
ICARDA	0.040	0.026	0.000
ICRISAT	0.087	0.080	0.080
ILRI	0.044	0.338	0.046
Int'n Center for Insect Physiology and Ecology (ICIPE)	0.018	0.000	0.000
IPGRI	0.022	0.000	0.000
IWMI	0.007	0.000	0.000
Kazakhstan	0.019	0.058	0.014
Nippon Foundation	0.687	0.250	0.250
Others	0.912	0.110	0.049
Pioneer	0.063	0.150	0.150
Private Sector Consortium	0.266	0.180	0.180
Sasakawa Africa Association	0.000	0.014	0.000
Stanford University	0.007	0.000	0.000
Unidentified	0.000	0.000	4.600
US Dept of Agriculture	0.239	0.302	0.146
Washington State University	0.139	0.000	0.000
Water & Food/CP	0.323	0.478	0.000
Subtotal	7.440	10.633	14.983
Total Restricted	19.294	22.024	22.737
Total Grants	34.165	33.968	34.707

Summary and Statement of Activities	Actual 2006	Estimated 2007	Proposal 2008
Total Grants	34.165	33.968	34.707
Center Income	1.789	0.194	0.693
Total Revenue	35.954	34.162	35.400
Total Investment	35.560	34.062	35.100
Surplus (Deficit)	0.394	0.100	0.300

Table 10. Allocation of Member Grants and Center Income to Projects, 2006-2008 (in $millions)

Project	Member		Actual 2006	Estimated 2007	Proposal 2008
Project 01 - Conservation, characterization and utilization of maize and wheat genetic resources	Member	European Commission	0.000	0.535	0.500
		Japan	0.344	0.650	0.650
		Korea, Republic of	0.000	0.010	0.000
		United States	0.038	0.028	0.000
		World Bank	0.078	0.150	0.118
	Non Member	Bill and Melinda Gates Foundation	0.005	0.296	0.000
		Generation/CP	0.566	0.342	0.400
		Global Diversity Fund	0.092	0.000	0.000
		GRDC	0.120	0.000	0.000
		Pioneer	0.000	0.000	0.000
		Private Sector Consortium	0.266	0.180	0.180
		US Dept of Agriculture	0.000	0.000	0.000
	Unrestricted + Center Income		3.051	1.675	1.052
		Project Total	4.560	3.866	2.900
Project 02 - Technology-assisted tools and methodologies for genetic improvement	Member	European Commission	0.000	0.638	0.600
		Korea, Republic of	0.057	0.065	0.060
		Rockefeller Foundation	0.359	0.242	0.187
		United States	0.147	0.080	0.200
	Non Member	Bill and Melinda Gates Foundation	0.015	1.256	0.000
		CRC for Molecular Plant Breeding, Australia	0.198	0.000	0.000
		Generation/CP	0.513	0.338	0.500
		HarvestPlus/CP	0.000	0.032	0.000
		Others	0.000	0.010	0.000
		Unidentified	0.000	0.000	1.000
	Unrestricted + Center Income		0.741	1.334	1.653
		Project Total	2.030	3.995	4.200
Project 03 - Stress tolerant maize	Member	ADB	0.203	0.250	0.042
		Canada	0.013	0.000	0.000
		European Commission	0.000	0.135	0.101
		Germany	0.025	0.354	0.444
		IFAD	0.456	0.445	0.150
		Peru	0.002	0.040	0.070
		Rockefeller Foundation	0.807	0.770	0.000
		South Africa	0.035	0.035	0.035
		Spain	0.057	0.000	0.030
		Switzerland	0.857	0.972	0.750
		Syngenta Foundation	0.395	0.380	0.298
		United Kingdom	0.202	0.126	0.150
		United States	0.268	0.105	0.100
	Non Member	BASF, Germany	0.042	0.150	0.000
		Bill and Melinda Gates Foundation	0.153	3.233	5.000
		CIAT	0.012	0.000	0.000

Project	Member		Actual 2006	Estimated 2007	Proposal 2008
		CONACYT, Mexico	0.087	0.188	0.000
		FENALCE	0.208	0.201	0.126
		Int'n Center for Insect Physiology and Ecology (ICIPE)	0.018	0.000	0.000
		Pioneer	0.063	0.150	0.150
	Unrestricted + Center Income		2.821	2.374	3.054
		Project Total	6.724	9.908	10.500
Project 04 - Nutritious and specialty trait maize	Member	Canada	1.190	0.859	0.600
		European Commission	0.000	0.026	0.000
		Germany	0.143	0.262	0.029
		India	0.102	0.000	0.000
		Mexico	0.000	0.000	0.100
		OPEC Fund	0.064	0.000	0.200
		Peru	0.034	0.000	0.000
	Non Member	HarvestPlus/CP	0.603	0.430	0.250
		Nippon Foundation	0.417	0.000	0.000
		Others	0.054	0.100	0.000
		Unidentified	0.000	0.000	0.800
	Unrestricted + Center Income		1.706	1.445	1.521
		Project Total	4.313	3.122	3.500
Project 07 - Drought tolerant wheat with enhanced quality	Member	Australia	0.237	0.078	0.000
		Canada	0.414	0.000	0.000
		IDB	0.010	0.000	0.000
		Iran	0.015	0.000	0.000
		Italy	0.031	0.038	0.000
		Mexico	0.000	0.000	0.000
		South Africa	0.025	0.000	0.035
		Turkey	0.165	0.068	0.080
		United States	0.005	0.038	0.038
	Non Member	Busch Agri Research	0.015	0.000	0.000
		CONACYT, Mexico	0.024	0.000	0.000
		CRC for Molecular Plant Breeding, Australia	0.222	0.000	0.024
		Fundacion Guanajuato Produce A.C.	0.025	0.007	0.000
		Generation/CP	0.077	0.000	0.000
		GRDC	0.525	0.432	0.446
		ICAMEX	0.047	0.007	0.000
		ICARDA	0.040	0.026	0.000
		Kazakhstan	0.000	0.058	0.014
		Others	0.031	0.000	0.010
		Unidentified	0.000	0.000	1.000
		US Dept of Agriculture	0.019	0.111	0.000
		Washington State University	0.139	0.000	0.000
	Unrestricted + Center Income		3.202	1.439	1.453
		Project Total	5.268	2.302	3.100

Project	Member		Actual 2006	Estimated 2007	Proposal 2008
Project 08 - Disease resistant wheat with high productivity and quality	Member	Australia	0.240	0.140	0.140
		India	0.048	0.352	0.200
		Iran	0.045	0.109	0.000
		Japan	0.977	0.550	0.574
		Korea, Republic of	0.030	0.030	0.030
		Spain	0.266	0.272	0.272
		Sweden	0.011	0.000	0.000
		Switzerland	0.000	0.039	0.049
		United Kingdom	0.228	0.000	0.000
		United States	0.412	0.836	0.050
	Non Member	Agrovegetal	0.079	0.134	0.106
		Bill and Melinda Gates Foundation	0.000	0.000	2.000
		Fundacion Guanajuato Produce A.C.	0.022	0.007	0.000
		Fundacion Sonora	0.038	0.060	0.020
		GRDC	0.337	0.342	0.260
		HarvestPlus/CP	0.417	0.575	0.250
		ICAMEX	0.016	0.007	0.000
		Others	0.498	0.000	0.039
		Sasakawa Africa Association	0.000	0.014	0.000
		Stanford University	0.007	0.000	0.000
		US Dept of Agriculture	0.220	0.191	0.146
	Unrestricted + Center Income		2.339	1.781	1.564
		Project Total	6.230	5.439	5.700
Project 10 - Maize and wheat cropping systems	Member	ADB	0.006	0.000	0.000
		Australia	0.022	0.099	0.096
		European Commission	0.014	0.000	0.000
		Germany	0.545	0.321	0.000
		IFAD	0.198	0.000	0.000
		India	0.144	0.056	0.000
		Rockefeller Foundation	0.347	0.258	0.116
		United States	1.043	0.511	0.350
		World Bank	0.222	0.000	0.000
	Non Member	Cornell University	0.068	0.000	0.000
		Fundacion Guanajuato Produce A.C.	0.012	0.000	0.000
		GRDC	0.000	0.111	0.086
		ICRISAT	0.087	0.080	0.080
		ILRI	0.044	0.338	0.046
		Kazakhstan	0.019	0.000	0.000
		Others	0.007	0.000	0.000
		Unidentified	0.000	0.000	1.000
		Water & Food/CP	0.323	0.478	0.000
	Unrestricted + Center Income		0.936	1.137	0.726
		Project Total	4.037	3.389	2.500

Project	Member		Actual 2006	Estimated 2007	Proposal 2008
Project 11 - Knowledge, targeting and strategic assessment of maize and wheat farming systems	Member	Denmark	0.023	0.000	0.000
		European Commission	0.000	0.320	0.300
		FAO	0.041	0.040	0.000
		Germany	0.027	0.016	0.000
		IFAD	0.024	0.000	0.000
		Rockefeller Foundation	0.043	0.000	0.000
		United States	0.120	0.063	0.010
	Non Member	Bill and Melinda Gates Foundation	0.017	0.499	0.000
		CIAT	0.006	0.000	0.000
		HarvestPlus/CP	0.006	0.000	0.000
		IPGRI	0.022	0.000	0.000
		IWMI	0.007	0.000	0.000
		Nippon Foundation	0.270	0.250	0.250
		Others	0.125	0.000	0.000
		Unidentified	0.000	0.000	0.800
	Unrestricted + Center Income		1.667	0.853	1.340
		Project Total	2.398	2.041	2.700
		Total Restricted	19.097	22.024	22.737
		Total Unrestricted + Center Income	16.463	12.038	12.363
		Total	35.560	34.062	35.100

Table 11: Internationally and Nationally Recruited Staff, 2006-2010 (in $millions)

	Actual 2006	Estimated 2007	Proposal 2008	Plan 1 2009	Plan 2 2010
NRS	555	555	555	555	555
IRS	85	82	82	82	82
Total	640	637	637	637	637

CIMMYT-Table 12: Currency Structure of Expenditure, 2006-2008
in millions of units and percent

	Actual 2006			Estimated 2007			Proposal 2008		
Currency	Amount	$ Value	% Share	Amount	$ Value	% Share	Amount	$ Value	% Share
EUR	0.000	0.900	3	0.000	0.700	2	0.000	0.800	2
INR	0.000	2.000	6	0.000	1.800	5	0.000	1.700	5
KES	0.000	2.000	6	0.000	2.300	7	0.000	3.000	9
MXN	0.000	9.500	27	0.000	9.400	28	0.000	9.600	27
Others	0.000	0.800	2	0.000	0.700	2	0.000	0.700	2
USD	0.000	19.460	55	0.000	18.362	54	0.000	18.500	53
ZWD	0.000	0.900	3	0.000	0.800	2	0.000	0.800	2
Total		35.560	100 %		34.062	100 %		35.100	100 %

Table 13. Statement of Financial Position (SFP), 2006-2008 (in $millions)

Assets, Liabilities and Net Assets	2006	2007	2008
Current Assets			
Cash and Cash Equivalents	23.645	26.820	26.300
Investments			
Accounts Receivable			
- Donor	4.711	3.000	3.200
- Employees			
- Other CGIAR Centers			
- Others	1.073	1.200	1.200
Inventories	0.437	0.500	0.520
Pre-paid Expenses	0.055	0.080	0.080
Total Current Assets	29.921	31.600	31.300
Non-Current Assets			
Net Property, Plan and Equipment	14.991	15.400	15.800
Investments			
Other Assets			
Total Non-Current Assets	14.991	15.400	15.800
Total Assets	44.912	47.000	47.100
Current Liabilities			
Overdraft/Short Term Borrowings			
Accounts Payable			
- Donor	9.377	11.000	11.200
- Employees	1.390	1.600	1.800
- Other CGIAR Centers	7.464	7.800	7.000
- Others	1.639	1.800	1.800
Accruals and Provisions	1.152	1.200	1.200
Total Current Liabilities	21.022	23.400	23.000
Non-Current Liabilities			
Accounts Payable			
- Employees	0.877	1.000	1.200
- Deferred Grant Revenue			
- Others	0.450		
Total Non-Current Liabilities	1.327	1.000	1.200
Total Liabilities	22.349	24.400	24.200
Net Assets			
Unrestricted			
- Designated	14.991	15.400	15.800
- Undesignated	7.572	7.200	7.100
Total Unrestricted Net Assets	22.563	22.600	22.900
Restricted			
Total Net Assets	22.563	22.600	22.900
Total Liabilities and Net Assets	44.912	47.000	47.100

Table 14. Statement of Activities (SOA), 2006-2008 (in $millions)

		Unrestricted	Restricted		Total		
			Temporary	Challenge Programs	2006	2007	2008
Revenue and Gains	Grant Revenue	14.871	16.412	2.882	34.165	33.968	34.707
	Other revenue and gains	1.789	0.000	0.000	1.789	0.194	0.693
	Total revenue and gains	16.660	16.412	2.882	35.954	34.162	35.400
Expenses and Losses	Program related expenses	10.208	16.412	2.882	29.502	29.385	30.250
	Management and general expenses	7.367	0.000	0.000	7.367	7.277	7.450
	Other losses expenses	1.039	0.000	0.000	1.039	0.000	0.000
	Sub Total expenses and losses	18.614	16.412	2.882	37.908	36.662	37.700
	Indirect cost recovery	-2.348	0.000	0.000	-2.348	-2.600	-2.600
	Total expenses and losses	16.266	16.412	2.882	35.560	34.062	35.100
	Net Operating Surplus / (Deficit)	0.394	0.000	0.000	0.394	0.100	0.300
	Extraordinary Items	0.000	0.000	0.000	0.000	0.000	0.000
	NET SURPLUS / (DEFICIT)	0.394	0.000	0.000	0.394	0.100	0.300
Object of Expenditure	Personnel	9.922	5.861	0.813	16.596	16.566	16.800
	Supplies and services	3.881	5.427	1.044	10.352	8.696	9.200
	Collaboration/ Partnerships	0.922	3.831	0.835	5.588	5.700	5.800
	Operational Travel	0.719	1.197	0.119	2.035	2.000	2.100
	Depreciation	0.822	0.096	0.071	0.989	1.100	1.200
	Total	16.266	16.412	2.882	35.560	34.062	35.100