Improving Rural Livelihoods:

CIAT's Medium-Term Plan 2007-2009

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CIAT MEDIUM-TERM PLAN

CONTEXT AND PROGRAM DISCUSSION

During 2006 CIAT is undergoing a set of programmatic, organizational and financial transitions that will ultimately result in a substantial recasting in the implementation of the Medium Term Plan 2007-2009, introducing change beyond the scope of what can be detailed at this time. Consequently, this document reflects ongoing, as yet incomplete transitions. Although this MTP displays some significant changes for 2007 that were not foreseen in the MTP 2006-2008, it is being delivered to the Science Council and CGIAR members at a time when the full scope of changes for 2007-2009 have not been thoroughly worked out. This MTP should be read as an interim document that takes into account the base from which changes are being made; describes some changes already being implemented; and points to some of the future directions of change.

CIAT continues to operate broadly within the scope of the Strategic Plan 2001-2010 which aimed at promoting sustainable rural livelihoods through research partnerships to generate knowledge and technologies that can help the rural poor in the tropics attain three critical conditions of competitive agriculture; agroecosystem health; and the capacity for innovation. Within this framework, however, CIAT is being reshaped to enhance integration and focus in its research.

Principal driving forces in this continuing process of fundamental reform at CIAT include the recommendations of Center Commissioned External Reviews (CCERs) in May 2006 and significant financial pressures despite maintenance of a consistent total income.

***General CCER Findings*:** In the period May 8- May 19 four simultaneous separate but parallel CCERs were conducted. The review panels assessed the three major program areas of CIAT, what we call our Research for Development Challenges: Sharing the Benefits of Agro-biodiversity; Enabling Rural Innovation and Integrated Management of Agro-ecosystems in the Tropics; as well as the governance and management of the center.

With few exceptions, the panels found the quality of the staff and of the research at CIAT to be high. The major substantive recommendations were: to more tightly focus the research program; to attain greater integration of that program; and to improve lines of authority and responsibility.

They also noted that CIAT's trademark is the capacity to integrate biophysical and social sciences in problem-solving research teams. They found that as a result of the quest for special project funding, made urgent by reductions in unrestricted funding, there has been a plethora of small disciplinary projects, which run counter to our comparative advantage. Consequently, one of the panels recommended that Enabling Rural Innovation be subsumed within Agro ecosystem management to create a single People and Agro-Ecosystem Management Research for Development Challenge.

The Sharing the Benefits of Agrobiodiversity review panel recommended that we conceptualize these in terms of well defined international public goods products (intellectual and technological) and organize the product teams and the partners that are necessary to achieve these, with well defined targets and milestones. They saw that this approach is working well in our implementation of both the Harvest Plus and Generation Challenge Programs and recommended it as an effective model across all of our program. The particular benefits that we see of using this approach is that scientists and projects can focus on time-bound outputs, with project planning over discrete periods rather than having open-ended projects. With regard to effective management of staff inputs the product approach will allow us to reconstitute and dissolve teams as appropriate. This will allow us to maintain more flexibility and dynamism in our research while keeping focus on outputs.

Altogether, the four CCER panels made over 60 specific recommendations. These are now being analyzed in detail and a formal response to each recommendation will be forthcoming shortly. In the interim the BOT and Management have begun to implement programmatic and organizational change guided by two main principles:

1. Greater integration across disciplines around common goals.
2. Increased focus on the delivery of clearly identified products or outcomes.

***Financial Developments*:** There has been a convergence of financial pressures on CIAT that require us to make important adjustments. The principal forces that have come to bear on our financial outlook include:

- Our core funding is well below the system average as a proportion of the total. A gradual decline over the last ten years was accentuated by significant reductions from two core donors in 2005.
- The drastically different composition of our overall funding, which has seen restricted project income more than double.
- High volatility in the local currency, combined with the extended devaluation of the dollar causing a jump in operating expenses at headquarters in Cali.
- Continuing lower-than-optimum levels of reserves, which might otherwise have permitted the Center to continue on the more measured pace of change we set out upon.

Ongoing declines in unrestricted funding in 2005 coupled with unfavorable exchange rate movements and an unanticipated rise in unrestricted expenditures have resulted in an estimated 2005 deficit of $0.89 million, drawing down reserves down to $5.17 million by the beginning of 2006. This is clearly not a sustainable operating basis. Thus, several important steps for financial management 2006-2009 are being implemented as part of new Business Plan approved by the Board of Trustees (BOT) in February 2006:

- Implementing longer term staff reductions and strategic program cuts in a manner which maintains our commitment to CIAT's organizational culture of openness and social justice. Immediate strategic reductions in expenditures in

unrestricted funded projects and in support/administrative services with an initial target of $3.45 million in 2006 was undertaken in February. Coming out of the BOT meeting in May 2006, this target has been effectively raised to $4.0 million in expenditure cuts for 2006.

- Renegotiating cost recovery with donors of existing restricted projects. Some have already consented to this, and we are extremely grateful to them.

- Implementing procedures for new proposal development to ensure full cost recovery and align contract funding more closely with core agenda.

- Promoting further growth in restricted contract funding and seek continued stability in unrestricted funding.

- Overhauling internal budget processes to improve indirect cost recovery and direct charges for services to restricted contracts

- Enhancing budgeting practices to mitigate exchange rate risk and improve overall performance.

- Building up financial reserves to CGIAR standards by 2009

***Programmatic Changes 2006*:** This MTP is designed to continue the implementation of the Strategic Plan 2001-2010, with, as noted above, a reduction in some activities, reflecting $4.0 expenditure reductions in 2006. Two projects, Communities & Watersheds and Information & Communications for Rural Communities will be phased out during 2006, and only a few selected elements from these projects will continue in 2007. Some research, such as the hydrology work of Communities and Watersheds, will be integrated into the Spatial and Economic Analysis for Policy and Decision Support project - which also leads CIAT's involvement in the Water for Food Challenge program. Other previously planned outputs from this project will not be realized unless additional special project funding is obtained. Similarly, the market information and some community learning elements of InforCom will be absorbed by the Agro Enterprise project, otherwise the realization of the outputs of the project Information and Communications for Rural Communities (SN4) is fully dependent on obtaining additional restricted resources, in the absence of which the previously planned future outputs will not materialize.

Second, it is planned that the core strategy of research on the genetic improvement of beans and cassava, including ancillary activities in genetic resources and biotechnology, will not be fundamentally changed, although the pace at which some research is implemented may be moderated. Unrestricted investment in rice and forages research will be reduced by about one-third each. It is expected that these will remain strong programs, but that funding will increasingly come from Latin American countries and user associations. CIAT's work on forages and animal nutrition has become truly global,

in close collaboration with ILRI, CIAT sees a tremendous potential for impact in Africa through adaptation of forage varieties and management knowledge from Latin America.

Third, in the absence of the identification of additional restricted resources, research on soils in Latin America will be largely phased out, and most of the future research outputs foreseen in the MTP 2006-08 for the project PE2 in Latin America will not be realized. When the budget allows it in future, we will give priority to appointing a scientist at post-doctoral level to provide the necessary soils expertise essential to support land management projects in Latin America. Outputs of Tropical Soils Biology Fertility in Africa will go ahead as planned.

Fourth, some partnership activities with Colombia, GFAR and the French research system are being discontinued. These reductions will not directly reduce research outputs as they were principally of an institutional strengthening or partnership nature.

***Future Directions*:** The strength of CIAT's research lies in its interdisciplinary nature. Even the simple case of varietal development requires inputs of many disciplines, as demonstrated through the strong legacy of participatory breeding. CIAT must strive for an environment that facilitates and enables truly interdisciplinary research, not just multidisciplinary (parallel) research.

To achieve the required focus and greater integration CIAT will evolve from a multi-project based organization into a targeted, product-based organization. These products will range from improved germplasm to integrated management systems. All products will be developed and tested together with the target groups and development stakeholders.

The BOT, the Staff and the Management all feel that by concentrating on fewer, well selected, areas of high potential benefit to the poor in the tropics, CIAT will achieve fresh vigor and greater impact. In our experience, research focus on a well defined development outcome is indeed one of the best ways of inducing effective interdisciplinary integration. Both the BOT and management feel this is a good approach for achieving the desired focus and integration within the program. Thus, we will embark on a rapid participatory process with staff and partners to identify, screen and decide on a limited number of "Products" using the MDGs, the Science Council Priorities and our special competencies as the main selection criteria.

Some of these will be straightforward and rather obvious. We would, for example, certainly maintain improved beans, cassava, forages and rice as four of our product lines within which we are already focusing on stress resistance, improved nutritional quality and increased productivity. Others will be more complex, such as the development of policies, institutions and technologies that lead markets, especially for high value products, to benefit the poor. While making that selection during 2006, we will continue to be organized in our current structure, less the projects that have been cut. Our aim is to have identified the products, developed the research plans and organized the research teams for each by the end of this year for full implementation in 2007.

Scientists will belong to 'communities of practice' which represent their skills sets. Particularly the social scientists need to become embedded within the interdisciplinary projects, not an isolated group. For this reason we are placing the Rural Innovation Research for Development Challenge under the Agroecosystems RDC to create a new People and Agroecosystems Research for Development Challenge. Rural Innovation will remain as a community of practice to provide external visibility of the strong emphasis on social sciences within CIAT, but staff will answer to their individual 'product development' teams. In cases where scientists rely on particular access to equipment (molecular biology, spatial analysis) they may be located together, otherwise disciplines should be grouped around the product foci. Thus, as is already the case, an economist or anthropologist etc. may work principally within one of the commodity groups.

As indicated above, the major work of CIAT scientists will be organized into two Research for development Challenges: "Sharing the Benefits of Agrobiodiversity" and "People and Agroecosystems". Each of these RDCs, will be headed by a RDC Team Leader whose responsibilities include integration within the RDC and between the RDCs and the regions. Reporting to the RDCs will be Product Team Leaders who will be responsible for both the leadership of research and the financial leadership of the projects they are managing. RDC Team Leaders will report to the DDG for Research.

Where possible staff will be redeployed from headquarters to strengthen key research product activities in each of the three regions, Central America, Africa and SE Asia. Regional Coordinators will become Regional Research Leaders, charged with the integration of activities around regionally-focused products. Their role will be gluing together the different 'product-development' activities and issues around a coherent vision at global scale.

2005 RESEARCH HIGHLIGHTS

CONSERVATION AND USE OF TROPICAL GENETIC RESOURCES

Race structure in common beans determined with microsatellite markers

The microsatellite markers we have developed at CIAT have given us the opportunity to dissect genetic diversity in common bean on a larger scale and to a finer degree than has ever been possible before. The most polymorphic and reliable SSR loci have been identified based on a micro core of 44 CIAT parents and evaluation of 150 microsatellite markers. A manuscript was prepared on the discrimination power and allelic diversity values for all these microsatellite markers and ws accepted in Theoretical and Applied Genetics. The research was the basis for marker selection in additional diversity studies carried out or finished during the year. Two notable studies that were part of MSc degrees at the Univ. Nacional extended the evaluation of the loci by testing the reliability of 30 to 50 microsatellite markers in detecting race structure in common beans. In these studies, a total of 120 genotypes were selected to represent the three races present in each of the gene pools of common bean (Andean and Mesoamerican) and race structure analysis showed that commercial seed class was a good predictor of race structure and was better than morphological differences at distinguishing races. As a result the principal divisions in common bean can be described as Durango-Jalisco, Mesoamerica, Nueva Granada and Peru. Races Chile and Guatemala appear to be admixtures of new alleles perhaps from wild bean introgression. Another interesting result was the finding that for microsatellite markers, allelic diversity is higher in the Andean gene pool than in the Mesoamerican gene pool, a reversal from previous studies with other types of markers which will allow the use of microsatellites to a greater degree to investigate trait inheritance in the Andean gene pool. In parallel with the work on race structure, we are analyzing data for the microsatellite evaluations of the Andean and Mesoamerican core collections (350 genotypes each) and the national or CIAT collections for Bolivia, Brazil, China, Colombia and Cuba which were conducted as part of the Generation Challenge Program. A publication on the Colombian collection has been published and a mansucript has been prepared for the Mesoamerican races. We hope to use this information for association mapping studies and to guide evaluation of other national collections especially in secondary centers of diversity such as Africa and Asia.

New genetic markers for marker assisted selection of common beans at CIAT

Marker assisted selection is a priority in the bean breeding program because of the large number of segregants screened and the diverse array of biotic and abiotic limitations being tackled. Until recently, all marker assisted selection in common beans was done with SCAR markers. In this year's annual report we describe the development of CAPS (Cleaved Amplified Polymorphic Sequence) markers for *Apion godmani* resistance and the screening of microsatellites for selecting geminivirus resistance genes. In addition we evaluated COS (Conserved Orthologous Sequence) markers for use in mapping of drought QTLs. This builds on experience with low phosphorus tolerance which is a trait we have completed a series of QTL studies for and which have been published in three

consecutive articles in Plant and Soil, Journal of Functional Biology (2004) and Crop Science (2005). While diversifying the types of markers in use at CIAT, we continue to validate SCAR markers in practical, real-life plant breeding situations. Notable for this year, was the collaboration with Univ. Nacional where we have introgressed the *bc*-3 resistance gene for BCMV and the *Co-4*^{2} and *Co-5* resistance genes for anthracnose into large red seeded climbing beans for the Colombian market. The combination of markers was found to work well for climbing beans especially for a shuttle breeding program between CIAT and Univ. Nacional that is part of a Colciencias funded project. In this project, marker assisted selection and phenotypic screening in both field and greenhouse sites is proving to be complementary and efficient. Two MS c students have been trained from the Univ. Nacional as part of this project and are forming part of a cadre of local practicioners of marker assisted selection both within the academic and public sectors building on work we did in the previous two years with CORPOICA.

Evaluation of nutritional quality traits in common bean

This year we report on methodologies we have developed for evaluating two anti-nutrients (tannins and phytates) in common beans from different commercial seed classes and among parents of QTL mapping populations. In the case of tannins we developed separate calibration curves for tannins isolated from each commercial seed class. We then applied the calibration curves to evaluate genotype x environment interaction of total, soluble and insoluble condensed tannins in Andean breeding lines grown at three locations in Colombia. While location effects were found, location x genotype interactions were not significant. Furthermore, genotypic differences in average total condensed seed coat tannins seemed not to be due to the genotype's seed color with red mottled and large red seeded varieties having similar variability for tannin. Fortunately breeding for higher minerals in the NUA high mineral Andean lines seems not to have increased tannin levels. This is important since these red mottled genotypes have been promoted and widely tested in Colombia, Bolivia and Eastern and Southern Africa. The NUA lines are also the basis for a bioefficacy trial with Univ. del Valle where they will be given to pre-school children in a feeding program in Cali. As part of this project we have increased the amount of NUA seed to approximately 1 ton of grain both for distribution and for the feeding trial. In terms of seed phytates evaluated for a set of mapping parents grown under high, medium and low soil phosphorus, the highest accumulating genotypes were the P inefficient genotypes such s DOR364, while the lowest phytate content were found in seed of the P efficient genotypes G2333 and G19839. This has been observed previously in studies of low P tolerance where under low P conditions efficient genotypes produce a larger amount of grain for a given amount of soil P. In this study the same genotypic differentiation was observed under both medium, high and even low soil P levels, especially for the genotype DOR364, although interestingly G19839 had higher phytate content in the medium P than in high P unlike G2333 that had higher phytate content in high P compared to the medium P treatment.

Our final goal with the tannin and phytate information is to better understand how to breed common bean for better nutritional quality. So far breeding has been with the goal of higher mineral accumulation (see this year' s annual report section on the development of the NUA lines) but in the future we may try to reduce anti-nutrient content. However,

the results presented this year indicate some of the difficulties that may be found with reduction of tannin or phytate levels.

Efficient protocol for isolation of microspores in cassava developed

Cassava is one of the most important calorie-carbohydrate sources in the tropics, adapted to a broad range of environments including tolerance to drought and acidic soils. This important staple food for subsistence farming is also becoming an important raw source for industrial applications worldwide. Cassava breeding is cumbersome and inefficient compared to other crops. Efficient breeding is needed to maintain cassava's competitiveness respect to other commodities. The inefficiency in cassava breeding is mainly due to its highly heterozygous nature and inbreeding depression affecting the selection of early generations of breeding materials in replicated field trials. The *in vitro* production of doubled haploids (DHs, homozygous) lines would serve as a baseline for the development of populations allowing the identification of valuable recessive traits and providing the opportunity for the incorporation of molecular tools. This project seeks the development of an *in vitro* protocol for the generation of doubled haploids from cultured anthers or microspores via androgenesis, establishing a suitable model system for different ecotypes of cassava. This initiative is being financed by the Rockefeller Foundation, New York, ZIL, Switzerland and CIAT. Results and detailed information are found in SB2 Reports from 2004 and 2005. Suitable genotypes for the development and standardization of a protocol to generate doubled haploids in cassava were identified after a pre-selection/ evaluation of 45 genotypes representing broad environmental adaptation according to the CIAT breeding program. One of the main bottlenecks affecting microspore culture in cassava was elucidated, which includes obtaining high yielding-homogenous microspore suspensions allowing culture at 10^5 cells/ml. A methodology for viability monitoring during microspore isolation and the standardization of protocols for selecting optimal plant donor and tissue within the plant were established. Low temperature has been proven to be a crucial factor for keeping viability of cassava microspores during the flower bud harvest and isolation process. Factors were identified allowing an effective flower bud shipment for collaboration abroad. Microspore separation using Percoll gradient 30-40-50% allowed a cleaner and better separation of microspores by size and developmental stages than a 50-60-70% gradient. Results corroborated last year results indicating putative cell divisions from pre-chilled tetrads cultured at 10^4 cell/ ml in B5 liquid medium at 26°C in the darkness. Histological analysis of cassava microsporogenesis was initiated in September 2005. Improvements of the protocols were introduced and information generated will be used to better design a reproducible responsive microspore culture protocol. Current work focuses on tailored conditions for culturing microspore suspension rich in selected type of stage of development. The progress attained and report herein is pioneer in the establishment of a reproducible protocol for the generation of doubled haploids in cassava.

Phyhylogenetic Patternsi n the Genus Manihot Mill. (Euphorbiaceae): Biogeography and Comparative Ecology of Mesoamerican and Southamerican Species

Evolutionary relationships among wild *Manihot* species are still uncertain. Current studies have emphasized on the origin of cassava (*Manihot esculenta* subsp. *esculenta*), one of the most important crops in tropical countries, without regarding the rest of

species. In order to quantify inter-specific genetic variability among wild *Manihot* species, and to establish a molecular phylogeny of the genus, three plastid (*accD-psaI* spacer, *trn*L-F spacer, and *trn*L intron), and three nuclear DNA regions (*G3pdh*, *CAM1*, and *CAM2*) were sequenced. *Cnidoscolus* was included as outgroup. Tree topology and geographical distribution of species were used to infer a biogeographic hypothesis of the genus. The age of the different nodes was estimated by means of a molecular clock calibration. Ecological data obtained from the last monograph of *Manihot*, was also used to infer the adaptation process of the species to their current habitats. Nuclear *G3pdh* was chosen to infer the evolutionary relationships of the species, due to the lack of variation of the chloroplast genome, the possibility of gene duplications in the *CAM1* region, and the positive effect of natural selection on the *CAM2* region. The phylogeny shows a Central American clade, sister to the South American species. The diversification of the last clade began in Brazil during the Pleistocene, followed by migration of species towards other parts of the South American continent. Glacial and interglacial periods could play an important role, modulating the adaptation to dry habitats. The predominance of shrub forms could occur early in the evolution of *Manihot* species, although a better sampling of species is needed.

Molecular marker-assisted selection (MAS) for the improvement of local cassava germplasm in Tanzania for pest and disease resistance

The low adoption of improved cassava genotypes coming from centralized breeding programs in many African countries have led to the proposal of a decentralized breeding scheme involving molecular marker-assisted selection (MAS) and participatory plant breeding (PPB), to accelerate the improvement of local, farmer preferred varieties for pest and disease resistance. Improved introductions of cassava from CIAT having resistance to the cassava mosaic disease (CMD) and the cassava green mite (CGM) were evaluated in the field and 80 genotypes selected. Simultaneously, 27 and 24 varieties were selected from local varieties collected from the Southern and Eastern zones respectively From the CIAT introductions and local varieties were established in a controlled and polycross crossing block at Chambezi experimental station situated about 60km North-west of Dar es Salaam. To date over 20,000 crosses have been made and at least 40,000 sexual seeds, assuming an average of 2 sexual seeds per cross, are expected. Pollination is still on going to achieve a target of 60,000 sexual seeds in total. The seeds will be planted in January 2006 and molecular markers will be used to identify disease and pest resistant genotypes for transfer to the single row trial stage.

Simple sequence marker (SSR) evaluation of global germplasm resources in cassava

Part of the activities of sub-programme 1 of the Generation Challenge Program (GCP) is the characterization of global crop genetic resources to define the genetic structure of germplasm collections as a first step to looking for new genes and alleles that contribute to solving the challenges of modern agriculture. A decision was made to analyze 3000 cassava accessions, 1500 accessions from CIAT's world germplasm collection, 1000 accessions from IITA's African collection and 500 accessions from EMBRAPA national cassava gene bank, with 36 SSR markers. Data analysis includes assessment of genetic structure using principal coordinate analysis (PCoA) and multidimensional scaling (MDS) based on individuals, cluster analysis based on country samples, and an estimation of genetic diversity and allelic richness. Results obtained so far are the SSR

characterization of 2,575 genotypes with 30 SSR markers. A cluster analysis based on country of origin reveal a clear separation between accessions from Africa and the rest of the world confirming findings from previous studies that shows that global cassava germplasm diversity is structured by region. Sources of this genetic differentiation could be selection for adaptation to agro-ecologies, particularly diseases. Other results include the identification of a separation of some accessions from Ghana, Nigeria and Central America. The source of the observed structure could be selection in the African accessions and introgression from wild relatives as well as independent domestication events for the Central American accessions.

Development of physiological and genomics technologies to trait gene discovery
The molecular biology section is focusing on three research areas which are 1) environmentally-friendly technology development; 2) abiotic stress tolerance; and 3) high value crops. The first area is directly related to the Nitrification Inhibition (NI) Project. IWe have started refining the bioassay system as part of a collaboration with JIRCAS in Japan to measure NI activity and the assay system is being used for screening Brachiaria and rice genotypes. A new NI project will be launched by JIRCAS from April, 2006 for 5 years and the planned activities in this project will enhance understanding of biological NI toward genetic improvement of this trait in Brachiaria and other crops in collaboration with JIRCAS.

The second research area is mainly related to drought/water saving technology. For the Generation CP and DREB project we lack expertise in crop physiology for drought, particularly in rice. Some efforts were made this year on this aspect and we will develop a more strategic plan to build the expertise at CIAT. We have made some progress on understanding physiological and molecular aspects of aluminum tolerance in *Brachiaria.*

With regard to high value crops, the main focus is the utilization of full-length cDNA clones for cassava genetic improvement which was developed in collaboration with RIKEN in Japan. About 20,000 cDNA clones will be sequenced by RIKEN by March and the resultant genomic resources can be shared by both institutes to identify trait gene(s) of interest. Discussion is underway to develop collaborative work between Asia (Thailand), Japan and CIAT.

Molecular analysis of a BC3F2 population from the cross Lemont x O. barthii
Wild rice species represents valuable genetic resources to broaden the genetic base of cultivated rice. Two rice samples collected in Salahondita, Pacific Coast and Santa Rosa, Villavicencio, Meta were shown to be a tetraploid species (CCDD) belonging to *O.latifolia*. After several backcrosses to O.sativa, it was possible to recover fertile plants having introgressed traits from the wild progenitor; some plants presented additional chromosomes. These hybrid plants represent a very valuable genetic resource for genetic and breeding purposes. The presence of bivalents at diakinesis in F1 plants could be indications of recombination between genomes of different species. Chromosome behavior was abnormal in F1, BC2 and BC3 progenies, which causes high plant sterility. Polymorphic markers were identified which could be used to assess introgressions from the wild progenitor. Preliminary results showed that *O.latifolia* is resistant to rice blast,

rice hoja blanca virus and *Tagosodes oryzicola*. This finding has very important positive implications for our breeding program since new alleles become available for further breeding work.

In vitro Propagation and Regeneration of Solanum quitoense (Lulo) Plants and their Use as Elite Clones by Resource Farmers

A four year project (2001-2005) on the development of *in vitro* approaches for lulo funded by the Colombian Ministry of Agriculture and CIAT was accomplished. The objective of this work was to develop *in vitro* protocols that facilitate *(a)* the conservation of germplasm*, (b)* the multiplication and distribution of healthy elite clones selected by farmers, *(c)* the evaluation of *in vitro* propagated plants vs. sexual seeds propagated plants in farmer's fields and *d)* the high efficient plant regeneration as a first step for setting the basis and development of gene transfer technology to this tropical fruit species. *Solanum quitoense,* also known as lulo in Colombia and naranjilla in other countries, has great potential to become a premium product for local and export markets.

Recently, lulo evolved from being a fruit for local fresh consumption to become an industrial high value crop as ingredient of juices, yogurt, flavoring and processed food increasing its market value. Various diseases and pests affect its production, and plant breeding is at a young stage. A major constraint for the rapid adoption of lulo by the local farmers is the limited availability of elite clonally propagated germplasm free of pathogens. Rapid clonal multiplication of high-quality planting materials is of paramount importance to obtain uniform elite plants. Genetic transformation could also facilitate splicing in genes for traits of interest. Results showed (detailed information are found in SB2 Reports from 2001 to 2005) the establishment of an efficient, reproducible true type *in vitro* propagation protocol of elite clones and field grown clones selected by farmers. It was also demonstrated a stepwise progress for the scale up use of the technology from the laboratory to the greenhouse, small scale experimental field to larger scale farmers field.

With the participation of farmers a process was initiated to evaluate the advantages/ disadvantages of using *in vitro* propagated plants as planting materials to establish new crops. Thousand of *in vitro* propagated lulo plants were generated from selected commercial clones by experienced resource farmers and evaluated in the field using participatory research approaches in two commercial zones in Colombia (Pescador, Cauca, and Tierradentro, Huila) with the aim of comparing in the field the performance of the *in vitro* plants with those conventionally propagated materials through seeds. The potential advantage of the *in vitro* source is the supply of pathogen-free, homogenous plants, maintaining the selected traits of the elite materials. According to the farmers, the *in vitro* generated plants showed higher vigor, earlier development and rooting respect to seed propagated plants, which was corroborated by the statistical analyses. *In vitro* propagated plants flowered and fructified earlier than seed-derived plants. It was also found that one of the *in vitro* material derived from a selected in Cauca (clone JY-E1) showed the highest productivity. This clone was selected by farmers from Tierradentro-Cauca and then was evaluated in a different location (Pescador-Cauca). This project had set a pilot experience that now with funding from the Ministry of Agriculture competitive grant is allowing expanding these findings to other lulo growing regions in Colombia

including Valle del Cauca, Caldas and Risaralda, as well as germplasm exchange between farmers from different regions and a vehicle to canalized advanced breeding lulo material from Corpoica. It is also giving the ground for a regional new initiative under formulation seeking funding from Fontagro that includes Ecuador.

BEAN IMPROVEMENT FOR THE TROPICS

Breeding for higher mineral content in combination with agronomic traits

Improvement of nutritional quality must go hand in hand with improvement of agronomic characters. Data from 2005 in Mesoamerican bush beans demonstrate an ample advantage over checks in drought tolerance (200% or more yield under very difficult conditions!) while increasing iron concentration by about 20% in several lines. Black beans with higher minerals and drought tolerance were also resistant to angular leaf spot and BGYMV. While increases attained in minerals were real, this was still a relatively modest gain. Thus, in the next cycle of crosses, more care was taken to obtain mineral data on $F_{1.3}$ families across sites before making individual plant selections. Compared to the first cycle selections, this group expressed much better gain in iron and zinc (as much as 50 and 30% respectively), suggesting that the modifications in the selection procedure were effective for recovery of higher minerals. In small seeded heat tolerant climbers, derived from popular African cultivars G2333 and G685 and tested across sites, the range in seed iron content was from 36 ppm to 104 ppm for iron content with averages of 63 ppm for Palmira and 56 for Darien. These materials will undoubtedly be very popular in mid-to-low altitude production areas in Africa.

***Development of molecular markers for resistance to* Apion godmani**

The bean pod weevil (*Apion godmani*) is a serious pest of bean in Mexico and Central America. Resistance exists in Mexican landraces selected in past years. However, attack will vary from year to year, making breeding for resistance unpredictable. Efforts to identify molecular markers for resistance were initiated as long as ten years ago, but were hindered by small population size, erratic phenotypic data and lack of adequate markers. Continuing efforts to overcome these limitations, in collaboration with the Mexican national program, have resulted in the first reliable markers. A total of nine RAPD bands that were significantly associated with resistance were selected for cloning. Fifteen primer sets were designed for the nine RAPD bands and were tested on a segregating population through bulk segregant analysis and as a segregating population. Most of the PCR products were monomorphic as SCARs but a single SCAR (W6800R) showed a polymorphic fragment with clear positive and negative signals in PCR amplification. All monomorphic SCARs were tested with frequently-cutting (4 bp recognition sites) restriction enzymes, revealing CAPs polymorphisms for four of the PCR fragments. The molecular markers were mapped to loci on chromosomes 2, 3, 4 and 6 (linkage groups b01, b08, b07and b11, respectively). In single point regression analysis, individual markers explained from 3.5 to 22.5% of the variance for the resistance trait with the most significant markers mapping to chromosome 2 (b01). Two additional significant markers were mapped to chromosome 6 (b11) and explained from 4.3 to 10.2% of variance depending on the season. There may be additional resistance genes on chromosome 4

(b07) and chromosome 3 (b08). These are among the first specific markers developed for tagging insect resistance in common bean and are expected to facilitate breeding for resistance to *A. godmani*.

An integrated approach to control of* Pythium *root rot

A participatory rural appraisal was carried out in two major bean producing areas in Uganda. Diseases emerged as the most important constraint to production, with root rots clearly being the most important disease. *Pythium* is the major root rot pathogen but can occur in combination with *Fusarium spp.* or *Rhizoctonia solani.* Bean is grown in an intensive agricultural system together with sorghum, maize, sweet potatoes, Irish potatoes, bananas and peas. A study was carried out to determine the role of other crops in the disease problem. Pythium isolates significantly affected the level of disease on CAL 96, sorghum and peas, suggesting that these two latter crops could play a role in root rot. Therefore in developing management strategies for root rots, it would be advantageous to consider a systems' approach rather than a commodity approach. The effects of four root rot management options i.e. farmyard manure (FYM), green manure (GM-*Crotalaria)*, NPK fertilizer and a fungicide (Ridomil) previously known to have useful effects against bean root rots were evaluated on sorghum, maize, peas and beans. The amendments decreased root rot severity and improved early season crop tolerance, crop survival, and dry matter relative to the control. Ridomil apparently gave protection against *Pythium* species. Plant recovery was evident in plots amended with GM, FYM and NPK. The potential of biocontrol was explored. Isolates of *P. ultimum* and of *Mortierella* were screened against each other for their potential use as biocontrol agents. *Mortierella* markedly reduced disease severity when added as antagonist to the pathogenic *Pythium*.

Finally, a backcrossing program to transfer resistance into popular market class types (backgrounds) was initiated in 2004. Twenty backcross populations were generated. Currently $BC_{s5}F_3$GLP2 x RWR 719 with 111 progenies have been given to partners in Kakamega (Kenya) and were also planted in Kawanda for seed multiplication. A molecular marker for a resistance gene was identified at CIAT headquarters. This is the first report of tagging and developing a SCAR marker for a *Pythium* resistance gene in common bean.

Expanding the use and impact of Participatory Plant Breeding

A Participatory Plant Breeding (PPB) Monitoring tour involving 14 NARs scientists from eight countries was conducted in May 2005, and highlighted salient trends and accomplishments of the bean networks in the field of PPB. Over 50% of the plant breeders in the ECABREN and SABRN networks are employing participatory approaches in variety selection and breeding (27 scientists out of a total of 53). In the last three years, the bean networks have made important gains in learning how to get PPB-selected varieties released through the formal system. Releases include: in Ethiopia, two by the Ethiopian Agricultural Research Organization (EARO) in 2003 with 3 in the pipeline; and two in work led by the Southern Agricultural Research Institute (SARI) at Awassa in 2002 and 2 others recommended for region-specific use. In northern Tanzania, the Selian Agricultural Research Institute (SARI) anticipates multi-release of nine

materials in 2006. Two varieties identified by the community of Bukoba in Southern-west Uganda, working with the National Agricultural Research Organization (NARO) have now been released. Selection criteria of different users groups (women/men, more market-oriented/home consumption) are well understood across a range of agro-ecological zones and such preference information is feeding back to fine-tune formal breeding programs. While yield and disease resistance remain among the key decision-making criteria, three others stand out across sites: *Early maturity* (linked to both drought escape and to 'filling the hunger gap") is perhaps first priority (above absolute yield) in moisture-stressed regions; *marketability* (for both domestic and export concerns) increasingly proves key, even for the poorest; and *cooking time* (as well as *taste*) have risen in importance as rural farmers move to supply town/urban markets, and as fuelwood becomes harder to access. In summary, the bean networks and ECABREN, in particular, are developing capacity to get farmer evaluations taken seriously as an input and even a determining factor in official release; and to move PPB varieties through formal systems.

IMPROVED CASSAVA FOR THE DEVELOPING WORLD

Cassava along with maize, sugarcane and rice, constitute the most important sources of energy in the diet of most tropical countries of the world. The globalization of the economies during the past decade made evident that tropical maize production is not competitive and opened a wide range of opportunities for cassava not available before. Therefore, in addition to the traditional food security role that cassava has played, there is an increasing interest in cassava as raw material for many different industrial uses. Currently cassava is undergoing a revolutionary expansion that has greatly diversified the objectives of the project. IP3 project has reacted to this opportunity developing products that can better fit the needs of the different industrial uses. In doing so, the reader may have the impression that the project targets too many objectives or that lacks focus. By and large, however, all the activities can be grouped targeting three large areas:

- Genetic improvement for higher and more stable production, including the development of high-value clones for the industry.
- Development and diffusion of adequate cultural practices for reduced impact in the environment and increased productivity.
- Research for more efficient or new processing methods for value addition.

High-protein in the roots traits confirmed.

During 2005 a breakthrough discovery confirming cassava clones with 2-3 times more crude protein in their roots (6-8%, dry weight basis compared with the typical 2-3%) was accepted for publication. High-protein cassava will increase income to farmers that will produce a value-added cassava for improved livestock nutrition and will also improve the diet of million of people for whom cassava is a daily staple food. Because of the low protein content of "normal" cassava, the feed industry can only pay for cassava roots 60-70% of the price of alternative sources of energy (typically maize) in the diets. High-protein cassava roots offer the advantage to the feed industry that their utilization may not

require changes in the formulation of diets nor additional source of proteins compared with maize. In many tropical countries, maize is currently imported from temperate regions. Therefore, it has become strategic for these countries to find local source(s) of energy for the feed industry. The high protein trait adds nutritional value to the root, increasing their value to the system, and making it more competitive. This, in turn, may increase the possibilities to compete with (imported) maize. This trait also offers an interesting possibility of collaboration between the feed industry with the animal nutrition and crop breeding research community.

Discovery of a mutant with waxy starch

For many years the cassava-breeding project at CIAT has gradually but consistently shifted its attention towards the production and/or identification of cassava clones with high-value for industrial uses. For the feed industry clones with increased nutritional value was a key target. The starch industry has requested persistently clones with altered starch properties in their roots. Acyanogenesis is an important trait for the processed food industry, and clones with molecules simpler than starch are now requested by the different initiatives that have been created to produce carburant ethanol and the bioplastics industry. The introduction of inbreeding in cassava was partially justified by the fact that it would facilitate the identification of clones with useful recessive traits. During the past few years hundreds of partially inbred plants were grown and evaluated in search of useful traits. During 2005 an S1 plant, grown at CIAT and harvested in early 2006, was found to have a modification of its starch with markedly reduced amylose content and a very distinctive amylogram (indicating differential pasting properties). The starch behaves as a typical waxy starch, one of the most common requests by the industry. This discovery, is very important not only because of its value-added characteristic (a waxy maize starch is about 30% more expensive than normal maize starch) but also because it proves the concept that inbreeding cassava will eventually allow for the identification of useful recessive traits.

Molecular markers for resistance to Cassava Mosaic Disease

Perhaps the single most limiting factor for cassava in Africa is the devastating Cassava Mosaic Disease (CMD). The disease is not present in the Americas and a related pathogen affects cassava grown in India. The absence of CMD in the Americas prevents CIAT's ability to breed for resistance to the disease. The biotypes of the vector that occur in the Americas *Bemisia tabaci* (a white fly) do not readily feed on cassava. However, recent discoveries suggest that this may change prompting the cassava breeding projects to develop a pre-emptive measure should the disease be accidentally introduced into the americas. The only feasible approach to do that is through the use of marker assisted selection using molecular markers developed at CIAT. During the past 3 years CIAT has been selecting for resistance to CMD using markers linked to a CMD resistance gene. Evaluations at 6 and 9 months after planting (in Tanzania and Nigeria) of 503 genotypes bred at CIAT for CMD resistance revealed 224 genotypes with no visible foliar symptoms for CMD and176 genotypes that did not show any visible foliar symptoms for CMD and cassava green mite. The large number of susceptible clones that had been selected with markers for resistance to CMD conferred by the *CMD2* gene was, however, unexpected. Further analysis of the results by family revealed that families with over 90%

of genotypes susceptible, had as a source of resistance, the parent C127. These results suggest that the C127 parent (one of the 17 F_1 progenies of TME3, the source of *CMD2)*, is a susceptible genotype. When families having this parent were removed from the analysis, the percentage of resistant genotypes was 70%, which is the expected percentage, given that *CMD2* controls 70% of CMD resistance. These results provide an excellent example of the usefulness of marker assisted selection and provide an ideal strategy to build up resistance to the disease in cassava germplasm adapted to the Americas.

Further progress in understanding frog skin disease

Cassava frog skin disease (CFSD) remains a frustrating problem for cassava research in Colombia. The diseases causal organism has not been definitively identified, nor its vector agent. The only protocol for the certification that a plant is disease free is through grafting into the indicator genotype *Secondina*. This is, however, a cumbersome procedure that needs about four months to provide results. Therefore the only practical procedure is to rely on the symptoms, which express (frequently) only in the roots. In spite of the measures taken at CIAT based on the elimination of any plant showing symptoms in the roots and the imposition that no vegetative cuttings will be taken if the roots of the plant have not been first analyzed to make sure they are symptoms-free, the incidence of the disease cannot be adequately reduced. During the past year increasing evidence of the association between CFSD and a phytoplasm was provided. It has not been determinate that the phytoplasm induces CFSD but results are very promising for such an elusive disease. Significant progress was also achieved in reducing the list of candidate vectors that may be involved in the disease. It has been decided, that *Scaphytopius marginelineatus* and *Peregrinus maidis* are prime candidates as vectors of CFSD

Evolution of B. tabaci to adapt feeding in cassava

During the year a scientific article demonstrating the adaptation of *Bemisia tabaci, Biotype B. (Grennadius)* to cassava, was published. This is a very interesting study where CIAT scientists could gradually adapt insect populations to feed first on an intermediate plant species and then to cassava. Perhaps it is the first scientific evidence of such adaptation directed by mankind that could be liked to the evolutive potential of a pest from one host (beans) to another unrelated plant host (cassava). The importance of this research relies on the possibility of the insect (vector and perhaps the "builder" of viruses such as cassava mosaic disease) to quickly adapt to cassava as has already been reported to occasionally occur and in, more general terms, the power of nature or artificial selection to promote this change.

IMPROVED RICE FOR LATIN AMERICA AND THE CARIBBEAN

Enhanced gene pools

Broadening the genetic base of irrigated rice in Latin America.

Rapid population growth in Latin America and the Caribbean (LAC) is putting increasing pressure on the already strained food-producing resources of these regions. On the other hand, the domestication process, artificial selection, and intensive breeding of crop varieties by man narrowed down the genetic base in many crops, problem that is more critical in self-pollinating crops like rice. This reduced genetic variation renders modern crop varieties more vulnerable to biotic and abiotic stresses, and could explain the already observed slower rate of genetic progress achieved by plant breeding programs in several important food crops, including rice.

Different approaches are being implemented by the Rice Project in collaboration with the CIAT Biotechnology Research Unit, FLAR and National Rice Programs to address this issue, including the utilization of wild rice species, population improvement gene technologies, and the introgression of the IRRI new plant type into the Latin American gene pool.

Data presented in previous annual reports shows that we have been successful in transferring traits of agronomic importance from *O.rufipogon, O.glaberrima* and *O. barthii* to improved varieties and elite breeding lines; thus bases for further improvement in yield potential and tolerance to main biotic and abiotic stresses are in place. The first step in this strategy was the introgression of genes of interest into cultivated rice through several backcrosses to the improved parent and selection of best lines under high disease pressure. The second step was to cross selected interspecific lines with different elite lines or varieties to allow further recombination of desirable traits. In 2005 several promising lines originated from crosses such as Perla 2/*O.rufipogon*, Bg90-2/*O.glaberrima* // Fedearroz 50, and Lemont/*O.barthii* / /WC were identified and selected. These lines showed high yield potential, and improved grain quality and tolerance to main diseases. Seed of them was increased for distribution to NARs and partners in 2006.

On the other hand, advanced lines derived through recurrent selection method from the PCT-6 population were identified and seed increased. This population was developed for irrigated conditions and selected for several years under high disease pressure in Santa Rosa and for yield potential in Palmira. Selected lines showed high yield potential, good grain quality and tolerance to main diseases and will be distributed to NARs and partners in 2006. Finally advanced lines derived from crosses between the IRRI new plant type and elite lines from our breeding program were also identified for distribution to NARs.

Identification and Molecular Characterization of Two Wild Rice Accessions Collected in Colombia

Wild relatives of rice were collected in Salahondita (Patia river, near Tumaco, Nariño) and Santa Rosa, Villavicencio, Meta and were shown to be *O. latifolia* a tetraploid species (CCDD). After several backcrosses to *O. sativa*, it was possible to recover fertile plants having introgressed traits from the wild progenitor. In some plants these introgressed traits could be the consequence of additional chromosomes. These hybrid plants represent a very valuable genetic resource for genetic and breeding purposes. The presence of bivalents at diakinesis in F1 plants could be indications of recombination

between genomes of different species. Chromosome behavior was abnormal in F1, BC2 and BC3 progenies, and there was a high amount of plant sterility. Polymorphic markers were identified which were used to assess introgressions from the wild progenitor. Preliminary results showed that *O. latifolia* may be a potential source of resistance to rice blast, RHBV and *T. oryzicolus*.

Rice Composite Population Improvement

The CIRAD/CIAT rice collaborative project concentrates on broadening the genetic base of rice through composite population improvement using a recurrent selection combined with conventional breeding methods. Recurrent selection adds another methodology to develop improved varieties but is not intended to replace others breeding methods. Basic composite populations are developed, shared and enhanced with regional partners in Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Guatemala, Nicaragua and Venezuela. In Colombia, basic upland composite populations are enhanced using two recurrent selection-breeding methods: mass and S_2 progenies evaluation. At each step of enhancement, fertile plants are selected for the development of segregating lines and progeny selection using the conventional pedigree method. The most advanced upland lines are shared with LAC partners through the CIAT-ION nurseries and are locally screened and selected. The most promising lines are evaluated at countries' regional yield trials. The first upland rice commercial variety coming from population breeding will be released by Bolivia in January 2006. In addition, several candidate advanced lines are in the process of becoming varieties in different countries. The partners in these activities are members of the "Working Group on Advanced Rice Breeding" (GRUMEGA its Spanish acronym) which promotes collaboration in research, capacity building and the development of the rice sector.

Integrated crop, pest and disease management

Durable resistance to rice blast

Hot spot breeding for rice blast has led to the development of rice line/varieties that have more durable resistance to rice blast. The genetic basis of the high level of durable resistance to rice blast in the cultivar Oryzica Llanos 5 is being characterized in collaboration with Kansas State University in two Recombinant Inbred Lines (RILs) from a cross between the susceptible cultivar Fanny and O. Llanos 5. A linkage map was constructed using 250 molecular markers: SSR, RFLP and RGAs. Eleven loci, distributed on chromosomes 1, 2, 3, 4, 5, 6, 8, 9, 11, and 12, were associated with the resistance of the cultivar. As a whole, the observed durable resistance in Llanos 5 is the result of a combination of quantitative and qualitative resistance genes. Fedearroz 50 is a highly popular variety that was released in 1998 and it is grown on approximately 50% of the rice production area in Colombia. It is also being grown in Venezuela, Costa Rica and Panama. It has remained resistant to rice blast and it has similar combination of quantitative and qualitative resistance genes. A very comprehensive characterization of the rice blast pathotypes in terms of their avirulence/virulence diversity has allowed us to identify resistance gene combinations conferring durable blast resistance. A combination of three quantitative resistance genes was shown to confer stable resistance for 5 year under very high rice blast pressure.; these gene are now being incorporated into

commercially and widely grown varieties in LAC but that are susceptible to rice blast. We now have a much better understanding of what it takes for a rice plant to remain resistant to rice blast and the tools, including conventional methods and molecular markers to assist breeders in developing rice cultivars with these gene combinations. Already the work has had impact in lowering pesticide use and increasing yields in those varieties that have this complex durable resistance. These techniques have been transferred to our partners in the region for implementation in their local breeding programs.

Understanding the Genetics of Resistance to Rice Hoja Blanca Virus

Plant resistance to Rice Hoja Blanca Virus (RHBV) is a combination of resistance to the virus and to the planthopper vector *Tagosodes orizicolus*. Since the virus cannot be mechanically inoculated, it is difficult to separate the components that are most important for resistance to the virus. Crosses were made between Fedearroz 2000 X WC366 and this focuses on the resistance to the virus. Another cross was made between Fedearroz 50 X WC366 that focuses primarily on the resistance to the insect. The combination of the information learned from the genetic and molecular analysis of the segregating population will be used to understand the plant/vector/virus interaction. To date, several potential QTLs have been identified for resistance to RHBV and *T. orizicolus*. In both crosses the short arm of chromosome 4 has a significant association with resistance to RHBV. In this region, two candidate genes have been identified. One is a gene that is associated with resistance to the brown planthopper in Asia and the other is a gene involved in gene silencing which is a known mechanism of resistance to viruses. In addition, there is a QTL on chromosome 7 that has a very strong association with resistance to *T. orizicolus*. This association is only found in the cross of Fedearroz 50 with WC366. These associations are strong enough that micro-satellites used in this study could serve in a system of marker-aided selection for these traits. The development of Molecular Assisted Selection as a Breeding Tool is a priority for the CIAT rice project.

Scaling up analysis gene flow analysis from rice into weedy rice at landscape under farmers' commercial conditions

Red rice (*Oryza sativa* L.) is a weed that infests most rice growing areas throughout the world. This weed shows a high similarity with cultivated rice varieties in the early growth stages. It has a wide range of characteristics, including competitive ability, tillering capacity, flowering date, seed shattering and dormancy, pigmentation of several plant parts in particular of the pericarp that make it a problem that is difficult to control. The presence of red rice both reduces the yield and the millers reduce the price they pay based on the percentage of red rice in the harvested seed. The objective of this study is to assess the impact of specific traits on biodiversity (genetic structure of recipient population) due to gene flow over time at the landscape level in countries that harbor land races, weedy/wild species of these two crops. This information will be used to develop guidelines for environmental safety and co-existence of different types of agriculture systems in the Neotropics. In the case of rice, herbicides are used by farmers to control weedy rice. Herbicide resistant rice varieties had been released in several agroecosystems sympatric to natural environments that harbor native wild relatives of rice. This mutagenesis (not transgenic) derived herbicide resistance (imidazolinone resistance) had

been bred into elite local materials and released as improved varieties in Central America and Colombia. It is easy to trace herbicide resistance to evaluate the unintended transfer of traits deployed in the crop by cross-pollination to the sexually compatible weedy rice complex. The herbicide is used as a form of chemical control for positive selection in the rice fields, and the wild *Oryza* relatives found in natural environments in the crop contact zones act as the indicators of neutral selection. This model will give information on impact of resistance genes that may affect fitness of derived hybrids, invasiveness, population dynamics and genetic structure of the corresponding wild/weedy. This information is useful for *in situ* conservation of rice diversity. Protocols and methodologies using molecular markers will be established for assessing gene flow at landscape level (rate and direction) allowing comparison to those under controlled conditions.

Intensification and diversification of rice cropping systems for small farmers.

Participatory Rice Breeding: Building capacity and developing varieties for small upland rice producers

Rice is a crop mainly produced by small farmers, and in Latin America these farmers are facing many challenges. They tend to have the least amount of infrastructure and machinery and since most are upland rice farmers they are more dependent on rainfall. With the advent of the Central American Free Trade Agreement, these farmers must compete with subsidized rice. In 2002, the CIAT-CIRAD started participatory rice breeding in Nicaragua in collaboration with INTA. These activities involve local groups of expert-farmers and use appropriate participatory breeding approach and methods. Already many workshops, field days and courses have been held and this is helping to strength the local organizations. Through changes in cultural practices, these farmers are increasing their yields. At the same time, the farmers are involved in the process of evaluation and selection of rice lines that fit their needs and in the short span of this project several varieties are about to be released. These varieties are more adapted to the local cropping systems and have relevant characteristics, which include drought tolerance, high yield potential, adequate grain quality and they mature early. This last trait is important, because it allows the farmers more options on the date of planting, more likelihood of escape drought and options to rotate with a second crop, and this helps increase their income. With the reductions, the rice project will unite the participatory rice breeding activities in Output 1. This will lead to the elimination of Output 3 and insure greater integration of our breeding activities.

TROPICAL GRASSES AND LEGUMES

Grass and legume genotypes with high forage quality are developed

***Developed and tested a methodology to screen for forage quality of large number of Brachiaria hybrids using NIRS*:** Results from this year confirm that it is possible to detect with NIRS differences in crude protein (CP) and in vitro dry matter digestibility (IVDMD) among entries in a population of *Brachiaria* hybrids. Significant genetic

variation among hybrid clones was detected for both IVDMD and CP. Large variation among sampling dates was also detected. However, it is encouraging that despite the large effect of sampling date on both quality parameters, the interaction of genotype with sampling, while statistically significant, was less than that for genotypes. Hence, it appears that sampling field-grown plants even on only a single date should be effective in identifying *Brachiaria* genotypes that are superior for quality traits.

Grass and legume genotypes with known reaction to pests and diseases and to interaction with symbiont organisms are developed

***Selected apomictic and sexual Brachiaria hybrids with multiple resistance to spittlebug*:** We continued to make significant progress in incorporating resistance to spittlebug in the *Brachiaria* improvement program using a recurrent selection scheme. A series of replicated tests were carried out in 2005 to evaluate the resistance of *Brachiaria* genotypes to *Prosapia simulans* and to four major species of spittlebug present in Colombia (*A. varia*, *A. reducta, Z. carbonaria*, and *Mahanarva trifissa)*. A total of 6 (18%) apomictic hybrids were selected for having resistance to all 5 species of spittlebug. In addition, this year 565 new sexual hybrids were tested for resistance to three spittlebug species and results showed that 96%, 95% and 94% were rated as resistant to *A. varia*, *A. reducta*, and *Z. carbonaria*, respectively

Grass and legume genotypes with superior adaptation to edaphic and climatic constraints are developed

Developed a high-throughput method to screen Brachiaria hybrids for adaptation to low fertility acid soils: A hydroponic screening method using stem cuttings was developed to quantify two key traits associated with adaptation to acid-infertile soils: root vigor and Al resistance. Using the hydroponics screening method, 9 *Brachiaria* hybrids (out of a pre-selected population of 139 apomictic/sexual) were superior to *B. decumbens* cv Basilisk (parent in the breeding program and selected for superior adaptation to acid-infertile soils) in terms of root length in the presence of toxic level of Al. Among the 9 selected hybrids, one was superior to *B. decumbens* cv Basilisk in terms of fine root development (lower root diameter), which is an indication of superior adaptation to low nutrient availability in the soil.

Superior and diverse grasses and legumes delivered to NARS partners are evaluated and released

Expert system for targeting forages-Selection of Forages for the Tropics (SoFT) - was released: Forage research over the last 50 years has identified many tropical grasses and legumes that have a role in farming systems in developed and developing countries. Information on the adaptation and use of these species resides in peer-reviewed literature and research reports with limited distribution and, often most importantly, in the memories of forage agronomists with decades of experience of working with a wide range of forages in diverse farming systems. To address these deficiencies a knowledge system was developed for the identification of forages suitable for specified niches within smallholder farming systems in the tropics and subtropics. The main features of the data base are: a) information in fact sheets on the adaptation, uses and management of forage

species, cultivars and elite accessions, b) a selection tool built on LUCID™ that enables easy identification of best-bet species, c) bibliography of more than 6,000 references and abstracts on forage diversity, management and use which enable users with poor library facilities to access summaries of some of the key literature, d) global maps of climate adaptation for each species and e) a collection of photographs and images of species to help in their identification and use.

TROPICAL FRUITS

Tropical Fruits is under new management since June 2005. A transition phase has taken place during the second semestre of 2005, although main activities have not been affected.

Research highlights reported here align with outputs initially presented by previous management in the MTP 2005-2007, which were then reduced to two main outputs in the MTP 2006-2008.

- The Homologue ™ software was available for public distribution in Nov 05. Homologue arose from the need to search for regions with similar conditions to those found at one target point so that a question like "Where else in the world are there similar conditions"can be answered. Answering this question is critical when deciding what to grow where, and becomes a decision making tool to reduce the uncertainty of chosing a variety or species when either planting a new orchard, or in the process of diversification of agricultural systems. By building up several analyses of this sort one can construct a "Cloud" of probability showing all the places where a particular crop or variety could be expected to do well, based on a limited set of site experiences. (**Output 1**)
- Successful multiplication and distribution of healthy elite clones selected by farmers. Expectations of better performance of cloned materials successfully fulfilled in the field, which resulted in greater interest from lulo farmers to continue with further experimentation in their plots. The performance of *in vitro* propagated plants vs. sexual seed propagated plants in farmer's fields allowed farmers to recognize the benefits of clonal propagation, as farmers observed segregation of unwanted characteristics in seed propagated plants. (**Output 2**)
- An optimum direct plant regeneration procedure via organogenesis using petiole explants without sonication was established in lulo. This protocol is suitable for the development of gene transfer technologies for this species, and it becomes a platform for future development of *Agrobacterium*-mediated transformation protocols. (**Output 2**)
- Two projects seeking disease resistant clones in Lulo (*Solanum quitoense*) and avocado (*Persea americana*) to be implemented in 2006-2008 were funded as special projects. (**Output 2**)
- The Moko disease caused by *Ralstonia solanacearum* has been the focus of attention due to its devastating effect on the Plantain industry in Colombia. Research on this topic was commissioned to CIAT by the Colombian Ministery of

Agriculture (MADR). A BIO–PCR technique was developed for detecting *R. solanacearum*. This technique had increased sensitivity, and detected only live cells of the pathogen in soil and plant tissue. The first report of the pathogen's genetic diversity as determined by RAM analysis was presented. This analysis permitted identification of intra-subspecific groups of strains that have common biological properties, evolutionary relationships, or geographic origins. *Ralstonia solanacearum* DNA sequences were reported to GenBank.

- First occurrence of an emerging tomato strain of *R. solanacearum* race 1, a new pathotype that genetically clusters with plantain strains (race 2) was observed and reported. Greenhouse inoculation showed that the tomato strain was pathogenic to plantain, hence, bringing into question the practice of plantain–tomato rotations.

CROP AND AGROECOSYSTEM HEALTH MANAGEMENT

Pest and disease complexes described and analyzed

- Primers specific to 16 microsatellite loci were identified and developed in the bean anthracnose pathogen, *Colletotrichum lindemuthianum*, and the potential of these primers to distinguish between Andean and Mesoamerican groups and to provide information on the genetic structure of the pathogen were demonstrated.

- A multiplex PCR assay was developed for simultaneous detection of six pathogenic *Pythium* species and a potential biocontrol agent. Three markers linked in coupling to the *Pythium* root rot resistance gene in RWR 719 were identified. Two of these were turned into sequence characterized amplified region (SCAR) markers, and the potential use of these markers in marker assisted selection (MAS) was demonstrated. This is the first report of tagging and developing a SCAR marker for a *Pythium* resistance gene in common bean. Three major intercrops of beans i.e. maize, sorghum and peas, in the bean-based system of southwestern Uganda were affected by root rots implying that they may be hosts of the pathogens. Management options effective for bean root rots are also beneficial to other crops such as sorghum and field peas in bean based cropping system. Formulating management strategies for root rots need to consider a systems approach rather than a crop's approach. Furthermore, *Mortierella* sp (strain MS10) was shown to have antagonist effects to pathogenic *Pythium* isolates with marked reduction in disease severity in screen house studies offering potential as a biocontrol agent against *Pythium* root rot.

- The rice blast resistance genes present in 211 commercially grown Latin American rice cultivars were identified and nine groups of potential sources of complementary resistance genes were defined for their use in a breeding program aiming at developing commercial rice cultivars combining desired agronomic traits and blast resistance.

- Endophytic plant growth promoting bacteria (PGPB) were isolated from *Brachiaria* hybrid (CIAT 36062) and characterized. Introduction of these bacteria into the *Brachiaria* hybrid cv. Mulato (CIAT 36061) resulted in improved growth (more leaf, stem and root biomass) relative to the control (indigenous bacteria only). A specific primer was developed that was useful to detect endophytic bacteria associated with species of *Brachiaria* plants using one step PCR instead of nested PCR.

- Standardized protocols were developed for risk evaluations of genetically modified organisms (GMOs) on non-target soil organisms. No statistical differences were detected in abundance and diversity of soil organisms in conventional versus genetically modified cotton [Bollgard ® Bt Cry 1A ©] during the 2003-05 period in the Cauca Valley, Colombia.

- Random amplified microsatellites (RAMs) technique was employed to make an intraspecific and interspecific analysis of *Ralstonia solanacearum*, causal agent of bacterial wilt of Musaceae and of other plant species.

- Research was initiated on the molecular characterization of the anthracnose pathogen, *Colletotrichum* spp., infecting tree tomato, mango and lemon tahiti in Colombia.

Pest-and-disease management components and IPM strategies developed.

- Resistance to the bean weevil (*Acanthoscelides obtectus*) was identified in *Phaseolus vulgaris* x *P. acutifolius* hybrids. New accessions and lines with insect resistance were identified.

- Mulching with green manures increased bean yields of susceptible bean cultivars and this increase was associated with a reduction in root-rot incidence and increased soil nutrient availability.

- Several bean lines with multiple resistance to *Pythium* root rot and angular leaf spot (ALS) diseases have been selected and will be distributed to different countries for multi-locational evaluations. Some have already been distributed to Kenya and Malawi.

- Economic threshold of white grub species *phyllophaga menetriesi* on three crops (maize, cassava, and beans) was defined. methodology for mass rearing of white grub species was developed. a highly virulent strain of the bacterium *paenibacillus popilliae* and an entomoparasitic nematode, *heterorhabditis bacteriophora*, were identified for the control of the white grub *phyllophaga menetriesi*.

- Numerous sexual hybrids (SX03, SX05) of *Brachiaria* with high levels of antibiosis resistance to *Aeneolamia varia*, *A. reducta*, and *Zulia carbonaria* were

identified. High levels of antibiosis resistance to *A. varia*, *A. reducta* and *Z. carbonaria* were detected in 9 apomictic hybrids (series BR04) of species of *Brachiaria*. Furthermore, six apomictic hybrids of the MX02 series, selected for resistance to *Prosapia simulans*, also showed resistance to *A. varia*, *A. reducta, Z. carbonaria*, and *Mahanarva trifissa*. Another six apomictic hybrids of *Brachiaria* of the series BR02 and 11 of the series MX02 were identified as resistant to *A. varia*, *Z. carbonaria*, *Z. pubescens*, and *M. trifissa* under field conditions.

- Four *Brachiaria* hybrids showed high levels of resistance to *Rhizoctonia* foliar blight under field conditions that are comparable to the resistant accession (*B. brizantha* CIAT 16320). A transformation protocol was developed, for the first time, for the endophytic fungus *Acremonium implicatum* associated with species of *Brachiaria*. This endophyte contributes to disease resistance in its host plant.

- A biocidal protein identified from the tropical forage legume *Clitoria ternatea* was effective against diseases of tomato under field conditions. This protein, designated 'finotin', is a heat stable, highly basic small protein with a broad and potent antifungal, antibacterial and insecticidal properties.

- An emerging tomato strain of *Ralstonia solanacearum* race 1, a new pathotype that genetically clusters with plantain strains (race 2) was detected in Colombia. Greenhouse inoculations showed that the tomato strain was pathogenic to plantain, hence, bringing into question the use of plantain–tomato rotations.

NARS' capacity to design and execute IPM research and implementation, and applications of molecular tools for pathogen and pest detection, diagnosis, diversity studies as well as novel disease and pest management strategies strengthened.

- A collaborative mechanism has been set up to facilitate national partners to integrate application of marker assisted selection (MAS) in their breeding programs in Africa.

- Expanded diffusion of technology activities within the DFID-funded project on Sustainable Management of Whiteflies continued.

- Assistance in disease and pest diagnosis, development of molecular tools for rapid detection of pathogens provided to NARS in Africa and Latin America.

- Novel approaches with potential for promoting integrated pest and disease management (IPDM) technologies were evaluated at target project sites in Africa. Trained modified farmer field school (MFFS) groups were effective in knowledge sharing and dissemination of IPDM technologies. Cohesive and dynamic farmer research groups (FRGs, over 300 groups with more than 50,000 well trained farmers) have evolved at project sites in Uganda, Kenya, Tanzania and Malawi. Farmer to farmer knowledge sharing enhanced technology dissemination and adoption (60-85% adoption rate) in several countries in Africa. Farmers used

traditional (drama, songs, poems) and conventional (seminars, demonstration and learning plots, field days and visits, radio, promotional materials) pathways in technology dissemination. The process of learning by doing and seeing succeeded in using the psychology of development that helped to build farmers' confidence in the effectiveness of indigenous practices that they blended with improved IPDM technologies. The approach and processes used in the project (Evaluating novel / innovative approaches in scaling up integrated pest and disease management (IPDM) technologies) have helped to improve the skills of individual farmers and groups in the identification and management of production constraints (such as diseases, insect pests, soil fertility and markets), demand and search for information on solutions and new technologies. The practical sessions used in implementing IPDM project activities helped to empower men and women farmers in the management of their own resources.

- Eighteen (BSc), 18 (MSc), 7 (PhD) thesis students supervised in 2005.

- Integrated disease and pest management related courses and seminars were given to more than 1362 professionals and farmers from countries in Latin America and Africa.

- More than 312 visitors from various institutions visited the PE-1 project research programs, both at CIAT headquarters and in Africa.

- Fifteen staff members (both junior and senior staff) received awards for their research work.

- Forty-three refereed journal articles, 7 book/book chapters, 59 conference papers and 3 technical manuals and booklets were published. More than 11 articles have been written on some of our interesting research results in newspapers and other outlets.

Global IPM networks (Integrated Whitefly Management Technology) and knowledge systems developed.

- A book entitled "Whitefly and Whitefly-borne Viruses in the Tropics: Building a Knowledge Base for Global Action" was published.

- Important changes in whitefly species composition were detected in the Cauca Valley region of Colombia. These changes in whitefly species composition were accompanied by the emergence of new whitefly-borne viruses affecting snap bean, tomato, and pepper.

- Varying levels of resistance or susceptibility was detected to some of the insecticides commonly used for whitefly control in the Cauca Valley region of Colombia.

- The ovipositional rate (N_o. eggs/female) of the cassava whitefly *Aleurotrachelus socialis* on a given genotype is a good indication of the level of resistance in that genotype. Research results indicate that a relationship may exist between proteins in the cassava leaf and resistance to the whitefly, *Aleurotrachelus socialis*.

- Numerous resistant genotypes from interspecific crosses with *Manihot esculenta* and wild *Manihot* species were identified, indicating the possible presence of resistance to the whitefly *Aleurotrachelus socialis* in *M. flabellifolia*, *M. peruvians*, *M. tristis* and others.

- The high rate of survival and short generation time of the cassava whitefly, *Aleurotrachelus socialis*, feeding on the commercial variety Chirosa, explain its rapid population increase in cassava plantations.

TROPICAL SOIL BIOLOGY & FERTILITY (TSFB)

Advances in Conservation and Sustainable Management of Below-ground Biodiversity (CSM-BGBD) Project: The year 2005 was a major milestone for the CSM-BGBD project funded by Global Environmental Facility (GEF). It is the year when nearly all partners in the project met in a joint meeting in Brazil to present the results from the BGBD inventory they had carried out in their individual countries. Brazil, Cote d'Ivoire, India, Indonesia, Kenya, Mexico and Uganda were all represented by a minimum of five participants. Technical papers were presented covering: Benchmark area descriptions and socio-economic characterization, Inventory of soil macro-fauna, Inventory of nematodes and Meso-Fauna, The inventory of legume nodulating bacteria, arbuscular mycorrhizal fungi and ectomycorrhiza, The inventory of pathogenic and antagonistic fungi and insect pests, Presentation of the standard methods, Ecosystem service and soil quality indicators, Analysis of BGBD at landscape level and in different land use intensities, Output of economic valuation of BGBD for different soil functions and environmental services, Information management and data sharing in the project. The overall conclusion from the technical reviewers during the meeting was that the project had succeeded in agreeing on appropriate standard methods for most of the functional groups mandated and has used them to assemble a unique and comprehensive dataset. Apart form these technical observations; the project was subjected to a mid-term review and the reviewers of the project returned a final mid-term review rating of 'Good' for the project and recommended its continuation into the second phase that has been approved by the GEF.

Overcoming phosphorus (P) deficiency in West African farming systems through Hill Placement and improving phosphate rock (PR) efficiency: Work done by TSBF-CIAT and its partners for several years with funding from Rockefeller Foundation focusing on phosphorus (P) availability has resulted in technologies that are now being taken up by farmers. The focus on P was because it is the most limiting nutrient to cop productivity in West Africa and about 80% of the African soils have inadequate supply. The technologies include hill placement of small quantities of P. The work has shown that leguminous crops and cover crops in natural and managed fallows can take full advantage

of biological nitrogen fixation in the presence of adequate P levels in the soils. For several years, we have observed that the efficiency of Phosphate Rocks (PRK and PRT) can be increased above that of soluble P when a little amount of the soluble P is combined with the PR. Combining PR with 25% water-soluble P in has not shown any differences from its combination with 50%, 75% or 100% water soluble P. This clearly shows that placement of small quantities of water-soluble P fertilizers can improve the effectiveness of phosphate rock. To increase the impact of this outcome, Governments in West African Countries will require to invest more in bringing PR closer to the people or by facilitating this process to be carried out by entrepreneurs.

Knowledge of spatial and temporal dynamics of soil macrofauna in the Quesungual Agroforestry System allows improved soil biota management: The activities of soil animals such as earthworms, ants and termites can markedly influence soil structure, organic matter decomposition and nutrient cycling. In marginal environments, soil fauna can make an important contribution to soil quality and soil fertility. The steeplands of southern Lempira department in Honduras represent a typical marginal environment, where the traditional slash-and-burn agriculture has been gradually, and successfully, replaced with slash-and-mulch agroforestry known as the "Quesungual System". The dramatic increase in organic matter input following slash-and-mulch, the regeneration and presence of native trees within fields, and the diverse landscape consisting of a mosaic of secondary forest, agroforestry and pasture that exists within the study area suggest considerable potential for high soil macrofauna abundance and diversity. During quantification and characterization of the soil macrofauna community one of the most important results was that absolute numbers of soil macrofauna in soils under Quesungual were much higher than expected, when compared with other agricultural systems of the semi-humid tropics. Numerically, termites, ants and earthworms were the most abundant soil fauna, in that order. In terms of biomass, earthworms were dominant. Farmers' knowledge synthesized during participatory mapping of soil quality on-farm was instrumental to allow relevant stratification needed to guide spatially explicit sampling and spatial analysis of soil macrofauna. Spatial distribution of soil fauna distribution as reflected by earthworm casts and ant nests indicate that earthworm abundance is positively affected by the abundance of pruned trees, while ant abundance is negatively affected by tree abundance. This research has important implications for farm management, as it shows that farmers can manage litter cover and macrofauna activity by manipulating pruned tree density and distribution.

Nicaraguan farmers start validating the management principles of Quesungual slash mulch agroforestry system (QSMAS) in their own farms: Twenty farmers from drought-prone areas of Nicaragua visited the farmers that are practicing the Quesungual on their farms in Honduras. The main objective of their visit was learning from farmers practicing the system the main management principles and benefits of the Quesungual. Six months later six farmers from Somotillo, Nicaragua showed their own Quesungual plots to a group of researchers from the MIS consortium. They are very excited about the good adaptation of the system and expressed their willingness to teach other farmers from similar regions in Nicaragua the benefits of the Quesungual. This type of farmer-to-

farmer exchange proved to be a dynamic mechanism of knowledge sharing and an effective way to disseminate ISFM principles.

Strengthening research for development capacity of the AfNet: The year 2005 was marked by a continued growth of AfNet membership to over 350 members. During this period, AfNet continued the implementation of the Network trials located in over 80 sites in different agroecological zones distributed in East, South, Central and West Africa regions. These experiments have increased understanding on the sustainable management of the natural resource base and have generated and demonstrated new technologies that can help boost food production among the smallholder farmers in the continent. AfNet Steering Committees meeting was held during which the role of the Network in achievement of the TSBF Strategy was discussed. AfNet successfully organized two training courses: Participatory Approaches to Research and Scaling Up, attended by 37 participants, and the Decision Support Systems for Agrotechnology Transfer (DSSAT) training workshop attended by 29 participants. AfNet ensured the review of over 100 papers presented during the Yaoundé Symposium in readiness for the publication of the AfNet Symposium Book and the Special Issue in Nutrient Cycling in Agroecosystems in 2006. Several proposals were also developed of which 10 received funding from various donors. AfNet published the TSBF newsletter, *The Comminutor*, which highlighted research issues in Latin America. The Network continues to be a pan African Network and will continue in its effort to coordinate and promote information sharing for the sustainable and integrated management of natural resources in the continent.

Improving food security for western Kenyan farm households with integrated soil fertility management for local vegetable crops: We analyzed the food security in vegetable yields of subsistence households, which were producing kale for market and those, which were cultivating traditional African vegetables (TAVs) for home consumption. By comparing kale-producing households with TAV producing households in terms of the allocation of labour and capital and the coping mechanism enacted to cope with transitory food insecurity, we found that households producing kale have a higher level of food security. This increased food security stems from three key factors: the malleability of kale to be a vegetable and a high-value cash crop; the dedication of all households members to the daily maintenance of kale; and the location of farms adjacent to a water source. These three key factors allow for women to be able to access kale for home consumption, increase the purchasing power of households, and also, boost the total yield of vegetables cultivated on the farm. TAV producing households were found to be vulnerable to an insufficient vegetable supply largely because of geographic location and the overburdening labour demands on the women to singularly produce all household vegetables.

Improved decision making for achieving triple benefits of food security, income and environmental services through modeling cropping systems in Ethiopian Highlands: Food security in the Enset-based Ethiopian highlands is constrained mainly by land degradation, land fragmentation and limited access to technologies and skills. Enset (*Enset ventricosum*) is a perennial herb with edible corm, supporting about 13 million people in Ethiopia. A household survey, supported by field measurements, was conducted

over three years (2000–2002) with 24 representative farmers to identify their production objectives and to quantify their available land resources, cropping system, crop yields and market price, for developing models to facilitate their decision making. Farmers identified three major production objectives depending on their household priorities, socio-economic status and resource base. In Scenario I, farmers were primarily interested in producing enough food from their farm. In Scenario II, they wanted food security and to fulfill their financial needs. In Scenario III, farmers were interested solely in generating cash income, regardless of its effect on food production. The change from current production systems to Scenario I offer high quality livestock feed, while Scenario III offers low quality livestock feed whereby about 84% of the feed is coming from coffee husk. Moreover, a shift from the current system to Scenario I would not have any effect on the level of soil erosion, while a shift to Scenario II and III will reduce soil erosion by about 39 and 52%, respectively, mainly as a result of expansion of the area of perennial crops.

Tools for ex-ante evaluation of land use and management alternatives, and for valuation of ecosystem services - ECOSAUT Model: CONDESAN, GTZ and CIAT during the first year of the WFCP project implementation were focused on developing tools for impact assessment of sustainable land uses and valuation of ecosystem services. Therefore, a multicriteria optimization model was designed for the ex-ante analysis, by means of which optimal values of the decision variables that maximize or minimize watershed management objectives can be identified without violating imposed constraints. Linear programming has been applied successfully to measure the tradeoffs between the economic performance of different activities and the environmental externalities. Thus the model permits to evaluate the economic and social potential of the alternatives in improving the quality of life, and the results can stimulate private and official investors to fund some of the alternatives. The project uses the model to support stakeholders in making decisions about multiple land-use options calculating the environmental and socioeconomic costs of changes in land use and technology under different spatial and temporal scenarios. In addition, shadow prices are calculated for determining the price of services and goods that do not have a market price (production of sediments, water flows, etc). This model and approach are being used in the analysis of the five pilot Andean watersheds (Colombia, Ecuador, Peru and Bolivia) in order to support the identification of land use alternatives and management practices that promote the internalization of externalities. The main externalities that are the subject of analysis and interventions are retention of sediments, water quantity and quality, and carbon sequestration.

RURAL AGROENTERPRISE DEVELOPMENT

In 2005 the RAeD team have made considerable progress in our mission to make markets work better for the poor. Activities focussed on:- (i) scaling out best practices for market engagement with partners using the new CIAT agro-enterprise guide series; (ii) devising new business development services (BDS) and support tools to assist farmers and traders in better business decision making and (iii) the design of new business models to link

poor farmers with higher value markets. This research has generated a considerable number of case studies, reports and research papers, most of which were developed with partners. Action based research was significantly scaled out through the "learning alliance" research platforms, which are providing practical ways of engaging service providers and differentiated types of farmers with a range of differentiated market opportunities; farmers ranging from those in extreme poverty to progressive poor farmers and market types ranging from lower value, high volume products for local markets up to high value, niche fruit, vegetable and beverage products for export.

***Operating at scale**:* Learning alliance activities expanded in 2005 from 17 to 33 countries, with expansion in Latin America, Africa and Asia. To further promote and advance this work, RAeD co-hosted a conference on developing "learning alliances" as a research tool. Additional work in Colombia through "Partners for Business Action" is being adopted by Cauca Valley Government, thus deepening the process of enterprise learning.

New areas of operation: In 2005, the agro-enterprise approach was tested with ethnic minority groups in uplands areas of Lao PDR and Vietnam. This work is investigating how to link highly marginalised groups, living in remote areas with existing and new markets. This is particularly interesting for the team, because this is some of the first marketing process work being done in these centrally planned countries.

New strategic studies: were initiated to assess the impact of market information services in Uganda and also to evaluate potential for making service markets work for the poor. PhD studies were finalised on mechanisms to foster public: private partnerships in Colombia and Honduras and another PhD study is evaluating the assets, capitals and skills required in establishing effective farmer market groups. This study being undertaken in Tanzania is also evaluating the skills sets required by service providers seeking to shift from a production orientation to marketing and the facilitation of local BDS.

***Business Development Support*:** included new developments in market information software through TRADNET. TRADENET, an off the shelf software package that provides easy solutions to MIS is being developed through a consortium of public and private sector partners and the software platform is now being used in 14 countries[1]. More policy related work in this area also included managing a conference on approaches to developing marketing institutions in ACP countries, that was undertaken in collaboration with CTA[2].

Assimilating High Value: Being non commodity focussed, RAeD has always promoted diversification, for farmers with assets to take on higher levels of risk. This year, as indicated in CIAT's "In Focus magazine", entitled "Getting a Handle on High Value", the RAeD team were actively involved in the GFAR / CGIAR conference on enabling poor

[1] The TRADENET market information platform is deployed in Benin, Burkina Faso, Cote D'Ivoire, El Salvador, Ghana, Guinea, Honduras, Mali, Niger, Nigeria, Senegal, Togo, and Uganda.
[2] CTA – Centre for Technical Assistance for ACP Agriculture (African, Caribbean and Pacific)

farmers to benefit from high value markets. In this area, RAeD is developing partnerships with larger private sector actors through initiatives such as the Sustainable Food Lab, evaluating supermarket linkages and working with niche coffee markets in Colombia[3]. At the practical level high value work is implementing market chain studies with partners on horticultural crops, in Latin America for export and supermarkets, on persimmon, industrial cassava and livestock in Vietnam and on export beans, pigs and potatoes in Africa. This process has allowed the team to segment clients and service providers more effectively so that research and IPGs, are better focussed on specific issues, that pertain to high and low value produce and its related services.

Seeking leverage points: the team initiated work to explore ways of broadening the agro-enterprise approach and place greater emphasis on identifying key drivers and leverage points in the marketing system that will bring most benefit to poor communities. This study tour was undertaken with CRS[4] and CLUSA[5] to review key market drivers.

PARTICIPATORY RESEARCH APPROACHES

Outcomes, impacts, performance and sustainability of strengthened social capital on NRM

An important research focus has been on understanding the various dimensions of social capital as a strategy for improving planning and decision-making strategies in community-based organizations. A diagnosis study in Uganda has improved our understanding of the different dimensions, levels and types of social capital. Research analyzed potential for joint community action; social networks and different forms of inter- and intra-household support, village-level interactions and wider scale linkages; gender roles, and interest in NRM initiatives. This study has increased understanding of mechanisms and approaches for strengthening social capital, and improving the organizational capacity of local communities for collective action, and participation in implementation of bylaws and NRM action plans.

Community-driven Participatory monitoring and evaluation (CD-PM&E) as a tool for learning and empowerment

Research analyzed lessons and experiences from applying a novel monitoring and evaluation approach developed by the IPRA project, for the past six years. The study found that community-driven PM&E systems are a powerful tool for enabling local people to articulate their objectives for projects and activities, and taking control of these initiatives. One of the most important results is the role of CD-M&E systems in creating a transparent process to share how group funds are managed. This information sharing is critical to the success of groups. CD-PM&E is providing a systematic process for generating, managing and analyzing data and has led to improved project management and reporting at all levels. Communities are using PM&E information to make R&D institutions more accountable and responsive to local priorities.

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[3] This work is being done in collaboration with CIAT's Land Use project
[4] CRS – Catholic Relief Services
[5] CLUSA – Co-operative League of the USA

Strengthening Rural Innovation Systems through Network Analysis
In 2005 we mapped and analyzed the innovation systems associated and two farmer research groups in Cauca, Colombia (with support from PRGA). We developed a prototype method for participatory network analysis, planning and monitoring and evaluation. We also used the innovation history method to map and analyze with the successful development of four bean varieties in East Africa (with support from PABRA). We also received funding for an impact assessment project that will allow us to map the networks of 18 CPWF projects in Africa and Asia. While the work in Cauca enables us to study the structure of individual farmer groups, the PABRA and CPWF work allows us to investigate the position of farmer groups in research and development networks. Preliminary results from Cauca show that there are clear network differences between a well-established and active CIAL and a newer, less dynamic one.

Pro-poor knowledge-sharing methodologies
Results showed that (a) adoption of new structure and the development of new attitudes regarding the farmer-professional relationship, on the part of the so called "knowledge managers", is possible and (b) greater satisfaction and technology appropriation on the part of producers is reported. This has made possible to set a model in place, in the four agro ecological regions of Bolivia, to make a turn in regards to the traditional top-down, delivery-oriented methods to facilitate agricultural innovations. The knowledge management research project has been developed within the context of the objectives for reducing poverty, empowering poor farmers to utilize technological knowledge and strengthening the conditions for guaranteeing food security within the framework of SIBTA, the FDTAs and the enterprises supplying technical assistance services.

Enabling Rural Innovation (ERI) in Africa
Research examined the hypothesis that better market opportunities provide incentives for demand and investment in agricultural innovations. Preliminary results from cross-sectional household surveys and action research on linking farmers to markets in selected sites in eastern and southern Africa revealed mixed results, with significant differences based on gender, wealth categories, crops and survey areas. There was evidence that better access to markets and increased income led to increased investments in farm inputs (including inorganic fertilizer) and the application of soil conservation measures. However, for the majority of women and poor farmers in Uganda, re-investing in ISFM was not among the first three priorities. Investment on other livelihood needs (buying or renting more farmland, livestock, paying school fees and buying clothes) received higher priority.

Results of an external evaluation conducted in Malawi sites revealed significant improvement in gender relations and women's status in the community. There was evidence of livelihood impacts due to increased income opportunities and utilization of cash income from community agro enterprise to improve dietary diversification, children's education and general household welfare.

Applying PM&E to increase the relevance of Research, Development and Technology Transfer (RD&TT) processes

An external evaluation conducted to analyze the benefits and challenges of community-driven PM&E processes in Bolivia found that evidence of acceptance of CD-PM&E and a trend towards its institutionalization in several RD&TT organizations and producers' associations. The study also indicated that the methodologies being developed have the potential of being public goods beneficial to other developing countries in the world, such as Uganda. Results of the study found that the participatory methodologies were being used by the new Bolivian Agricultural Technology System (SIBTA) and also by other organizations in the country. Other findings included: (a) The CD-PM&E processes were resulting in a change in farmers' attitudes towards SIBTA from passive to active (as in decision-making). (b) SIBTA's applied technological innovation projects (PITAs) were including a, "Social control as an element for improving quality" through the application of CD-PM&E systems in these projects. (c) Resource poor farmers were becoming stronger actors in the execution of projects for socio-economic development, and showing their ownership of RD&TT projects, thereby ensuring sustainable benefits. (d) Service providers were using information from CD-PM&E to improve their performance and services.

Methods for strengthening rural planning

Research conducted with R&D partners in Africa has led to the development and publication of a field guide for strengthening rural planning processes. This handbook titled " *The Power of Visioning: A Handbook for Facilitating the Development of Community Action Plans*" (Sanginga and Chitsike, 2005) provides a rich source of materials, tools and skills for stimulating positive change in rural communities by engaging with and facilitating farmers and communities to develop articulate their needs and opportunities, and develop realistic action plans.

SYSTEMWIDE PROGRAM ON PARTICIPATORY RESEARCH AND GENDER ANALYSIS

Capacity developed for mainstreaming gender analysis and equitable participatory research in selected CG Centers and NARS

Training

- *CIAT/Africa training on participatory research and gender analysis of AfNet:* Workshop in collaboration with Tropical Soil Biology and Fertility Institute (CIAT/TSBF) to develop skills and knowledge of scientists belonging to the African Network for Soil Biology and Fertility (AfNet) in farmer-participatory research and scaling-up. (*See also* section 6.1.)
- *ASARECA workshop on strategic planning for gender analysis and organization change:* Second workshop (of three) for change-agents involved in mainstreaming gender analysis in eight NARS. Comprised assessment of gaps in ongoing research; design of strategies for gender analysis, and organizational development for mainstreaming; development of monitoring and evaluation indicators for mainstreaming; and development of action plans for implementing organizational development. (*See also* section 6.1.)

- *Participatory plant breeding book:* The Participatory Plant Breeding Working Group planned to publish a book on plant breeding with emphasis on participatory methodology, as recommended in 2002. A draft outline was circulated and 18 of a projected 27 contributions had been received by the end of 2005. The book will be (co-)published by (with) FAO.
- *Participatory plant breeding:* Various lectures and courses held in Eritrea, Italy, Jordan and Mexico (*see* section 4.3).
- *Raising awareness of participatory plant breeding:* Presentations made in Syria and Iran (*see* section 4.3).

Collaborative action research
CGIAR

- *Institutional analysis to identify opportunities and constraints for mainstreaming gender analysis in ILRI:* Research Theme representatives met in March 2005 to reflect on the role of PR and GA within ILRI, and to learn about mainstreaming methods. An e-mail discussion among key scientists and PRGA focused on strategies for institutional assessment of PR and GA. One or two ILRI staff will implement the institutional analysis, while ensuring engagement of a wide ILRI audience. A protocol for a gender audit and an action plan for mainstreaming were designed, and a Memorandum of Understanding (MoU) signed between ILRI and PRGA.
- *Quality of participatory research and gender analysis at ICRAF:* Without formal policy, strategy or conceptual model, participatory research has become integral to ICRAF's work, reflecting a diversity of methods, quality and outputs (mainly a result of ICRAF's decentralized working mode and rather weak internal learning and exchange mechanisms). ICRAF emphasizes work with and through partners to ensure impact and sustainability, while focusing on its strengths as an international organization. Meanwhile, gender issues are more variably integrated into the Center's work. A number of areas have been highlighted where improvements could be made in all these areas.
- *Mainstreaming gender analysis in the research process of CIP:* Workshop on "Women feeding cities: Gender mainstreaming in urban agriculture and urban food security," co-organized by CIP's Urban Harvest program and RUAF in September 2004 (part-funded by PRGA). Strategy for gender mainstreaming (developed by Urban Harvest under 2004 PRGA grant) will be pilot-tested. CIP has committed itself to gender mainstreaming. Activities involving PRGA, Urban Harvest, CIP and at least one East African NARI will feed into the development of a framework for the application of gender analysis throughout CIP's research agenda.
- *Assessment of capacity development for participatory and gender analysis among ICARDA and its partner institutions:* The dominant view of PR and GA among ICARDA and partner researchers is that of functionality—improving the efficiency, effectiveness and impact of research; and primarily based on researcher-generated technologies. Within ICARDA, researchers are divided between those who favor a multidisciplinary approach (handling research from a variety of disciplinary perspectives, which tends to assign PR responsibility to

social scientists on the team) and those who favor an interdisciplinary approach (integrating concepts and methodologies from various disciplines and perspectives into a common framework, which tends to result in shared responsibility for PR). Concerns raised included the following: institutional—more support needed from management; methodological—lack of clear methods, especially for data collection and analysis; integration—would like to see integration across disciplines, projects and with other actors (e.g. NARS, NGOs, private sector); capacity—insufficient in-house expertise in PR and GA, too few women researchers; and capacity development. ICARDA uses diverse approaches for capacity development (e.g. workshops, fieldwork, on-the-job training), which is aimed primarily at NARS researchers and research assistants—ICARDA has a large formal training program (320 people trained in 2005). Lessons have been learned, but there is room for improvement (the assessment made recommendations).

Regional networks, NARS, NGOs and universities

- *Mapping gender mainstreaming at CARE Laos:* An 8-month study documented organizational "best practices" for mainstreaming gender; identified opportunities and constraints for mainstreaming; and identified key areas for further input. CARE Laos has come a long way in a short time (less than 3 years). The study made 10 recommendations for the next steps in the gender-mainstreaming process.
- *Assessing participatory learning and action in China (China Agricultural University):* The final Learning Workshop was postponed to February 2006, which will lead to a comprehensive assessment of outcomes and an action plan.
- *Institutionalizing gender-responsive research and development in agriculture and natural-resource management research through women's networks (Eastern Himalayas Network):* A comprehensive planning workshop was held in October 2005, and a second workshop was scheduled for February 2006.

Evidence of the impact of participatory research and gender analysis methods assessed, and methods developed to permit impact-assessment results to be effectively integrated into research-for-development decision-making

Empirical studies

- *Participatory research projects at CIMMYT:* Eighteen CIMMYT scientists reported on 19 self-defined PR projects. The most common goal is increasing productivity, and the main motivation for using PR is to understand farmers' preferences better; primary beneficiaries are marginal farmers, but these are not generally disaggregated by gender. An "average" CIMMYT PR project lasts for less than 5 years, has an annual budget less than US$100,000, works in either Africa or Asia, and has six project sites, involving 400 farmers and 8 scientists (this "average" masks a great deal of variation). The majority use functional types of PR—divided between increased relevance through knowledge of farmers' preferences and constraints, and improved dissemination. However, interaction among PR projects is limited, as is experience-sharing—areas that are highlighted

for potential investment, especially given CIMMYT's dedication of about US$9 million per year to projects with PR components. The report lays the groundwork for further advances at CIMMYT.

- *Assessing impacts of farmer participatory research approaches—A case study of local agricultural research committees (CIALs) in Colombia:* Preliminary results show significant social and human capital benefits for CIAL members, who learned more about agriculture, experimented with new technology, and were seen as experts and advisors in their communities. They had improved communication and leadership skills, and increased relationships with neighbors and outside institutions. They experimented more with new crops, learned new skills, and had higher levels of commitment to their communities, which in turn led to increased community participation. Where CIALs had identified new technology and converted into commercial seed producers, communities benefited from easy access.
- *Participatory cassava breeding in northeast Brazil:* Four communities involved in an 8-year cassava-breeding project were surveyed in 2002. Project participants proved to be representative of their communities in most characteristics (except for area planted to maize, income from processed cassava and income from non-cassava crop sales), despite representivity not being an original selection criterion. However, women were overlooked by the project, whose contribution in selecting varieties for dumpling production was therefore missed. Adoption rates were high after 4 years, although some farmers had tried and rejected experimental varieties. Some 44% of farmers were willing to pay for planting material, although this is not common practice. However, no large increases in yield or revenue were reported—but this should be viewed in the context of declining cassava yields, whereby adoption had stabilized yields. Reports of increased time devoted to cassava production are likely to be a direct result of increased area, since no labor-saving technologies were introduced by the project.
- *Impact of participatory natural-resource management research in cassava-based cropping systems in Vietnam and Thailand:* Data were collected from 800 farm households from 16 villages: 4 that participated in a 10-year farmer participatory research project and 4 that did not from each country. The cassava technologies themselves (conservation techniques, management options and varieties) and farmer knowledge (measured by project participation) significantly affected adoption and productivity. Whereas 100% of project farmers adopted technologies in Thailand, only about 50% of project farmers in Vietnam did. The differences between participant and non-participant farmers were smaller in Thailand. The impact assessment was hampered by lack of a baseline survey, which also restricted rate of return analysis to financial analysis.
- *Institutional impacts of the cassava participatory research and extension project in Thailand and Vietnam 1993–2004:* Five focus-group discussions were conducted in 2004, comprising two disciplinary groups (research and extension) in Thailand and three geographical groups in Vietnam, to identify positive project impacts and hindrances to greater success. The impacts (benefits) and hindrances (constraints) were then ranked by each group.

- Benefits, Thailand: Both researchers (28%) and extension workers (22%) appreciated improved work management; extension workers perceived 62% of benefits from a combination of improved efficiency and motivation, while scientists felt that 55% of benefits arose from increased scientific and professional knowledge and understanding of farmers and their environments combined.
- Benefits, Vietnam: All three groups highlighted improved scientific and professional knowledge (25–30%), and improved management (14–23%); two groups allocated 18–28% to each of efficiency and understanding of farmers and their environments, while the third group allocated 37% and 8%, respectively, to these benefits; all three groups allocated less than 8% to improved motivation.
- Constraints, Thailand: Both researchers (35%) and extension workers (49%) saw internal management issues as the single most important institutional constraint to greater success; both groups perceived similar, relatively low, level of constraint coming from external economic and market conditions or lack of knowledge; divergence was shown in operating budgets (31% extension v. 2% research) and government policies (18% extension v. 29% research).
- Constraints, Vietnam: The two groups that included universities saw knowledge and information as the major constraint (33% and 48%), while the remaining group highlighted operating budget (23%, cf. less than 8% in the university-inclusive groups); two groups highlighted external economic and market conditions second (30% and 35%), while the third group considered this of no significance.

Development and dissemination of tools and methods, capacity-building

- *Impact Assessment Workshop, website and electronic discussion group for impact-assessors:* The workshop, co-organized with CIMMYT in October 2005, provided 25 empirical impact-assessment studies, which used a variety of approaches and methods. These studies, together with summaries of discussions, are available via the PRGA website in the form of draft papers and presentations. Particular highlights were:
  - the need to "build on the positive"—learning from the positive experiences of others (rather than dissecting "what went wrong" all the time);
  - the realization that there is no "one way" of doing impact assessment of participatory R&D, and that principles are more easily transferable than methods in many cases;
  - that it is profitable to include all types of stakeholders (especially end-users and donors) in planning for and conducting impact assessment;
  - that impact-assessors need time to reflect on their results;
  - that effective communication of results is vital.

  As a direct spin-off from the workshop, we established an electronic discussion forum for continued sharing and institutional learning.
- *Annotated bibliography of participatory research and gender analysis in agricultural and natural-resource management research:* The draft bibliography

(including abstracts) comprises 97 refereed journal articles covering impact (empirical results), practice (how projects were implemented) and (assessments of) methodologies. Publication is scheduled for the first half of 2006.

- *Participatory development of a methodology for strengthening social networks:* CIAT worked with two CIALs to develop a participatory methodology to help make rural innovation ecologies visible, help identify interventions for strengthening social networks, and help monitor and evaluate subsequent interventions. The nature and importance of social networks were explored with participating groups; a social-network questionnaire was designed; the networks were subjected to mapping and participatory analysis; and a strategic plan was designed on the basis of the analysis. The two CIALs are currently implementing their strategic plans. It remains to be seen whether the prototype can be applied to non-CIAL groups that do not have prior interest in PR. Meanwhile, the maps generated are being used as communication and find-raising tools by the groups.
- *Generations Challenge Program (GCP):* GCP aims to capitalize on the genomic revolution to benefit the world's poorest farmers. It needs to ensure that its research products are adopted, adapted and applied for the ultimate benefit of resource-poor farmers. A PRGA representative attended a meeting of one of the subprograms of the GCP, providing input into the GCP's delivery strategy document.
- *Water Challenge Program:* A project on the water productivity of crops in the Atbara basin of Eritrea was initiated in May 2004. PRGA is providing social-science backstopping to support the NARS, especially in setting up an impact-assessment plan and implementing it over the next 5 years.

Communication strategies for learning and change with partners

Website

- Spot-checking showed 158 users accessing website at one time in November 2005; however, users' contributions remain few.
- A sub-website for outcomes of the Impact Assessment Workshop was launched in October 2005, containing draft papers, presentations, abstracts and notes of discussions held at the workshop.
- The resource base is frequently added to, including a drive to have all PRGA Program and staff publications available for download.

Dissemination of research results to peers

- PRGA Newsletter was relaunched in September 2005, carrying notices of publications, web-based resources, meetings, etc. It is currently in electronic format only and sent out on PRGA Info listserv.
- A draft communications strategy proposes that PDF versions of publications be made available on CD-ROM to those with slow Internet access.
- A drive to rationalize the Program's listservs, so that PRGA Info acts as primary mailing list and others remain as discussion forums met with some problems; namely, that some users chose to end their subscriptions, and the most animated

discussion of the year took place on PRGA Info. PRGA Info ended the year with 600 members.
- Various presentations were given at scientific forums (*see* section 4.3).
- An article on participatory plant breeding was published in the electronic newsletter, *Plant Breeding News*.

Dissemination of research results to non-specialist audiences
- A 4-page summary of the Impact Assessment Workshop, and a half-page piece on the Program's role in mainstreaming participatory research and gender analysis were prepared for the CGIAR Annual General Meeting.
- Updating of PRGA-Info subscribers' information is in progress.

SPATIAL AND ECONOMICS ANALYSIS FOR DECISION AND POLICY SUPPORT IN AGRICULTURE AND THE ENVIRONMENT

Land Use Project #1. Opportunities for improved genetic resource management defined for regions: The Homologue software has been released as Beta version. Homologue was developed jointly with the Tropical Fruits Project. The software defines the probability for any selected location in the tropics to exhibit climatic and soil conditions similar to those of locations that are known to have favorable growing conditions for specific crops of interest.

Land Use Project #2. Practical risk management tools produced: We developed, implemented and tested together with colleagues of the CIAT Agro-Enterprise Project concepts for drought insurance. The methodology integrates crop growth modeling with climate simulation. The concepts have been successfully demonstrated in case studies in Central America and Southeast Asia.

Land Use Project #3. Detailed climate data sets developed for modelers: We contributed significantly to the generation of very high-resolution climate data. Various climatic variables have been generated for further use. An article in an international has been published to document the methodology and the data.

FINANCIAL HIGHLIGHTS

FINANCIAL OUTCOMES FOR 2005

OVERALL REVENUE AND EXPENDITURES

Compared with 2004, total revenue increased by 12% in 2005, from US$37.0 million to $41.5 million while total expenditures increased 16% from US$36.4 million in 2004 to US$42.4 million in 2005. Changes in total revenue and expenditures are due mainly to the additional restricted project implementation during 2005 with net restricted revenue increasing by 20%. In contrast, unrestricted contributions fell 7% in 2005 while unrestricted expenditures rose 7%. The increase in unrestricted expenditures is due principally to a revaluation of the Colombian peso. These movements in unrestricted income and expenditures resulted in ending 2005 with a deficit of US$0.9 million. Consequently the net reserves decreased to $5.2 million in 2005 after having risen in 2004 due to a US$ 0.5 million surplus that year.

Compared with the estimates reported in the MTP submitted in June 2005, actual 2005 revenue was 10% higher than projected, $41.5 million compared to a projected $37.5 million. Expenditures were 14% higher than estimated, rising to US$42.4 million compared to the projected $37.0 million. Hence CIAT finished 2005 with a deficit of $0.9 million compared with a projected surplus of $0.5 million. As explained above the increases in both revenue and expenditures projections were largely caused by a slightly higher rate in implementing restricted projects as well as exchange rate movements.

The top three donors in 2005 were CIDA, USAID and DFID, compared with USAID, CIDA and Switzerland in 2004.

EXPENDITURE ANALYSIS

Project expenditures: During 2005 there were significant changes in various projects due to increased restricted contributions and some internal adjustments in project organization.

Compared with the estimated for 2005 in June 2005, four projects SB-2, IP-5, PE-2 and SN-3 had increases of $1 million or more. Four projects IP-3, SN-1, IP-4 and CP-1 had increased ranging from $0.5 million to $0.9 million. Two projects IP-1 and PE-3 had decreases for $1 million or more. Four projects PE-1, SN-4, PRGA and BP-2 (PE-4 + BP-1) did not change significantly.

Expenditures by Undertaking, Activities and Sectors: Increasing productivity represented 45 percent, Saving Biodiversity 19 percent, Protecting the Environment 17 percent, Strengthening NARS 16 percent and Improving Policy 3 percent.
Expenditures by region: From the regional perspective, expenditures in Latin America and the Caribbean amounted 46 percent, Sub-Saharan Africa 36 percent, Asia increased

to 17 percent and Central and West Asia and North Africa (CWANA) remained stable at 1 percent.

Expenditures by object: Personnel costs decreased from 51 percent in 2004 to 49 percent in 2005. Supplies and services increased from 24 percent in 2004 to 25 percent in 2005. Travel expenditures decreased from 9 percent to 8 percent and the depreciation cost remained in 4 percent. The Collaboration/Partnership Cost category, which shows the expenditures implemented by Centers partners, represented 14 percent in 2005 compared with 12 percent in 2004. The personnel costs in absolute terms increased 11 percent from US$18.6 million in 2004 to US$20.6 million in 2005, mainly due to the revaluation of the Colombian peso against the US dollar during the last years.

FINANCIAL INDICATORS

Short-term solvency (liquidity). This indicator expressed as expenditures requirements in days, decreased from 77 days in 2004 to 61 days in 2005.

Long-term financial stability (adequacy of reserves). Expressed as CIAT expenditures requirements in days, this indicator also decreased from 63 days in 2004 to 47 days in 2005.

The new business plan approved by BOT as explained below projects deficit for 2006 and annual surpluses from 2007 to 2009 with the purpose of progressively improving these indicators and meet the CGIAR target at the end of 2008.

FINANCIAL DEVELOPMENTS IN 2006

In light of the 2005 outcome, including the deterioration in financial indicators noted above, in Febraruy 2006 the CIAT Board of Trustees approved a new CIAT business plan 2006-2009. The broad programatic and operational dimensions of this new plan are described above in the subsections “Financial Developments” and “Programatic Changes 2006”within the section “”Context and Program Discussion” of this report. Overall the revised plan for 2006 and beyond incorporates strategic reductions in programs of $4.0 million and a commitment to enhanced procedures for budgeting and fully recovering costs. Consequently, revenue, expenditures and results estimates for 2006 have been modified to reflect these changes and thus differ substantially from the projections for 2006 presented in June 2005 in the MTP 2006-08.

New estimates for 2006 are revenue at $43.7 million, and expenditures at $45.87, including a phase out cost of $ 3.1 million to cover the termination of contracts of both international and national recruited staff. This leaves a net deficit of $2.17 million for 2006 and the net reserves will fall the level of $3.3 million, including a $0.3 million accumulated balance in the capital fund. In the absence of the one time phase out costs,

CIAT would have generated a 2006 operating surplus. CIAT is actively seeking special support for these one time costs.

Compared with 2005 figures the unrestricted funding will decrease 3 percent, mainly because the CIDA Contribution for Africa has not been confirmed for 2006 and estimated cuts from USAID and Japan are projected. These unrestricted funding reductions are partially compensated with some exchange rate gains by the devaluation of the US dollar, estimated increase of the World Bank contribution and additional self generated income. Restricted funding and expenditures are planned to increase 9 percent in 2006. The majority of these increased funds go to collaborators and operations in the regions.

PROGRAM EXPENDITURES 2006

Expenditures by Priorities: Following Science Council instructions, beginning 2006 research projects are reported according CGIAR priorities. Main priorities for CIAT program for 2006 are: Conservation of staples crops 22 percent, Integrated land and water management 13 percent, Rural institutions and Markets for the poor 8 percent, Intensification and Genetic improvement of nutritional quality 6 percent. 9 priorities have less than 5 percent and 5 are not priority for CIAT.

Expenditures by Undertaking, Activities and Sectors: Increasing productivity represents 43 percent, Saving Biodiversity and Protecting the Environment 18 percent, Strengthening NARS 15 percent and Improving Policy 3 percent.

Expenditures by region: Compared with 2005 expenditures in Latin America and the Caribbean decrease from 46 percent to 44 percent in 2006. Sub-Saharan Africa increases from 36 percent to 38 percent. Expenditures in Asia and Central and West Asia and North Africa (CWANA) remain constant at 17 and 1 percent respectively.

Expenditures by object: Overall personnel decreases to 47 percent for 2006, Supplies and services decrease to 20 percent. Collaboration/Partnerships Costs increase to 22 percent. Travel expenditures decrease to 7 percent and depreciation costs maintain constant at 4 percent.

FINANCIAL PROJECTIONS FOR 2007—2009

As with previous submissions, the MTP projection for the following 3 years is extrapolated on the basis of the current year, however as a result of the structural adjustment implemented the expenditures will decrease 10 percent during 2007 and 3 percent additional in 2008 while the income for 2007 – 2009 remains stable at the level of 2006.

The following table summarized the financial projections for the 3 years of the MTP :

CIAT BUSINESS PLAN 2006 - 2009

	2006	**2007**	**2008**	**2009**
Total Income	43.700	43.800	43.800	43.800
Total Expenditures	45.870	41.355	40.280	40.040
Surplus / (Deficit)	-(2.170)	2.445	3.520	3.760
Net Reserves at the end of the year	**3.302**	**5.747**	**9.267**	**13.027**
Reserves indicator	27 days	53 days	88 days	125 days

Project Descriptions and

Log Frames for 2006-2009

CIAT PROJECT SB-2: CONSERVATION AND USE OF TROPICAL GENETIC RESOURCES

NARRATIVE PROJECT DESCRIPTION

Rationale & Changes

Rationale:

Over the last decade biology is experiencing a revolution with the sequencing of several plant genomes (*Arabidopsis*, rice, …), the linking of sequence information with functions and phenotypic expressions, and the computerization of such sequence information (becoming part of what is now known as 'bioinformatics'). Biotechnologies such as transformation, cell fusion and culture widen the possibilities to include alien genetic information into crop genomes and thus to increase variability for breeders and farmers. While these technological breakthroughs are taking place very rapidly, feeding growing populations face two challenges: yields in cereals, legumes and other major staples are reaching a plateau, and the resource basis that allowed genetic progress, namely the useful genes found in landraces and wild relatives is eroding.

The task ahead is thus two-fold. On the one hand, we need to conserve the biological capital that has made the increase in crop productivity possible, in order to sustain it. To that end, planners and conservationists specially in the countries of origin of crop diversity need to know about the location, nature and extent of that diversity, and its potential economic significance, in order to generate incentives for conservation. On the other hand, plant breeding must accelerate the delivery of its products while widening its offer, that is, including multi-pest resistance, tolerance to drought, improved nutritional quality, technological traits facilitating harvest, etc. Again knowing the extent of the original variability is a condition for progress, or a sure warranty to avoid wastes of time and efforts (if the trait does not exist), and thus an incentive for looking to artificially induced variability.

Our primary mission is to generate information about genetic diversity in mandate and non-mandate crops in order to increase its use by farmers, breeders, geneticists, and from there to generate social and economic returns across the society. It is also to generate biotechnological solutions to complex problems when biological and/ or genetic knowledge is scarce, for instance about conservation requirements of poorly known crop species, or about the control of traits affecting nutritional quality or reacting to environmental stresses, or simply through the delivery of a germplasm accession selected through GIS tools because of its full evaluation.

Our outputs are designed along the drives: (i) characterization of genetic diversity of wild and cultivated species and associated organisms, (ii) genes and gene combinations use to broaden the genetic base, (iii) biotech tools used by NARS partners resulting in improved conservation and utilization (for instance through breeding) of agrobiodiversity, (iv) increased availability of designated collections, and improved conservation technologies, (v) collaboration with public and private partners enhanced and NARS strengthened in the

conservation and utilization of sets of agrobiodiversity, and (vi) seed systems under stress strengthened.

Our research strategy focuses on the exploitation of the genetic collections of beans, cassava and tropical forages for which CIAT has a global mandate. These collections have been assembled since the early 1970s and have been designated to FAO; the are currently the largest and most diverse in the world for these crops with over 61,000 designated accessions to date. Our strategy focuses next on the application of the most advanced genomic tools for marker-assisted selection of the four commodities (beans, cassava, forage grasses and rice for Latin America), for tracking genes of actual/ potential interest in these crops and other selected crops with added value, and for disclosing the geographic patterns and history of genetic diversity. Last but not least a fundamental aspect is in the training of human resources to apply these biotechnological solutions to advance their own programs to conserve and use agrobiodiversity in a way that improves human and environmental health.

Changes:
In Output 1, it seems that a better targeting for collecting wild relatives of beans and cassava will be possible, thanks to advances in the use of molecular markers and GIS technology, thus resulting in an improved target output. In Output 4, it seems that thanks to recent research results in slow-growth *in vitro* and in cryopreservation, and if resources are secured, security back-ups for the cassava collection at CIP and INIBAP can be advanced.

CG System Priorities:
CIAT Sb1-Sb2 (standing for 'saving biodiversity') project serves the CG System priority area 1 ('Sustaining biodiversity for current and future generations'). Responding to Priority 1A ('Conservation and characterization of staple crops'), the project keeps 'in-trust' the largest collections in the world for the mandate crops of CIAT (i.e. beans, cassava, and tropical forages), under an agreement with FAO, and intends to do so under the International Treaty on Plant Genetic Resources for Food and Agriculture. The project also responds to Priority 1B ('Promoting conservation and characterization of under-utilized plant genetic resources to increase the income of the poor') by the application of already developed technologies to germplasm conservation of little known tropical species such as highland papayas, Andean fleshy fruits, palms. The project responds to Priority 5A ('Science and technology policies and institutions') when individually or through the SGRP it provides the technical background to lawyers and policy makers about laws and regulations controlling access to genetic resources, benefit sharing (like the Andean Decision 391), introduction and management of transgenical crops (like the Cartagena protocol).

Through the CIAT commodity projects, the Sb1-Sb2 project also serves the CG System priority area 2 ('Producing more and better food at lower cost through genetic improvements'). The project has long helped the breeders in establishing the marker technology in marker-assisted selection, for instance in insect (bruchids in beans, and spittle bugs in *Brachiaria* forage grass) and disease (blast in rice) resistance (priority system 2A). More recently, capitalizing on former evaluations of bean germplasm for iron

and of cassava germplasm for carotenoids, the project supports several works for the Challenge Programme HarvestPlus and the project Agrosalud, targeting at several biofortified crops in vitamins and minerals (priority system 2C). Two problems (possibly partly related for beans and forage grasses) – drought and tolerance to acid soils and aluminum toxicity – are being tackled through marker-assisted selection (priority system 2B), once that some QTLs have been found associated with those traits. Cassava being a champion to produce starch under drought stress, efforts there are devoted to yield increase (priority system 2A), if possible with higher contents in proteins in the root thanks to Central American germplasm (priority system 2C). The production of specialty starches is also an intermediate objective of cassava germplasm evaluation (priority system 1A) and enhancement (priority system 2D). At the request of Colombia, CIAT has launched an initiative in tropical fruits (priority system 3A). Such initiative in terms of species to work on and problems to be tackled is being shaped through different consultation processes with the different partners and stake-holders. Beneficiaries of such advances are rural populations in Latin America, Africa and South East Asia.

Impact Pathways:

Output 1 ('Genomes of wild and cultivated species of mandate and non-mandate crops and of associated organisms characterized') has beneficiaries in the CG community of breeders and geneticists, and then in the community of users for these crops throughout the world. For instance, the definition of races in common bean has helped focusing breeding efforts worldwide. In several cases (e.g. the *Cratylia* legume of the cerrados of Brazil included into mixed agricultural systems under drought stress in Central America), because of the direct use of genebank accessions after characterization, the users can directly be farmers and cattle husbandry. Conversely, the improved characterization can impact on the orientation of the conservation effort. For instance the recent use of cpDNA polymorphisms not only indicates where common bean has been domesticated but also which parts of the natural variability were well represented in the genebank and which were not. The tools developed for that characterization are also made available to these internal and external user communities. The role of CIAT is that of primary source of research. But it is also an enabler, when through comparative genome mapping sequences responsible for one trait in a mandate crop can be expressed in another crop (bean versus soybean for instance, or cassava versus rubber).

Beneficiaries of Output 2 ('Genomes modified: genes and gene combinations used to broaden the genetic base of crops bean, rice and cassava, and forage species *Brachiaria'*) are mostly in the breeders' communities concerned with those crops, in the CG and beyond. This part also includes the documentation of gene flows between bred cultivars and traditional landraces and their wild relatives. The primary user target concerns national authorities responsible for policies and regulation frameworks for the safe introduction and management of transgenical crops. The tools used in transformation and in gene flow monitoring can be used by breeders and geneticists working on the production and in the introduction and management of such crops. CIAT is primarily a provider of research products, but also a catalyser when tools developed by CIAT and partners are being used by others.

Output 3 ('Increased efficiency of NARS breeding programmes by using biotech tools') seeks to benefit NARS of Latin America and Africa primarily, by translating the benefits of marker-assisted selection. The impact will be measured in terms of reduced time to the delivery of improved varieties, and focused selection processes and economies of scale. The outcome will affect a larger community of users of biotech tools, as some of the products include public awareness packages for universities and teaching in biology. With many activities focused on training and capacity building, CIAT role is mainly that of a catalyser. There is the assumption that partners will be active participants, and so that NARS of Latin America and Africa will be supported in their respective countries, while CIAT role will be to continue to raise awareness about the importance of such continuing support.

Beneficiaries of Output 4 ('Bean, cassava and forage germplasm collections multiplied and thus available, restored and safely duplicated. Germplasm conservation methods improved') include a large community of users much beyond the commodity projects of CIAT. Immediate availability of the designated collections means immediate use in evaluation and breeding, and is thus a condition to the success of many efforts of enhancement. Restoration that has been done already several times to NARS and national communities of farmers means lowering risks of loss of diversity, and recovering the base for future crop breeding and agronomy. While the improvement of conservation methods serves immediate needs of the project (namely to increase the biological relevance of the collections at lower costs), it also benefits NARS in several countries of Latin America and Africa for species of their interest and little investigated so far. CIAT is a primary research provider, but also an enabler, as it strengthens NARS to conserve better by the use of its improved methodologies.

Output 5 ('NARS strengthened in the conservation and utilization of sets of agrobiodiversity') benefits NARS of Latin America primarily because of proximity reasons, but recently through distance education and the availability of different technical guidelines through the web site, NARS of Africa and beyond. The ultimate benefits go much beyond genebanks and contribute to increase the availability of sets of agrobiodiversity to farmers and producers (much along system priorities 1 and 3). CIAT is a primary research provider and through its cooperation with IPGRI, some universities and biodiversity institutes on capacity building, a secondary research provider and a facilitator as well. One should assume their active participation that is almost warranted.

Output 6 ('Strenghtening stressed seed systems during emergency and recovery') benefits farmers and rural communities in countries of Latin America and Africa where natural and manmade crisis frequently (and recurrently) occur. CIAT links with seed providers, sometimes genebanks, and contributes to support local seed circuits and seed business, with social and economic benefits at the local level first where the crisis. CIAT work also encompasses emergency and chronic stress situations. CIAT is a primary research provider, also a secondary provider when working in association with charity NGOs. It is also a catalyser and an enabler so that future emergency food aid efforts are better oriented to the most vulnerable populations.

International public goods:
These include:

- Germplasm of the designated collections of beans, cassava and tropical forages. This germplasm is documented with full passport data in over 70% (namely geographic coordinates allowing analysis by GIS tools), and is characterized for essential morpho-agronomic traits (such as growth habit, time to flowering, maturity, etc). The rate of distribution to users inside and outside CIAT is on average 8,000 samples/ year. Perhaps sadly, but as a matter of fact, CIAT is the no. 1 keeper and provider of such documented germplasm, and has thus a unique comparative advantage.

- Genetic stocks. We are building collections of mutants (natural spontaneous mutations, EMS induced, or T-DNA transposon mutants) in order to understand better gene function and regulation, as well as special selections (e.g. isogenic lines) as reference materials in pathology, nutrition, genetics studies. In case of natural mutations in the original collections, CIAT has as above a unique comparative advantage.

- Knowledge and tools. We have advanced the understanding of gene pools, races and relationships with wild species in beans and cassava. CIAT's location and the possibility to evaluate the designated collections almost continuously by multidisciplinary teams of specialists facilitate the selection of germplasm and its documentation. Hardly someone else should do this work, although cooperative activities can be develop when for example a disease does not exist (e.g. white mold in beans in cooperation with US universities, ACMV in cassava in cooperation with universities in Africa). We have contributed to the saturation of the bean linkage map with different markers, and developed the first genetic map of cassava. We have developed marker assisted selection and QTL analysis for all commodities under improvement at CIAT. In many cases CIAT has a complementary advantage; in some cases given the very rapid developments in DNA sequencing, CIAT can outsource some technical work to institutes in Asia, and concentrates on result interpretation.

- Methods of networking, linking institutions in Latin America with ARIs in North America, Europe, Japan and Australia, also building relationships between the public and the private sector.

Partners:
A listing of all partner institutions can be found in our annual reports (2006, pages 409-418), but the most important ones (with respective person-years) are:

Output 1: NARS in Latin America, including those of Mexico (3), Guatemala (2), Honduras (1), Costa Rica (2), Colombia (6), Brazil (3), Venezuela (2), Peru (3), Chile (1), and Argentina (1). USDA (2) is a partner on a major initiative on bean germplasm, while Washington University (1) is partner on cassava diversity. France (1; cassava pathology).

ETH, Zurich (1; Brachiaria physiology). MassUniv (1; functional diversity). World Bank and GEF teams (wild functional genomics).

Output 2: NARS in Latin America include: Colombia (5), Bolivia (4), Costa Rica (1). In Africa: Kenya (2), Rwanda (2). Belgium (1; nitrogen fixation). University of Hannover, Germany (1, drought tolerance; 1, gene flow analysis). University of Geneve (1; TILLING). Sweden (1; cassava starch). Yale Univ. (1; Ac/Dc-mutants). United Kingdom (1; cassava deterioration). World Bank and GEF teams (biosafety regional project).

Output 3: partners are: Colombia (3), Venezuela (1), Brazil (1), Mexico (1).

Output 4: partners are: Colombia (3). SGRP (1). SINGER (2). CIP (1).

Output 5: partners are: Brazil (1), Colombia (2), Chile (1). IPGRI (3). FAO (1). WARDA (1).

Output 6: NARS in Latin America: Nicaragua (1), and in Africa: Ethiopia (2), Burundi (1), Zaire (2); partners in the USA (2).

HarvestPlus Challenge Program: IFPRI (3), CIMMYT (2), CIP (2), while other Centers (namely ICRISAT, ICARDA and IRRI) work in their respective eco-regions.

Generation Challenge Program: partners include: Brazil (2), Cuba (1), and Colombia (2); CIMMYT (2); France (1).

Project Funding:

Budgeting 2005-2009

Year	2005 (actual)	2006 (estimated)	2007 (proposal)	2008 (plan)	2009 (plan)
US Dollars (millions)	8.623	9.611	9.069	8.750	8.631

CIAT PROJECT SB-2: CONSERVATION AND USE OF TROPICAL GENETIC RESOURCES (2007-2009)

Targets	Outputs	Intended User	Outcome	Impact
OUTPUT 1	Genomes of wild and cultivated species of mandated and non-mandated crops and of associated organisms are characterized.	Breeders, agronomists and other crop scientists working on/ using these crops and associated organisms.	Production or breeding methods are more efficient as compared to previous years. Varieties with improved or novel traits are produced and adopted.	Farmers' livelihoods are improved by increased crop productivity, by producing new crops for niche markets, or by using varieties that require less pesticides or costly inputs.
Output Targets 2007	Allele mining in *ex situ/ in situ* collections of wild relatives of beans, and cassava for genes of traits of economic importance.	Breeders and crop geneticists, and conservationists dealing with these crops and their wild relatives.	Breeders and crop geneticists, and conservationists dealing with these crops and their wild relatives are better informed about allelic richness and its possible economic significance.	Agrobiodiversity conservation efforts are made biologically more relevant, and economically more sustainable, through better conservation- user links.
Output Targets 2008	Bioinformatics tools developed for data mining in relation to gene functions for traits of economic importance.	Breeders and crop geneticists.	Breeders and geneticists can use sequence data generated on traits of economic importance in beans, cassava, rice and *Brachiaria*.	Better utilization of existing *ex situ* collections, like core collections. Comparisons made possible between CIAT mandate crops and other crops for which gene maps have been developed, namely in view of QTL analysis for such traits.

Targets	Outputs	Intended User	Outcome	Impact
Output Targets 2009	Germplasm of wild species of beans and cassava recently acquired after the effective entry into force of the Treaty is characterized.	Breeders and crop geneticists in CIAT and world community.	Breeders and crop geneticists are informed about new sources of variability.	New sources of variability orient better collection efforts, definition of core collections and breeding activities.
OUTPUT 2	Genomes modified: genes and gene combinations used to broaden the genetic base of crops (bean, rice and cassava) and forage species (*Brachiaria*)	Breeders and crop geneticists worldwide working on these crops and relatives.	Breeders and crop geneticists have access to improved lines and genetic stocks, and benefit from increased knowledge about gene function/ regulation.	Better varieties requiring less expensive inputs are made available to NARS and farmers, resulting in gains of productivity, environmental sustainability, and in social benefits.
Output Targets 2007	Transgenic events tested under green house biosafety conditions Gene flows in rice and beans documented in farmers'fields in parts of Latin America	ARI and molecular biologists- breeders Biosafety authorities of Latin America.	Biosafety authorities have technical information about risk of gene flow (intensity, location, persistence) for better decision making.	Co-existence of different types of genetically modified crops made possible. Risk of gene flow to wild flora minimized.
Output Targets 2008	Transgenic lines of mandated crops generated with different constructs against biotic (e.g. Bt) and abiotic (e.g. DREB) stresses	Cassava and rice breeders at CIAT and in partner countries.	Cassava and forage breeders at CIAT and in partner countries have access to materials with novel genetic diversity to start new breeding activities.	Lines with novel traits (e.g. new forms of starch, natural insecticide) are adopted by farmers, and agriculture offers new options to food markets and industry.
Output Targets 2009				

Targets	Outputs	Intended Users	Outcome	Impact
OUTPUT 3	Increased efficiency of NARS breeding programmes by using biotech tools.	Breeding programs, biodiversity institutions concerned by biosafety issues, extensionists, rural health centers.	Breeding programs, biodiversity institutions concerned by biosafety issues, extensionists, rural health centers make a wider use of biotech tools developed/ improved by CIAT.	Biotechnology tools are better understood and thus used in crop breeding activities, or to deal with environmental biosafety issues.
Output Targets 2007	Training on MAS has been provided to several country partners in Latin America and Africa.	Breeders and breeding programs in developing countries.	Breeders and breeding programs in developing countries adopt MAS techniques used/ improved by CIAT.	Breeding programs produce elite varieties in much shorter times and more efficiently.
Output Targets 2008	Information package delivered to NARS in Latin America and Africa about biofortified crops.	Breeders, extensionists, rural health centers.	Breeders, extensionists and rural health centers take into account the biofortified crops produced by the Biofortification CP.	Biofortified crops are adopted, resulting in better nutrition of rural populations.
Output Targets 2009				
OUTPUT 4	Bean, cassava and forage germplasm collections, multiplied, and thus available, restored and safely duplicated.	CIAT commodity project and external users around the world can have access to characterized and viable samples at any time.	Partners and any other public or private institutions use CIAT designated germplasm in own research and development.	Breeding and agricultural development achieve net progress. Biological sciences are advancing thanks to the availability of material for study.
Output Targets 2007	25% of designated germplasm is documented at CIAT website	CIAT projects and external users have direct immediate access to germplasm information for use and research	Wider use of designated germplasm because of its web-based documentation.	Farmers can explore niche markets. Countries have a better documentation of sets of their agrobiodiversity

Targets	Outputs	Intended Users	Outcome	Impact
Output Targets 2008	Bean and forage collections safely duplicated at CIMMYT, and cassava at CIP.	(security backups are not intended for use)	Other national genebanks are also making security backups of their collections.	Designated germplasm collections secured against disasters, and availability guaranteed.
Output Targets 2009	Germplasm recently acquired (after the effective entry into force of the Treaty) has been multiplied and safely secured at CIMMYT/ CIP genebanks	Users have access to an increased germplasm basis.	Partners have new options of available and documented genetic diversity.	Breeding and agricultural development have cultivars with novel traits, thus increasing crop possibilities on markets.
OUTPUT 5	NARS strengthened in the conservation and utilization of sets of agrobiodiversity	National genebanks, botanic gardens, biodiversity institutes, university departments working in conservation/ utilization of agrobiodiversity.	NARS and national genebanks adopted new conservation methods improved/ promoted by CIAT.	NARS conserve more efficiently their germplasm collections and distribute benefits from utilization.
Output Targets 2007	Public awareness products for institutions working in *ex situ* conservation	National genebanks, botanic gardens.	National genebanks, botanic gardens have material to explain their work.	National genebanks and botanic gardens see their roles better acknowledged by the society.
Output Targets 2008	Distance education, presential courses run.	NARS dealing with aspects of conservation/ utilization of germplasm collections.	Personnel trained and/ or updated in conservation methods (e.g. DNA bank)	NARS conserve more efficiently their germplasm collections and improve methods towards utilization.
Output Targets 2009	Crop conservation strategies for beans, cassava and forages defined	National genebanks in charge of such germplasm commodities.	National genebanks have their role clarified namely in terms of responsibilities towards a global and rationale system of germplasm conservation.	Conservation of germplasm of such commodities implemented at the global level with increased efficiency and coordination.

CIAT PROJECT IP-1: BEAN IMPROVEMENT FOR THE TROPICS

NARRATIVE PROJECT DESCRIPTION

Rationale & Changes

Rationale:

The common bean is the world's most important grain legume for direct human consumption. Its total production exceeds 12 million MT, of which 7 million MT are produced in tropical Latin America and Africa. Beans are the "poor man's meat" and are particularly important in the diet of the underprivileged. Beans, like other legumes, supply proteins, carbohydrates, vitamins and minerals, and complement cereals, roots and tubers that compose the bulk of diets in most developing countries.

Common bean is also one of the most diverse crops in terms of its cultivation methods and its uses. It serves as mature grain, as immature seed, and as a vegetable (both leaves and pods). It is cultivated from sea level up to 3000 masl in monoculture, in association, or in rotations. The possibility of obtaining a harvest in as little as two months offers quick income, quick food supply, and also permits rotating with other crops or inter-planting among fruit trees or coffee before the primary crop produces income. At the other extreme are the aggressive climbing beans that subsistence farmers maintain in the garden for food security and continual harvest over a six month period.

Apart from subsistence cultivation, beans have become increasingly commercial over the past thirty years in national, regional and international markets. In Central America beans are the #1 income generator among the traditional field crops. In Africa farmers tap into regional bean markets in Nairobi, Kinshasa and Johannesburg. With the onset of globalization, the past decade has seen a growing international market that is now reported to reach 2.4 million MT. This heightens issues of equity for the small bean producers that have little other stable source of income, but some also see this as an opportunity. For example, bean represents 6% of external income for Ethiopia, and smll farmers in Bolivia produce the large white and red mottled classes for export. Snap beans are a high value, labor intensive crop of small farmers in Kenya and the Andes.

Our primary mission is to contribute to household and global food security by assuring an adequate supply of beans as a culturally acceptable and traditional staple; and to improve the income of small bean producers of Latin America and Africa, by making bean production more profitable. We also seek to improve human nutrition, both by maintaining the supply of beans, and by improvement of their nutritional value.

Our outputs are designed to respond in particular to the needs of small, resource-poor bean farmers in Latin America and Africa. Thus, we seek to create solutions to biotic and abiotic production limitations that require minimal inputs, and in the case of improved germplasm, with good market potential. **Our research strategy** focuses on the exploitation of the vast genetic resources of bean that exist as a complex array of major and minor gene pools, races and sister species. CIAT's gene bank with 41,000 accessions

of common bean and related species is our most unique resource, and has been the source of genes for disease and insect resistance, abiotic stress tolerance, nutritional quality and yield potential. Most traits are still selected by conventional means in field sites (in some cases backed up by greenhouse evaluations) where most important diseases, edaphic constraints and drought can be manipulated for purposes of selection. However, Marker Assisted Selection (MAS) is employed selectively but strategically, in most cases for disease resistance genes. CIAT pioneered participatory selection with farmers and this practice is being extended and systematized. While most outputs are seed based, others involve knowledge intensive agronomic practices. Still others are knowledge based. Our research is strategic with elements of both basic and applied, as called for by the particular challenge.

Changes:

In Output 1 it appears to be feasible to add an output target of small seeded lines with multiple abiotic stress tolerance, based on recent data. Also, the predicted rate of increase of iron in improved beans has been moderated slightly, based on recent experience with genetic gain.

CG System Priorities:

CIAT's bean project is housed principally under CG System Priority Area 2: Producing more and better food at lower cost through genetic improvements. Efforts are dedicated to improving yields through control of diseases and pests, tolerance to abiotic stresses (drought and low soil fertility in particular), and expanding the adaptation range of climbing beans. The bean project also places heavy emphasis on improvement of nutritional quality, especially through increase in iron and zinc content in the grain. There is potential to contribute to Priority Area 3A: Increasing income from fruits and vegetables, through the improvement of snap beans for both Africa and Latin America. The bean team collaborates with marketing specialists to create varieties with better market potential, including international export markets (Priority Area 5B). Finally, strengthening national institutions (Priority Area 5A) continues to be an important output, both in Africa where novel institutional arrangements and relations have been productive to achieve wide impact, and in Latin America where staff reductions have weakened national programs. On both continents national programs seek support to incorporate modern selection techniques.

Impact Pathways:

Outputs 1 (Improved, small-seeded bean germplasm) and 2 (Improved, large-seeded bean germplasm) have similar beneficiaries, end users and uptake chains. Both are targeted to small farmers and poor consumers in Africa and Latin America. Small seeded germplasm is often targeted to warmer climates or more difficult environments in Central America, Mexico, Venezuela, East Africa and Brazil. Large seeded germplasm is usually cultivated in more temperate climates in the Andean zone, the East African highlands and southern Africa, although in the African highlands small and large seeded types overlap, sometimes differentiated by soil fertility gradients within the farm, prevailing biotic constraints and household preferences. Improved germplasm is shared or developed jointly with NARS partners, who supply basic seed to a range of organizations interested

in production of seed (local seed companies, NGO's, CBO's, women's groups) who in turn distribute to farmers. Benefits accrue to farmers through stable food supply and improved income from sale of excess production. Urban consumers benefit of increased production through established but largely informal marketing structures. Assumptions for the successful delivery of these outputs include institutional and financial stability of partners, political stability, and institutional support. The role of CIAT is that of a primary research provider (of improved germplasm), at times a secondary research provider (backing up national bean improvement programs with technical expertise and training), and catalyser (to promote downstream alliances in the uptake chain).

Beneficiaries of Output 3 (Strategies developed for managing diseases and pests) are in some cases researchers (both inside and outside of CIAT), and in some cases are bean producers. For example, molecular markers benefit researchers directly, and farmers indirectly as subsequent beneficiaries. Uptake pathway for such methodologies is direct communication through workshops and courses, and indirectly through publications, leading to benefits of more efficient and effective bean research. This assumes that partners are in a position to implement such technologies. On the other hand, crop management practices are of direct benefit to farmers as users, potentially across all bean ecosystems. Uptake chain for agronomic practices are similar to those for seed based technologies; results are communicated to NARS and other partners (NGO's, CBO's etc) who have successfully diffused practices to farmers, to the benefit of farmers who enjoy more stable productivity. The role of CIAT is that of primary source of research.

Output 4, (Approaches and methods developed and available for strengthening institutional, organizational and collaborative capacity of NARS and sub-regional networks in Africa and Latin America) seeks to benefit partners at multiple levels through facilitated interaction, including farmers who are at the end of the organizational chain. NGOs, government extension agencies, farmer organizations, local seed companies, and non-conventional seed actors such as women groups, people living with HIV/AIDS and tobacco companies all participate and benefit. The output will generate impact on target beneficiaries through their participation in development of innovations, knowledge and technologies in strategic alliances with multidisciplinary research teams and NGOs. Scaling out of innovations and best practices to areas with similar environments will be done through strategic alliances of research and development actors. The latter will use their network and other communications mechanism to adapt knowledge and results relevant to them. Scaling up regionally and internationally will be done through international NGOs, advocacy, and communication. The outcome is enhanced communication and complementarity of actors with resulting cost efficiencies, and in the case of technology diffusion, increased and diversified adoption. Another dimension of this output is support to NARS in development of projects, benefiting national program researchers and with the outcome of their integration into the research project mode. This assumes a degree of consistency in partner personnel, while CIAT's role is that of facilitator.

International Public Goods:

The IPG of the bean project include:

- Improved germplasm with biotic and abiotic stress tolerance, and/or enhanced nutritional value, drawing upon the genetic resources of CIAT's extensive gene bank, pathogen isolate collections, and 30 years of experience in bean improvement. CIAT's geographical position and access to varied altitudes and research sites facilitates study and selection of germplasm.
- Improved practices for the management of pests and diseases, including monitoring of pathogen populations with modern molecular tools developed at CIAT.
- Knowledge and tools that contribute to the development and implementation of the above IPG's. For example, molecular markers for useful traits, developed with CIAT's in-house resources of genetic maps and markers. Knowledge of the structure of genetic resources housed in the gene bank, and ways to exploit them. Participatory breeding methods with varying degrees of involvement of farmers, traders and other key actors.
- Methods for networking, both formal among official sector researchers, and less formal among a broader range of partners, with special emphasis on research partnerships and on effective and sustainable seed systems reaching a large number of households.

Partners:

Most important partners and the respective person-years of professionals dedicated to bean research within the (several) outputs are:

Output 1: NARS in Latin America, including those of Mexico (6), Guatemala (2.5), Honduras (2, including EAP-Zamorano), El Salvador (2), Cuba (2), Haiti (1), Brazil (4) participate in the AgroSalud project to improve nutritional quality and productivity of bean, while Venezuela (2) and Bolivia (2) are partners in a similar project funded by FONTAGRO. Nicaragua (4.5) is a partner in breeding for drought tolerance. NARS in East, Central and Southern Africa including those of Ethiopia (3), Rwanda (4), Malawi and DRCongo (4), participate in the improvement for low soil fertility, productivity and drought. The University of Hannover, Germany participates in a project for transformation methods of bean to improve drought tolerance (2), and in a second project, seeking to establish physiological mechanisms of aluminum tolerance (2), which also includes Malawi (2) and Rwanda (4). Catholic University of Leuven (3) is a partner to improve nitrogen fixation technology.

Output 2: NARS in Latin America, including those of Colombia (5 between university staff, an NGO and the NARI), Bolivia (4 between university staff and a foundation) and Haiti (1) collaborate in the improvement of disease resistance of Andean bean with better nutritional quality under the AgroSalud and FONTAGRO projects. NARS in East, Central and Southern Africa, including those of Kenya (5), Rwanda (6), and Uganda (5) Tanzania (4) are partners in the development of disease resistance, medium altitude climbing beans (MAC), productivity and improvement of nutritional qualities in large seeded Andean beans.

Output 3: NARS in Honduras (Zamorano) (1), Colombia (2), Uganda (3), Rwanda (4), share in the use of markers for MAS, especially for resistance. South Africa (3) participates in pathogen characterization, evaluation and validation of resistance sources. Agriculture and Agri-Food Canada (AAFC) is a partner in diagnosis and characterization of soil borne pathogens (especially *Pythium* species) using molecular techniques, and development of molecular based diagnostic assays for soil borne pathogens.

Output 4: NARS as above –plus a wide range of NGOS, CBOS, farmers' groups, women's groups, –totaling over 300 direct-link partnerships, to make users aware of technologies and to get these technologies widely disseminated.

The ECABREN and SABRN bean networks coordinate nine NARS in East Africa and ten NARS in southern Africa, respectively. These networks participate in Outputs 1, 2, 3 and 4 with input from African NARS cited above, plus NARS in Burundi (3), Sudan (2), Zambia (1), Zimbabwe (1), Mozambique (3), Lesotho (3) and Swaziland (3).

HarvestPlus Challenge Program: IFPRI, CIMMYT, and CIP are immediate collaborators in the CP and the AgroSalud (Latin American) nutritional improvement project, working in the same agro-ecological zones, while ICRISAT, IITA, IRRI, and ICARDA are indirect collaborators under HarvestPlus. ECABREN and SABRN networks in Africa also participate in HarvestPlus.

Generation Challenge Program: Partners include EMBRAPA-Brazil (2), INTA-Cuba (1), Pairumani (an NGO) in Bolivia (2), National University in Colombia (2).

Sub-Saharan Africa Challenge Program: ICIPE, AHI and NARS in Rwanda, Uganda and D.R. Congo are immediate partners.

Project Funding:

Budgeting 2005-2009

Year	2005 (actual)	2006 (estimated)	2007 (proposal)	2008 (plan)	2009 (plan)
US Dollars (millions)	2.941	3.965	3.638	3.510	3.462

CIAT PROJECT IP-1: BEAN IMPROVEMENT FOR THE TROPICS (2007-2009)

Targets	Outputs	Intended user	Outcome	Impact
OUTPUT 1	Improved, small-seeded, bean germplasm resistant to major biotic and abiotic stresses with greater nutritional and market value.	NARS and farmers in Central America, the Caribbean, Brazil, East and Southern Africa	Adoption of improved varieties by farmers	More stable production, food availability, better nutritional status and income
Output Targets 2007	• 5-10 interspecific BC1-F3 progeny between common bean and *P. coccineus* that broaden the genetic base for tolerance to aluminum; resistance to ALS, root rots, anthracnose; and/or high mineral content. • 10 lines combining drought and low fertility tolerance confirmed, beating checks by 40% under each stress.	• CIAT breeders • NARS breeders • Farmers in Latin America	• Breeders incorporate broader diversity into populations • Farmers adopt drought tolerant lines in drought prone areas of Latin America	• Improved productivity in marginal environments
Output Targets 2008	• At least 40 lines combining drought tolerance with resistance to BCMNV, root rots, and/or ALS available for testing in Africa • ~30 small seeded F3-derived F5 families developed with tropical adaptation, 60% more minerals, abiotic tolerance, and 2 resistances (HarvestPlus)	• NARS, NGO's and CBO's	• Drought tolerant lines with critical resistance genes are used in drought prone areas in Africa	• Yield stability
Output Targets 2009	• 50 improved lines with varietal potential and 90-100 ppm iron (ie, 80% more iron) • At least 10 genotypes combining drought tolerance with aluminium resistance available for testing in Africa • At least 3 snap bean lines with resistance to rust and quality characteristics preferred in regional and export markets.	• NARS, NGO's CBO's, health workers and consumers • NARS breeders, NGO's CBO's and traders and farmers, in target countries	• Adoption of micronutrient rich beans • Adoption of stress tolerant lines in marginal environments	• Improved household nutrition • Improved productivity in marginal soil environments • Improved incomes

Targets	Outputs	Intended user	Outcome	Impact
		in target countries	• Adoption of snap bean and reduced chemical use.	
OUTPUT 2	Improved, large-seeded, bean germplasm resistant to major biotic and abiotic stresses with greater nutritional and market value.	NARS and farmers in the Andean zone, the Caribbean, East and southern Africa	Adoption of improved varieties by farmers	More stable production, food availability and income
Output Targets 2007	• 15 new large-seeded bush lines with high mineral trait and resistance to 2 diseases, mainly in the red mottled and red seed classes (HarvestPlus).	• NARS and NGO's	• High iron lines adopted	• Reduced levels of iron and zinc deficiency
Output Targets 2008	• 15 new large seeded climbing beans with high mineral trait (HarvestPlus) • At least 10 lines in major market classes combining resistance to Pythium root rots, BCMV and angular leaf spot	• NARS, NGO's and farmers' groups	• Farmers incorporate high mineral and disease resistance lines into diverse production systems	• Reduced levels of iron and zinc deficiency • Improved food security, & income.
Output Targets 2009	• Large seeded lines with 50% more iron enter formal varietal release process • More disease resistance genes for anthracnose or ALS introgressed into BCMNV resistant climbing beans	• NARS breeders, NGO's, CBOs, and farmer groups	• Adoption of micronutrient rich beans	• Reduced levels of iron and zinc deficiency
OUTPUT 3	Strategies developed for managing diseases and pests in bean-based cropping systems.	Breeders, entomologists and pathologists in CIAT and NARS	Best bet IDPM practices and genetic combinations for stable resistance deployed.	More stable bean yields

Targets	Outputs	Intended user	Outcome	Impact
Output Targets 2007	• Method available to quantify 2 major soil borne pathogens (*Pythium ultimum* and *Fusarium solani*), as a tool to assess disease management strategies, and to refine management of resistance breeding nurseries. • Molecular markers for Pythium root rot resistance used in MAS	• Pathologists in CIAT and NARS	• Breeders focus breeding on resistance to relevant pathotypes. • Breeders deploy markers in genetic improvement	• Reduced yield losses from root rots
Output Targets 2008	• Molecular markers linked to ALS implemented in MAS • Molecular tools for detection, diagnosis and diversity studies of key ALS and anthracnose pathogens made available	• CIAT and NARS breeders • NARIs researchers in LAC, Africa, IARCs	• Breeders deploy markers and enjoy improved efficiency in genetic improvement • Disease and pest characterization tools adopted by researchers	• More stable resistance in advanced lines leads to stable yield
Output Targets 2009	• Three sustainable crop management options enhancing micronutrient density in beans characterized • Multiple gene combinations to manage ALS developed through MAS	• NARS soil scientists, pathologists, entomologists and food scientists • CIAT and NARS breeders	• Increased utilization of integrated management approaches. • Breeders use lines with stable resistance in breeding programs	• Improve production and nutritional value of bean • Reduced yield losses from ALS
OUTPUT 4	Approaches and methods developed and available for strengthening institutional, organizational and collaborative capacity of NARS and sub-regional networks in Africa and Latin America	NARS in Africa and Latin America	Improved institutional performance by NARS, NGOs and other partners, reflected in more effective technology development and dissemination	More stable production, improved food availability, income and nutrition, especially for the poor and women farmers

Targets	Outputs	Intended user	Outcome	Impact
Output Targets 2007	• Innovative approaches and tools developed and made widely available to partners in Kenya, Malawi, Uganda, and Tanzania for IPDM and marker-assisted selection of varieties. • Innovative approaches and tools for attaining wider impact developed and widely available to partners in DRCongo, Tanzania, Madagascar and Mozambique. • Methods and tools for participatory plant breeding developed and made available in 5 SABRN countries • Breeding programs for biofortification firmly established in Honduras, Brazil, Bolivia, Guatemala, Venezuela, Kenya and Malawi.	NARS, NGOs, CBOs and farmers. NARS, NGOs, and farmers NARS, NGOs, and farmers	• Increased use of IPDM strategies that enable R&D institutions to reach more farmers, and of marker-assisted methods that improve cost-effectiveness in breeding new varieties. • Partner organizations promote technologies and reach end users more effectively • Partners access tools and methods in multiple languages to empower themselves • National program breeders incorporate biofortification as primary goal	Reduced effect of diseases and pests leading to increased and more stable bean production by farmers Increased production and incomes Increased production and incomes
Output Targets 2008	• An IPM system for whiteflies on snap beans refined and promoted in major bean producing areas of the Andean zone • Training of trainer cadre set up to serve PABRA countries to assure continuity in methodology innovation in region	• NARS, NGO's, CBO's	• Farmers reduce pesticide use, assuring production and profitability • NARS incorporate innovation methods leading to greater breeding impacts	• Less pesticide intoxication in rural communities and urban consumers • Increased production and incomes. Needs of more diversified users met.

Targets	Outputs	Intended user	Outcome	Impact
Output Targets 2009	• Fast track micronutrient dense bean varieties disseminated and promoted in eastern and southern Africa • Methodologies for mainstreaming sustained wider impact developed and recommendations availed for East, Central and Southern Africa • An IPDM system for bean root rots implemented and promoted in major bean producing countries in Africa	• NARS, NGOs, CBOs, farmer groups, seed certification agencies, seed producers • NARS, NGOs, and farmers • NARS, NGOs, and farmers	• Increased use of iron and zinc rich beans • Increased partner involvement in accessing technologies to a greater number of end users • Farmers adopt IPDM practices, reducing losses from soil borne pathogens	• Reduced incidence of iron and zinc deficiency in target communities and countries • Increased incomes and production, and stable production systems from increased soil microbial diversity

CIAT PROJECT IP-3: IMPROVED CASSAVA FOR THE DEVELOPING WORLD

NARRATIVE PROJECT DESCRIPTION

Rationale & Changes

Rationale:

Cassava is a very rustic crop that grows well under marginal conditions where few other crops could survive. Most cassava varieties are drought tolerant, can produce in degraded soils, and are resistant to the most important diseases and pests. The crop is naturally tolerant to acidic soils, and offers the convenient flexibility that it can be harvested when the farmers need it. These characteristics make this crop a fundamental food security component in marginal agriculture land. In addition to its important role in subsistence farming and food security, cassava is acquiring an increased role in rural development as raw material for many industrial applications. The most important industrial uses of cassava are as a source of energy in animal diets in the feed industry, for the starch industry and, more recently for the production of ethanol.

The main objective of the IP3 project has traditionally been for a high and stable productivity (through breeding and adequate cultural practices), which remains a fundamental goal for the varieties to be grown by resource-limited cassava farmers. However, there is an increasing interest in cassava as cash crop and its industrial uses, which do not only require high and stable productivity but also would benefit from specialty cassava with specific properties. Unfortunately, very little effort has been made to make a qualitative improvement of cassava to better fit the needs of the different industries. The globalization of economies and new technological breakthroughs are offering a unique opportunity for cassava never available to the crop before. Tropical production of maize is facing increasing problems in competition with maize from temperate regions. This situation has prompted government and private sectors of many tropical countries to turn to cassava as a competitive alternative to imported maize. In addition, advances in molecular biology, genetic engineering, plant-tissue culture protocols and starch technologies provide important tools that will allow bridging the main gaps between cassava and the cereals. There are three main approaches that have been implemented to face the new opportunities and challenges for cassava in the third millennium, which are described below.

1. *More efficient breeding scheme*. For cassava to remain competitive, a more efficient breeding scheme, particularly for low heritability traits such as yield, has been implemented. Changes introduced ranged from simple approaches such as the stratification of evaluation trials all the way to sophisticated molecular approaches such as marker -assisted selection for resistance to the Cassava Mosaic Disease, which is not present in the Americas.

2. Qualitative traits. In addition to changes for a more efficient breeding system for quantitative traits (≈ low heritability) we have shifted the objectives of the project to produce high-value cassava based on qualitative traits. In addition to high and stable productivity the project started to pay attention to quality of cassava roots. The

HarvestPlus program will produce clones with enhanced nutritional value particularly in relation to carotenoids, Fe and Zn. For the **animal feed industry** and human nutrition, increased protein content is the main objective. Clones with three times the normal levels of proteins have been identified. For the **starch industry** novel starch types are of huge economic relevance. Different strategies have been implemented to develop these novel types and a diversity of mutations have been identified, and among them, the long sought after mutation for a waxy cassava starch. For the production of **bioethanol** we are searching for a "sugary" cassava that will store molecules simpler-than-starch facilitating the fermentation process. Such mutations have been identified and we are trying to gain access to them, so they can be incorporated in the main breeding process. Other identified mutations (high amylose, small granule size, etc.) may reduce the costs of enzymes used in the fermentation process.

3. Sustainable and competitive production. Cassava cultivation can lead to negative impact to the environment because it is typically grown in marginal environments, which are more susceptible to degradation; because it is grown by resource-limited farmers that have little flexibility or capacity to introduce sound agronomic practices because the increase their production costs; and because of the scarcity of research in developed countries that may contribute to a more sustainable production of cassava. CIAT and the valuable intervention of CLAYUCA are conducting research to reduce the negative impact that cassava cultivation may have on the environment. This research has been particularly important in Asia where the introduction of contour hedgerows has been successful.

Changes:

The discovery of cassava germplasm with unique quality traits such as the high-protein roots, the waxy starch and different starch mutants resulted in increased emphasis in the creation, evaluation and sharing of genetic stocks related to Outputs 1 and 3. Because of the time involved in the transfer or introgression of high-value traits into mainstream gene pools there will be a heavier emphasis in these activities than anticipated.

CG System Priorities:

CIAT's cassava project is housed principally under Priority area 2 (Producing more and better food at lower cost through genetic improvements). All the priorities listed within this area are considered by the project: Maintaining and enhancing yields and yield potential of food staples; Improving tolerance to selected abiotic stresses (in our case particularly drought, low-fertility soils and acid soils); Enhancing nutritional quality and safety (specifically cassava roots with enhanced protein, carotenoids, Fe and Zn); and genetically enhancing selected high-value species. The last priority somewhat relates to the concept of high-value cassava such as the development of what is basically a "new crop" such as a clone whose starch contains almost no amylose (waxy starch).

The cassava project is also connected with Priority Area 4 (Promoting poverty alleviation and sustainable management of water, land and forest resources). The cassava project has conducted extensive research for the last decade and a half to promote sustainable production of cassava in Asia, particularly in sloped land. The main emphasis has been promoting adequate fertilization and the use of hedgerows to prevent soil erosion. These

activities can be seen as related to priority 4D (Promoting sustainable agro-ecological intensification in low- and high-potential areas).

Our efforts to develop high-value clones relates to priorities Making international and domestic markets work for the poor (5B); Increasing income from livestock (3B), for instance through the development of clones with enhanced nutritional value; promoting conservation and characterization of staple crops (1A) and Promoting conservation and characterization of underutilized plant genetic resources (1B).

Impact Pathways:

Output 1 (Genetic stocks improved gene pools developed and transferred to national programs) describes the traditional breeding activities conducted by the project. A significant change in this activity has been the recent introduction of high-value traits in the list of objectives and this creates a connection with Outputs 2 and 3. All these Outputs ultimately involve the same end-users but with varying emphases: national research programs; the processing sectors; cassava farmers and rural communities; and production chains. Whereas this is true for Asia and Latin America and the Caribbean, in the case of Africa, we have the additional presence of IITA.

Output 1 involves the development of improved germplasm to be shared, typically through NARs and IITA, with cassava farmers. Because of the diversity of environments where cassava is grown and the frequency of different production constraints, this germplasm has to have specific traits that allows it to adapt to these conditions characterized by biotic and/or abiotic stresses. The main outcome for this Output is the consolidation and strengthening of cassava based agriculture by developing a germplasm that will allow for a high and stable productivity. A competitive production of cassava is a key factor to be able to compete with other commodities, typically (imported) maize. The competitiveness of cassava can be increased considerably with the introduction of high-value traits, which is the main objective of Output 3. The way germplasm is shared is through direct shipment of *in vitro* plants from outstanding clones identified in CIAT's breeding activities in the sub-humid, acid soils, or mid-altitude valleys environments. In addition CIAT routinely produces and ships thousands of botanical seeds to NARs and IITA, who initiate evaluation and selection schemes with this seed. Assumptions for the successful delivery of these outputs include institutional and financial stability of partners, political stability, and institutional support. It is always a matter of concern the phytosanitary restrictions for the shipment of plants in vitro. The African Cassava Mosaic Disease is not present in the Americas. If the disease (or a similar one) appeared in Colombia, the shipment of germplasm in vitro would be greatly hampered. The role of CIAT is that of a primary research provider of the improved germplasm. It is important to emphasize that, at times, our role is of secondary research provider exploiting traits or elite germplasm developed (and generously shared) by NARs. *Manihot esculenta* originated and was domesticated in the region where CIAT is located. Consequently most pest and diseases have co-evolved with cassava in the region. This implies that CIAT has to be extremely cautious in the process of shipping germplasm outside the region by a thorough indexation process to prevent the shipment of pathogens and/or pests as well.

Output 2 (New methods for cassava breeding developed) relates to Output 1 because for cassava to remain competitive, efficient breeding methods need to be developed and implemented. It also related to Output 3 because these new breeding methods must facilitate the discovery and identification of useful, high-value traits. The intended users of this Output are mostly NARs involved in cassava breeding projects. Eventually a processing company may make the significant jump to start its own breeding project, as was the case for several years of a large company in Indonesia. The product of this output is knowledge, which is shared with the intended beneficiaries through scientific publications, training courses, conferences and presentations at scientific meetings. An important vehicle is personal communication through internet, including CIAT Webpage. The products of this Output range from the identification of traits to be selected for (i.e., leaf retention); methods for determining breeding values of parental lines; the use of selection indexes; the development of a protocol for the production of doubled-haploids; the introduction of inbreeding; and of course, the identification and use of molecular markers. The outcomes of this output will be more efficient breeding system that will allow cassava remain competitive in the global markets, but also a subtle consequence will be the stimulus for cassava breeders that a new era of advanced technologies has arrived for cassava. This is important because cassava is typically an undervalued crop within the NARs systems. The role of the cassava project at CIAT is mostly as primary research provider. Because of the strong links with partners there is a flow of information among us and, therefore, our role may also be of secondary research provider exploiting ideas developed by NARs. In the case of the activities related to the development of a protocol for the production of doubled-haploids there is an interaction with Wageningen University in which CIAT may be the secondary research provider, depending on the evolution of the research conducted. CIAT role can also be seen as catalyser promoting the incorporation of new ideas into cassava genetic improvement. Doubled-haploids are a promising avenue for the rapid production of homozygous cassava, which offers many advantages (identification of useful recessive traits, elimination of genetic load, making possible the implementation of back-cross, facilitated shipment and exchange of germplasm, facilitated genetic studies, etc.) in the genetic improvement of cassava

Output 3 (Research on the industrial uses of cassava and elite germplasm produced) relates with Outputs 1 and 2 as described above. The end-users are national research programs; the processing sectors; cassava farmers and rural communities; and production chains. The emphasis, however, are the processing sectors and production chains. A new actor that is not as important for the other Outputs are Universities in developed and developing countries. A good example of the economic relevance of the outcomes of this output is when cassava is used as source of energy in animal feed. Its price cannot be higher than 70% of the price of maize. This is because of the lower protein content in the roots. A cassava clone with 8% protein in their roots (dry weight basis) would make the value of that root similar to that of maize. The immediate consequences of deploying such cassava germplasm would be that the income of farmers will increase; the feed industry will be more interested in incorporating cassava roots in their feeds; and because there is an intermediate process (drying the roots) which typically takes place near the production fields, there will be enhanced economic activity in rural communities as well. Assumptions for the successful delivery of these outputs include institutional and

financial stability of partners, political stability, and institutional support. CIAT can be the primary research provider but also may act as secondary provider, if it was a partner who discovered the high-value trait. A key collaborator in this case is EMBRAPA-Brazil because of the wealth of genetic variation found in that country for *Manihot* species. This collaboration may result in a study case for the exploration, analysis and exploitation of Manihot species different from cassava because they have not been included as those with facilitated access in the International Treaty on Plant Genetic Resources for Food and Agriculture. The targeted end-users that will benefit from this Output are ultimately the actors of the production chains involved in the production of animal feed (higher nutritional value, particularly the high-protein trait); starches (novel types such as the waxy starch) and ethanol for vehicles (roots that store energy in molecules simpler than starch).

The ultimate beneficiaries of Output 4 (Development and use of biotechnology tools for cassava improvement) are farmers and rural communities growing and processing cassava. However, our immediate contacts are the NARs in Africa, Asia and Latin America from countries where cassava is grown; but also Universities from developed and developing countries and private sector. This Output is closely related to the second one and, therefore, one of the expected outcomes is a more efficient breeding system. A subtle, but significant, outcome is that cassava will attract young scientists who will see cassava not as a neglected crop but as a promising alternative for tropical agriculture and a challenging opportunity for their professional development. CIAT's role is clearly as a primary research provider. Because many of the biotechnology tools are developed for other crops CIAT role, in some cases, can be seen as a secondary research provider when adapting these technologies to cassava. In some instances CIAT role can also be as facilitator or advocate for some of these technologies, frequently affected by proprietary rights, made available to cassava. Of particular relevance is the fact that we can now select in Colombia for germplasm that is resistant to a disease not present in the Americas (ACMD). This is very important because it facilitates greatly the flow of germplasm from CIAT to Africa, knowing in advance that it will possess a high frequency of clones with the critical trait for their survival in that target environment. Furthermore molecular markers facilitate the pyramiding of genes against the same disease or the accumulation of sources of resistance to different pests and diseases.

Output 5 (Breeding for insect, arthropods and disease resistance and development of alternative methods for their control) has been an integral part of the cassava-breeding project at CIAT since its inception. The ultimate end-users of the results of this income are the farmers that grow cassava. However, the immediate beneficiary may be different. For the exploitation of genetic resistance to pests and diseases the breeding projects from CIAT, IITA and NARs are clearly the first one benefiting from these products. For approaches related to the biological control of diseases and pests NARs can promote their use but farmers can almost immediately benefit from implementing them. In addition to farmers rural communities benefit from the positive impact that these approaches have on the environment by preventing or reducing the uses of agro-chemicals. These technologies also have a direct impact on the production costs and/or the sustainability of cassava productivity. CIAT's role is as a primary (in some instances as secondary)

research provider. An interesting impact from this Output could be a benefit to other crops grown in temperate regions. For instance, cassava is probably the only crop susceptible to white flies that offers a genetic resistance to this pest. It is conceivable that the source of the resistance can be identified, cloned and transferred to other crops so that an additional tool to control "the pest of the century" becomes available.

Increasing the productivity of cassava in Asia using farmer participatory methods is Output 6. Farmers are the end-user of this Output. The expected outcomes are improved yields and more sustainable production in target countries; increased and more stable income for farmers (for example through improved nutrition and health of farm animals fed with cassava roots and foliage especially during the dry season); and more alternatives for the use of cassava products open to farmers. A key activity is the promotion of adequate fertilization practices and the use of hedgerows to prevent soil erosion in sloped land. NARs are also beneficiaries because the participatory methodologies employed were introduced through this project and is now used for other purposes in the region. The focus of this Output has gradually changed over the years. Whereas prime agriculture areas (for cassava standards) of Thailand were the target ten years ago, now the project concentrates in more marginal environments and resource-limited farmers in Cambodia, Laos and East Timor. CIAT's role is as a primary (in some instances as secondary) research provider. Because of the very nature of this Output, CIAT's role can also be envisioned as an advocate or catalyst for the development and deployment of sound agricultural practices. Assumptions for the successful delivery of these outputs include institutional and financial stability of partners, political stability, and institutional support. In the particular case of our operations in Asia, we are through an inter-phase because the scientist that has been working in cassava research during the last 20 years is close to retirement and a replacement (and the resources required for the position) will soon be needed.

The last Output (# 7) relates to the activities conducted by CLAYUCA (Latin American and the Caribean Consortium on Cassava Research and Development). Therefore it does not originate on activities conducted by IP3 project itself, but it is the result of a productive and close collaboration between the two research groups. The main outcome related to the interaction between CLAYUCA and IP3 is the adaptation and/or promotion of technologies and products developed by IP3 efficiently done by CLAYUCA. The strategic positioning of CLAYUCA as a bridge between IP3 project and NARs associated with CLAYUCA has been of great help in making these technologies and products available to NARs. In this regard CIAT can be seen as a secondary research provider and in many ways as a beneficiary of CLAYUCA's activities.

International Public Goods:

There are two main types of products developed by the cassava-breeding project at CIAT: knowledge and improved germplasm (including genes and DNA sequences). The project has been successful in writing a large number of research articles describing and sharing the knowledge and discoveries made in our project with the scientific community. The distribution of germplasm is cumbersome because of the phytosanitary restrictions imposed in the movement of in vitro vegetative tissues from country to country.

Nonetheless CIAT has been generous and responsible in making the germplasm collection and improved clones available to NARs. CLAYUCA has played a fundamental role in the introduction of many elite clones to its member countries.

The existence of the world cassava germplasm collection at CIAT offers us a unique situation to screen the germplasm in search of useful traits. It has been from the collection that a unique source of resistance to white flies was found. The search of high-value traits finds the collection a valuable source of genetic variability as well. In most cases these traits are readily made available to partners and collaborators. For instance the high-protein trait will soon be shared with IITA through a collaborative project that will hopefully be financed by Germany's BMZ and GTZ. Because of the declining core resources for the genetic improvement of cassava in some cases CIAT may develop strategic alliances with the private sector for their access to specific traits. This will generate resources that allow us to continue the activities that are considered strategic but that, unfortunately, do not receive the necessary funds from the system.

Partners:
A key partner for IP3 project is CLAYUCA with whom it interacts on a day-to-day basis, complementing or benefiting from its work and presenting join research proposals. This document does not mention specifically all and each one of the activities where CLAYUCA and IP3 collaborate but the reader should be aware of this close partnership.

Africa. IITA in Nigeria is a key partner in the deployment of knowledge and germplasm developed by CIAT in Africa. Since it is another CG Center we prefer not to mention their contributions to the different partnerships. National Research Programs of Africa include those of **Tanzania** (0.5); **Uganda** (0.5); **Kenya**; **Ghana** (0.5); **Nigeria** (0.5); **Mozambique** and **South Africa**. These countries contribute with access to field and laboratory facilities and, within parenthesis, the time of scientists directly involved with collaborative special projects.

*Asia.***Thailand**: Department of Agriculture (0.25), Field Crops Research Institute (2) and Kasetsart University. **Vietnam:** Thai Nguyen University (1); National Institute of Soils and Fertilizers; Hue University of Agriculture and Forestry (0.25); and Institute of Agric. Sciences (1). **China:** CATAS – Hainan (0.25). **Laos**: National Agric. and Forestry Research Institute (NAFRI) (1) and Provincial Agric. Forestry Offices (1). **Cambodia**: Cambodia Agric. Research and Developm. Inst. (CARDI) (1); Provincial Dept. Agric. For. Fish (1); CelAgric; C.J Cambodia Co. **India**: CTCRI (0.25). These countries contribute with access to germplasm, field and laboratory facilities and, within parenthesis, the estimated time of scientists directly involved with collaborative special projects.

Latin America and the Caribbean. **Brazil**: EMBRAPA-CNPMF (2); EMBRAPA-CENARGEN; IAC-Campinas. **Colombia**: CORPOICA (1); National University of Colombia (0.2);. **Venezuela**: Agropecuaria Mandioca (0.5); Universidad Central de Venezuela; INIA (0.5). **Cuba**: INIVIT (0.5); and CLAYUCA (2). These countries/institutions contribute with access to germplasm, field and laboratory facilities

and, within parenthesis, the estimated time of scientists directly involved with collaborative special projects.

Advanced Laboratories in Developed Countries. Wageningen University in The Netherlands (0.25); ETH – Zurich, Switzerland (1); Ohio State University in USA; Danforth Center (0.5) in USA; Uppsala University in Sweden (0.25). Collaboration between CIAT and these Laboratories is in joint projects where a field worker or a post-doctoral fellow is involved.

Private Companies. National Starch Company (USA / UK). AVEBE Starch Company (The Netherlands); Corn Products (Colombia and Brazil) Cassava Starch Manufacturing Mill (South Africa); Nigeria Starch Mill (Nigeria); PETROTESTING (Colombia) (1); DESARGO Ltda (Colombia). In most cases, these companies have been supporting cassava research at CIAT and also benefiting from it. One assistant originally working under CIAT payroll is now paid by PETROTESTING to develop clones adapted to the acid soil environment specifically for the production of ethanol.

Presence of the project in the world:

As described in the introductory paragraph the activities of the cassava improvement project can be broadly divided into three large categories around breeding, production practices and processing. It is acknowledged that not all these activities can be directly conducted by the project, nor that there is a need for this approach. The project benefits from the collaboration with other key institutions such as CLAYUCA and IITA. Below is a brief description of how the IP3 project interacts with different partners to address these objectives and to maximize the probabilities of having a positive impact.

	LAC	Asia	Africa
Breeding	Direct and through collaboration with partners.	Through collaboration with key partners	Direct and through strong collaboration with IITA
Production	Through a leadership by CLAYUCA	Direct work supported by NIPPON foundation and through collaboration with partners.	Activity mostly conducted by IITA but certain specific work done by CLAYUCA under contracts with private sector.
Processing	Through a leadership by CLAYUCA and collaboration with partners	Through collaboration with key partners, particularly in the private sector	Through collaboration with key partners in the private sector and through the leadership by IITA

Project Funding:

Budgeting 2005-2009

Year	2005 (actual)	2006 (estimated)	2007 (proposal)	2008 (plan)	2009 (plan)
US Dollars (millions)	3.356	3.145	2.747	2.650	2.614

CIAT PROJECT IP-3: IMPROVED CASSAVA FOR THE DEVELOPING WORLD (2007-2009)

Targets	Outputs	Intended users	Outcome	Impact
OUTPUT 1: Genetic stocks improved gene pools developed and transferred to national programs.				
Output targets 2007, 2008, and 2009	Generation, identifica-tion and transfer to national programs of elite cassava germplasm with high and stable productivity	National research programs and cassava farmers and communities in Africa, Asia and Latin American and the Caribbean (LAC).	Consolidation and strengthening of cassava-based agriculture.	Increased and stable income of cassava farmers and processing facilities. Enhanced food security of rural communities that grow cassava. Rural development.
Output targets 2007	Identification, indexation and transfer to national programs of cassava clones with higher than normal crude protein levels (> 5 %).	National research programs, private sector, processing companies and cassava farmers in Africa, Asia and Latin American and the Caribbean. Universities and advanced laboratories in developed countries.	Enhanced interest of the feed industry (domestic and export markets) to incorporate cassava as source of energy in the diets but with the additional advantage of the reduced or no need for additional sources of protein.	Enhanced nutritional status of people consuming higher-protein roots. Increased value and stronger markets for cassava products. Alternative sources of raw material for the feed industry.
Output targets 2008	Identification, indexation and transfer to national programs of cassava clones identified particular starch quality traits.	National research programs, private sector, processing companies and cassava farmers in Africa, Asia and Latin American and the Caribbean. Universities and advanced laboratories in developed countries.	Enhanced interest of the starch industry (domestic and export markets) to incorporate cassava as source of raw material in their operations.	Increased value and stronger markets for cassava products. Higher income of cassava communities. Reduced environmental impact in the process of production of modified starches.

Targets	Outputs	Intended users	Outcome	Impact
Output targets 2009	Production and shipment of botanical seed combining the high-protein trait with adaptation to different environments.	National research programs, private sector, processing companies and cassava farmers in Africa, Asia and Latin American and the Caribbean.	Enhanced interest of the starch and feed industries (domestic and export markets) to incorporate cassava as source of raw material in their operations. First steps for the exploitation of high-value traits.	Enhanced nutritional status of people consuming higher-protein roots. Increased value and stronger markets for cassava products. Higher income of cassava communities. Reduced environmental impact in the process of production of modified starches.
OUTPUT 2: New methods for cassava breeding developed				
Output targets 2007	First systemic study of inbreeding depression in cassava conducted and published.	Scientists from national programs, IITA and universities in developing and developed countries.	Proof of concept that inbreeding of cassava facilitates its genetic improvement. Sustained and faster genetic gains for cassava to compete with other crops like maize.	Increased and more stable income of cassava farmers and processing facilities. Enhanced food security or rural communities that grow cassava.
Output targets 2008	Results of a scientific meeting to discuss approaches to exploit heterosis in cassava made public	Scientists from national programs, IITA and universities in developing and developed countries.	Strategies to exploit heterosis in cassava defined by the maize breeders that did the same in that crop 40 years ago. Better hybrids will lead to increased and more stable income of cassava farmers and processing facilities	Increased and more stable income of cassava farmers and processing facilities. Enhanced food security or rural communities that grow cassava. Alternative approaches for breeding other tropical crops. Sustained and faster genetic gains for cassava to compete with other crops like maize.

Targets	Outputs	Intended users	Outcome	Impact
Output targets 2008 and 2009	Comparison of the first hybrids from partially inbred parental clones versus ordinary hybrids. Inbred parents have reduced genetic load and should produce better hybrids.	Breeders from national programs, IITA and universities in developing and developed countries. Scientists working with other crops in developing and developed countries	Better hybrids will lead to increased and more stable income of cassava farmers and processing facilities	Increased and more stable income of cassava farmers and processing facilities. Enhanced food security or rural communities that grow cassava. Alternative approaches for breeding other tropical crops. Sustained and faster genetic gains for cassava to compete with other crops like maize.
OUTPUT 3: Research on the industrial uses of cassava and elite germplasm produced				
Output targets 2007	Evaluation of S1 plants from mutagenized cassava and results of TILLING.	Scientists from national programs, IITA and universities in developing and developed countries.	Identification of commercially useful cassava mutants. Proof of concept of the adaptatio of novel technologies to cassava	Identification of a cassava mutant with waxy starch has been always requested by starch industry. Better competitiveness of tropical agriculture.
Output targets 2008	Field evaluation of first cycle of recurrent selection for high- or low-amylose starch.	Scientists from national programs and universities in developing and developed countries. Starch industry.	Cassava breeding projects learn to interact with processing sector and deliver products better suited for their needs. Shift in breeding objectives and menthods at NARs.	Enhanced industrial uses of the crop. Stronger markets for cassava. Rural development in cassava growing communities and reduction of poverty. Alternative sources of financing cassava research in Africa, Asia and LAC.
Output targets 2009	Results of quality of protein in high-protein cassava roots, and their use in animal feeding.	Scientists from national programs, IITA and universities in developing and developed countries. Feed industry.	Clear, scientifically-based conclusions on the additional value of high-protein cassava. Information on the formulation of animal feed based on high-protein cassava roots.	Enhanced industrial uses of the crop. Stronger markets for cassava. Rural development in cassava growing communities and reduction of poverty. Increased income from livestock production of cassava growers.
OUTPUT 4: Development and use of biotechnology tools for cassava improvement				

Targets	Outputs	Intended users	Outcome	Impact
Output targets 2007	Development of markers for high-carotene content in roots. First evaluation of transgenic cassava. in the field	Scientists from national programs, IITA and universities in developing and developed countries.	Cassava is no longer a *neglected* crop: new tools adapted for their application contribute in its genetic improvement. More efficient cassava breeding.	Increased and more stable income of cassava farmers and processing facilities. Enhanced food security or rural communities that grow cassava, particularly.
Output targets 2007	Analysis of homozygosity levels using molecular markers in relation to inbreeding depression.	Field and molecular breeders from national programs, IITA and universities in developing countries.	Better understanding in the genetic structure of cassava. More efficient approaches for the genetic improvement of cassava.	Increased and more stable income of cassava farmers and processing facilities. Enhanced food security or rural communities that grow cassava, particularly. Cassava joining the group of crops that are well understood.
Output targets 2008	Identification of root promoters for genetic transformation using genes to be expressed in the roots.	Molecular breeders from national programs and universities in developing and developed countries.	Cassava roots are its more important economic product, identification and cloning of root promoters are fundamental for the genetic transformation of the crop with genes affecting root quality traits.	Improved nutritional conditions of communities where cassava is an important component in the diet. More efficient breeding methods will lead to faster and more consistent genetic gains. Root promoters found in cassava can help other root and tuber crops, as well. Enhanced economic value of cassava.
Output targets 2009	Progress in the development of a protocol for the production of doubled haploids in cassava.	Field and molecular breeders from national programs, IITA and universities in developing and developed countries. Scientists working with rubber tree.	Introduction of inbreeding in cassava is a key step for a drastic and necessary change for its genetic improvement. Inbreeding through successive self-pollinations is proving to be very difficult.	More efficient breeding methods will lead to faster and more consistent genetic gains. Increased and more stable income of cassava farmers and processing facilities. Enhanced food security or rural communities that grow cassava, particularly.

Targets	Outputs	Intended users	Outcome	Impact
				This approach taken in cassava can help other long-cycle crops such as tropical fruits.
OUTPUT 5: Breeding for insect and other arthropods and disease resistance and development of alternative methods for their control.				
Output targets 2007	Significant progress in identifying the resis-tance gene(s) for white flies found in cassava germplasm (MECU 72)	Field and molecular breeders and entomologists from national programs, IITA and universities in developing and developed countries.	White flies are the vector of Com the CMD. Combining resistance to the vector and the disease provide a stable and effective solution to the CMD problem in Africa.	Sustainable cassava production. Potential benefit to other crops in developed countries (e.g. tomato in Europe) leading to a reduction in the use of pesticides. Improved health and productivity of cassava.
Output targets 2008 and 2009	Crosses with 7 or more wild *Manihot* species to introgress genetic variability in search of resistance genes for insects and diseases.	Breeders, entomologists and pathologists from national programs, IITA and universities in developing and developed countries. Cassava farmers.	Better understanding and exploita-tion of the genetic variability in the *Manihot* gene pool. Justification for the need of exploration and conservation of genetic resources.	Proof of concept for cassava of the value represented by related Manihot species. Increased collaboration with Brazilian and African research institutions. Improved health and productivity of cassava.
OUTPUT 6: Increasing productivity of cassava in Asia using farmer participatory methods				
Output targets 2007	On-station research on cassava leaf production, preparation of root and leaf silage and more productive pig and goat feeding.	Research and extensionists from national programs cassava farmers and/or small scale processors. Cassava breeders at HQ and NARs in Africa and IITA. Households involved in swine production, particularly the women that typically are in charge of feeding them.	Improved nutrition and health of farm animals fed with cassava roots and foliage, especially during the dry season. Enhanced research capacity of NARs Alternatives for the use of cassava products.	Increased and more stable income of cassava farmers. Enhanced food security of rural communities that grow cassava. Improved conditions of women who typically are responsible of feeding pigs in households of may different countries. Poverty alleviation.

Targets	Outputs	Intended users	Outcome	Impact
Output targets 2007, 2008 and 2009	Farmer participatory research trials on newly introduced clones and the use of balanced fertilization in East Timor, Laos, Cambodia	Research and extensionists from NARs, cassava farmers and/or small scale processors. Breeders at HQ and NARs in Africa and IITA. Cassava farmers.	Improved yields and more sustainable production of cassava in Laos, Cambodia, East Timor and Indonesia.	Increased and more stable income of cassava farmers. Reduction of the negative impact on the environment of cassava cultivation, particularly in marginal sloped land.
Output targets 2007, 2008 and 2009	Increased adoption of improved varieties, balanced fertilization, and soil conservation practices.	Research and extensionists from national programs cassava farmers and/or small scale processors. Cassava breeders at HQ and NARs in Africa and IITA. Cassava farmers.	Improved yields and more sustainable production of cassava in Laos, Cambodia, East Timor and Indonesia.	Increased and more stable income of cassava farmers. Reduction of the negative impact on the environment of cassava cultivation, particularly in marginal sloped land.
OUTPUT 7. Latin American and the Caribbean Consortium on Cassava (CLAYUCA).				
Output targets 2007	Nutritionally enhanced germplasm evaluated in farmer conditions in 3 Colombian sites. Research on different processing approaches.	Cassava agro-industrial projects in Colombia and other countries in the region.	High-value cassava germplasm available for agro-industrial projects, national research programs, cassava producers and processors.	Higher economic value for cassava production systems. Rural development in cassava growing communities.
Output targets 2008	Cassava foliage productions systems validated under commercial conditions and improved cassava germplasm for foliage production identified.	Cassava agro-industrial projects in Colombia and other countries in the region, Asia and Africa.	Cassava foliage consolidated as a raw material for animal feeding systems.	Higher income for cassava farmers. Enhanced food security. South-to-south cooperation

Targets	Outputs	Intended users	Outcome	Impact
Output targets 2009	Results of studies to produce ethanol out of cassava roots.	Cassava projects for the production of ethanol (from cassava and other starch crops) in Colombia and other countries in the world.	Cassava roots consolidated as a raw material for the production of ethanol. Better understanding of the interaction between germplasm and processing in the production of ethanol.	Higher economic value for cassava production systems. Rural development in cassava growing communities.

CIAT PROJECT IP-4: IMPROVED RICE FOR LATIN AMERICA AND THE CARIBBEAN

NARRATIVE PROJECT DESCRIPTION

Rationale & Changes

Goal:
To generate food security and employment associated with rice production with emphasis on improving the options for the small farmers.

Objective:
To produce robust high yielding rice varieties requiring lower inputs, we will provide well-characterized progenitors and advanced materials with an ample genetic base as well as information and training.

Research Outputs:
Our research is organized around three major outputs.
1) Enhanced gene pools
2) Integrated crop, pest and disease management
3) Intensification and diversification of rice cropping systems for small farmers.

Rationale:
There are opportunities for growth in the rice sector, because land and water are more abundant in Latin America than in other rice growing regions. The rice sector faces risks because there is a trend for more open markets and many countries subsidize rice production. Most rice producers are small to mid size farmers, and the governments in this region tend not to subsidize rice production. The Rice Project focuses on strengthening the rice sector, in the low and mid altitude regions of Latin America and the Caribbean. Our activities focus on problems that are locally important, and especially in the area of pest and diseases many of these constraints are unique to Latin America and the Caribbean. Our rice breeding activities are for both irrigated and upland rice.

We concentrate on developing advance materials with broad genetic diversity that incorporates a range of grain quality traits and resistance to the pest and diseases common in this region. To increase the genetic diversity, we work with interspecific crosses, composite populations and are developing biotechnology methods that allow the incorporation of traits more efficiently. These activities are generating both segregating populations and advanced lines, which are transferred to partners through either bilateral agreements or networks including FLAR, GRUMEGA and INGER. Our partners are then able to select advanced lines, or make their own selections from the segregating populations. These materials also serve as a source of parents in the breeding activities of our partners.

Unlike Asia, most of the rice in Latin America is planted by direct seeding. Since many small farmers do not have irrigated infrastructure, we are increasing our research on rice that has better tolerance to water stress and / or has increased efficiency in water use. This is a global effort that is being coordinated through the Generation Challenge Program.

We have been developing upland rice breeding populations and advanced lines for many years. The tendency in Latin America has been a decline in total area of upland rice but an increase in yields in those areas that remain in production. Improved varieties have made excellent impact in the upland rice ecosystems. Jointly with the Biotechnology Research Unit and in collaboration with JIRCAS (Japan), gene technology is being explored as an alternative to incorporate increased efficiency in water use for the irrigated rice ecosystems targeting reduction of water consumption.

For the small farmers, jointly with our partners, we put in place participatory variety selection and breeding schemes in different agro system of Central America. Early maturity, vigorous, high yielding varieties with adequate grain quality are some of the traits selected by farmers and helps gives their families the food security needed to experiment and adopt higher value crops. The recent activities to develop rice with higher levels of iron and zinc is being funded by CIDA-Canada in collaboration with Harvest Plus and should lead to the development of naturally biofortified varieties that will provide better nutrition for both the rural and urban rice consumers.

To sustain yields preventing the pressure of pests and diseases, we work in collaboration with our partners to disseminate Integrated Crop Management practices. FLAR has been active in promoting Integrated Crop Management Practices. With water becoming a more expensive and/or scarce resource and the need to produce rice at competitive prices, we are working with FLAR and other partners to develop a comprehensive set of management guidelines to reduce inputs while increasing yields. These activities are information intensive and require local support to be successful.

Significant Changes:

While the output targets for 2006 remain the same, the CIAT rice project is developing closer ties with both IRRI and WARDA. Part of the Output Target "Integrated Crop and Pest Management information developed and available in print and electronic media" in 2007 is the translation of documents from the IRRI Rice Knowledge Bank. In the area of genetic resources, CIAT and IRRI will increase our activities for INGER in Latin America.and the Caribbean. We have also agreed to the development of a common database for our genetic resources. Locally, GRUMEGA is developing a nursery that will include many of the best varieties throughout Latin America. Another area of change is the increase in cooperation between the FLAR integrated crop management activities and the integrated pest management activities of CIAT as well as in the breeding activities. In the area of Interspecific crosses, we are shifting our focus to *O. latifolia* which is a species that is native to the Americas.

During 2006, the core resources for the rice project have been significantly reduced. These changes are reflected in the consolidation or elimination of several of the Output Targets. The 2007 Output 2 target "Characterization and development of markers for 6 major rice blast resistance genes" has been incorporated into the 2008 Output 1 target "Implementation of Marker Aided Selection techniques for quality traits, RHBV and Rice Blast in varietal development".

The 2008 Output 2 target "Advanced sources of Rhizoctonia resistance available for at least five countries of LA" has been eliminated and activities in this area have been reduced. The rice project has decided to integrate the participatory rice breeding activities which were being reported in 2008 Output 3 target "Varieties and management practices developed for small rice farmers using participatory methods in 6 countries in LAC" with the Output 1 in 2008 "Integrated regional collaboration for the use and development of rice genetic resources through networking will result in at least 10 new varieties". This output was previously reported for 2009. The marker aided selection Output 1 target has been moved from 2008 to 2009.

CG System Priorities:

The Rice Project promotes the conservation and characterization of the relatives of rice. Red rice, which is a major weed is also being characterized, both to understand the origin of this pest and to consider using it as a new source of genetic diversity for selected traits. The following species: *O. glaberrima*, *O. rufipogon*, *O. barthi*, *O. glumaepatula, O. meridionalis* and most recently *O. latifolia* were crossed with cultivated rice (*O. sativa*) in efforts to increase the biodiversity of rice varieties and introduce traits of importance to Latin America. The Rice Project develops breeding populations and advanced lines with traits that include high yield, good grain quality, early vigor, strong tillers, tolerance to water stress, rice blast, Rhizoctonia, rice hoja blanca virus and the plant hopper *T. orizicolus*. More recently in collaboration with IRRI, we have started enhancing the nutritional quality of rice by developing lines that are higher in iron and zinc. This output is reflected in the CIAT project SB-2. The pest and disease traits that are incorporated into the new varieties are helping the farmer to reduce the use of pesticides. Using integrated crop and pest management is central to producing a sustainable agro-ecological system. The efforts to develop rice with better water use efficiency benefits the rice farmers with the least amount of infrastructure and should lead to the reduction of water in the irrigated systems.

Impact Pathways:

The Rice Project focuses on strengthening the rice sector, in the low and mid altitude regions of Latin America and the Caribbean. Our research is organized around three major outputs: 1) Enhanced gene pools; 2) Integrated crop, pest and disease management; 3) Intensification and diversification of rice systems for small farmers.

Output 1: Enhanced Gene Pools

This output is concerned with the characterization of genetic resources and how to use them efficiently.

The Future Harvest (CGIAR) rice genetic resources are held in IRRI, WARDA and CIAT. We are collaborating to ensure that this important public good becomes characterized and catalogued in a manner that makes it more accessible to the community of rice researchers. INGER is a network, which facilitates access to these materials.

We maintain many activities with other advanced research institutions and these activities contribute to bring recent technologies to the regional partners. These generate knowledge and technologies that include functional genomics, marker aided selection, transgenic rice, gene flow studies, biosafety and biofortification. Many of these activities are housed in the Biotechnology Research Unit and Agrobiodiversity Project of CIAT.

The CIAT contribution to regional varietal development has included populations that were derived from both *O. sativa* and other relatives. We attempt to develop populations with a high degree of diversity, yet include many important traits of agronomic importance. The parents of these populations normally include germplasm from our sister Future Harvest centers. CIRAD has also been a source of parental materials. We also have been in the forefront of new methods for rice breeding. The two principal methods are Recurrent Selection and Marker Aided Selection. Recurrent selection is an activity that has been promoted through GRUMEGA. During the last 10 years, it has held many Rice Breeder Workshops and many local partners have populations and advanced rice lines from these activities. This year, the second rice variety that was developed by recurrent selection was released in Bolivia by CIAT Santa Cruz and ASPAR.

We are a member of FLAR and most of the FLAR germplasm is developed using some of the CIAT germplasm. FLAR includes some of the strongest rice research institutions in Latin America and this is a valuable source for Germplasm Enhancement as well as other forms of collaboration.

The Regional Rice partners are responsible for the release of varieties, which is the main impact of Output 1. A very high percentage of the new rice varieties contain CIAT germplasm. Many of the varieties were developed into advanced lines before they were selected by our partners. The need for germplasm is highly variable and depends on the amount of rice production in a given country. In general, the less rice that is produced the more these programs need advanced materials. The larger rice programs use germplasm and segregating populations to make their own selections.

Output 2: Integrated Crop, Pest and Disease Management.

The breeding for resistance activities that are part of this output are integrated with the activities of Output 1 and achieve impacts through the same mechanisms and partners.

The characterization of the pest and diseases are an essential part of this output. This work is often done in collaboration with ARI or national partners. An example of the collaboration is the analysis of why the variety Llanos 5 has maintained stable (durable) resistance to rice blast for more than 15 years. This study was conducted with Kansas State University and has elucidated that both major and minor genes are contributing to the stable resistance. This information is being used in the breeding activities and in the development of molecular markers for this disease. A molecular analysis of resistance to rice hoja blanca and its vector are also being done.

The counterpart of the plant resistance is the diversity of the pathogens and pests. We have conducted extensive analysis of the diversity of the rice blast fungus. Similar characterization is being done for the causal agent of sheath blight. This can help determine which varieties could be deployed to mitigate losses or applications of pesticides.

The management of pest and diseases cannot be separated from crop management. FLAR is active in promoting Crop Management practices that are helping to increase the yields and lower the cost of rice production. We are working to combine IPM with the Crop Management to maximize the benefits. These activities depend on extension activities and high levels of collaboration. We have initiated in 2006, a project to study in select rice pathogens, the development of resistance to fungicides. The objective is to develop management strategies that mitigate the probability of pathogen resistance to fungicides through the judicious use of the pesticides. This should lead to lower pesiticide use which benefits the farmers and environment.

Output 3: Intensification and diversification of rice cropping systems for small farmers.

This activity includes participatory rice breeding and the main mechanism is working with farmer organizations. The small farmers generally have the least amount of land, equipment, irrigation systems, and credits (infrastructure) and need upland or aerobic rice varieties that use water and fertilizers efficiently. This activity integrates the advances in breeding methodology (recurrent selection), the use of diverse germplasm including the interspecifics and in the future the high iron and zinc rice lines using participatory methods to focus on the needs of the small rice farmers. These activities help the farmers by developing their organizational skills and can aid in their eligiblity for credits and other assistance. These farmers need to be aware of other opportunities to include other crops into their agro ecosystems especially high value crops. Rice is a food security crop, that also contributes to the farmer's income.

This output involves the training activities of the project. Many of these activities are integrated with the Outputs 1 and 2. CIAT has been a source of training for many of the scientists in the rice community and we continue to play a role in the development of rice researchers, extension agents and students in LAC. Access to information is extremely important for a competitive rice sector and this is an area in which more resources need to be devoted. The CIAT site strives not to duplicate information that is on other sites but to be a resource to help find the most useful information.

International Public Goods:

The "International Treaty on Plant Genetic Resources for Food and Agriculture" is an international agreement governing many of the world's most important crop diversity collections. The treaty will ensure that this diversity, which is critical for the rice crop improvement will remain in the public domain. In the area of germplasm, CIAT has decided to place most of its elite lines into this system. To do this, we will use the database format of IRRI and these should become part of the Future Harvest genetic resources.

Most of the technologies including database management programs, breeding methodologies, rice lines which are developed at CIAT enter into the public domain as international public goods.

One of the most relevant and important outputs of the CIAT Rice Project is the development and deployment of interspecific rice lines derived from crosses between wild rice species and cultivated rice. Most of our partners and NARs in LAC are not in a position to carry out this type of breeding work since they lack the expertise, resources and funding to do it. Besides, they re more concerned with the development of improved lines to address production problems that impinge on today's rice production but not on broadening the genetic base of rice or on problems for which no sources of genetic resistance are known.

Partners:

IRRI and WARDA are CGIAR institutions working on rice and with whom we collaborate in germplasm exchange and on problems of global importance. The Generation Challenge Program and INGER are two of the major joint activities.

We have an alliance with CIRAD and IRD of France, which is vital to our research activities. Two CIRAD scientists and one IRD scientist hold joint appointments with the CIAT rice project and contributed extensively to activities in Output 1 and Output 3. To increase our impact, we are a member of FLAR. This network includes members from fourteen countries. FLAR is a partnership of the private and public sectors for the international research of rice. Its mission is to generate new technologies to allow the Latin American rice sector to become more competitive, profitable and efficient with low environmental impact practices that propitiate lower unit costs and, as a consequence, lower rice prices to consumers. It generates both genetic resources (contributing to Output 1) and technology transfer of integrated crop management practices (contributing to Output 2 and 3).

The AgroSalud Project (housed in SB-2) is aiming at increasing the iron and zinc content in the rice grain includes partners throughout the region.

Brazil EMBRAPA & IRGA, Colombia FEDEARROZ, CORPOICA, U. Nacional U. del Tolima & U. de Antioquia, Peru INIA, Venezuela INIA, IVIC, FUNDARROZ & DANAC, Cuba IIA, Nicaragua INTA, Costa Rica CONARROZ, SENUMISA, INTA & U. Costa Rica, Guatemala ARROZGUA, Mexico Consejo Mexicano del Arroz, Bolivia CIAT Santa Cruz, ASPAR & CONARROZ, Dominican Republic IDIAF, Chile INIA, Panama U. de Panama, Uruguay INIA, Argentina INTA, CIB-FIBA, U. Corrientes & U. Tucuman are national institutions and we have activities many of which are carried out using the networks of FLAR, GRUMEGA, INGER and Biofortification. Many of these institutions develop rice varieties while other are more involved in the transfer of technologies to the rice farmers.

Universities including KSU, Cornell, Purdue, LSU, U. Arkansas, Texas A&M, U. Missouri, Rutgers, and Yale. We have collaborative projects and students that work on research of mutual interest. IAEA collaborates in the use of induced mutations for crop improvement.

Project Funding:

Budgeting 2005-2009

Year	2005 (actual)	2006 (estimated)	2007 (proposal)	2008 (plan)	2009 (plan)
US Dollars (millions)	2.621	2.450	2.017	1.946	1.920

CIAT PROJECT IP-4: IMPROVED RICE FOR LATIN AMERICA AND THE CARIBBEAN (2007-2009)

Targets	Outputs	Intended users	Outcome	Impact
OUTPUT 1: Enhanced gene pools				A robust rice sector will gene employment and maintain lo prices for the consumers. The expansion of the genetic base rice is leading to yield stabili better adaptability for abiotic biotic stresses.
Output Targets 2007 .	Advanced lines arising from interspecific crosses and recurrent selection will have been widely distributed and tested in more than 11 countries throughout the region	FLAR and rice breeding programs throughout the region	These interspecific crosses and recurrent selection populations will be a major basis for expanding the genetic diversity of cultivated rice in LAC.	
Output Targets 2008	Integrated regional collaboration for the use and development of rice genetic resources through networking will result in at least 10 new varieties.	FLAR, GRUMEGA, INGER-LAC and Rice breeding programs throughout the region	Increase interactions and efficiency of Rice Breeding Programs throughout LAC.	
Output Targets 2009	Implementation of Marker Aided Selection techniques for quality traits, RHBV and Rice Blast in varietal development.	FLAR and Rice breeding programs throughout the region	Rice breeding strategies for evaluation and selection of promising rice lines that result in more and better varieties released by the at a faster rate by rice sector.	

Targets	Outputs	Intended users	Outcome	Impact
OUTPUT 2: Integrated crop, pest and disease Management				Advanced techniques to deve resistant varieties faster and l mananagement practices will the use of agrochemicals and mitigate contamination to the farmers and environment. Th farmers will be able to produ at a lower cost.
Output Targets 2007 .	Control strategies implemented for the pest and disease complex associated with the invasive mite, *S. spinki*.	Rice scientists, extension agents and rice farmers	The use of pest management practices to reduce losses caused by the complex of *S. spinki* and diseases.	
Output Targets 2008	Identification of rice hoja blanca and planthopper resistance genes	Rice pathologists and breeders	The development of rice varieties with increased resistance to rice hoja blanca virus and *T. orizicolus*.	
Output Targets 2009	Implementation of strategies to prevent development of fungicide resistance in rice pathogens	Rice scientists, extension agents, rice farmers and regulatory agencies	Implementation of strategies for controlling and managing problems associated with the development of resistance to pesticides	

Targets	Outputs	Intended users	Outcome	Impact
OUTPUT 3: Intensification and diversification of rice systems for small farmers				More competitive rice produ so that the sector thrives ever faced with more open market will lead to a dynamic and ro rice sector that improves the livelihoods of small farmers.
Output Targets 2007 .	Integrated Crop and Pest Management information developed and available in print and electronic media.	Rice scientists, extension agents and rice farmers.	The information will be used in participatory farm groups as well as other rice farmers to reduce the yield gap and intensify the farming system. Also a large volume of scientific literature will be published.	
Output Targets 2008				
Output Targets 2009				

CIAT PROJECT IP5: TROPICAL GRASSES AND LEGUMES: OPTIMIZING GENETIC DIVERSITY FOR MULTIPURPOSE USE

NARRATIVE PROJECT DESCRIPTION

Rationale and Changes

Rationale:

Livestock development is recognized as a key element for increasing the income of poor smallholders given the increased demand for animal products that is being experienced in developing countries. However, a high proportion of smallholder crop/livestock systems are located in areas with prolonged dry seasons and with land in different stages of degradation, which lead to an inadequate supply of high quality feed for livestock throughout the year. In addition, in many cases smallholders with livestock and limited land (i.e. South East Asia) do not have easy access to fodder and have to walk long distances to harvest forages. Thus development and expansion of high yielding and high quality forages, particularly at the livestock – crop interface needs to take place if small farmers are to benefit from increased market opportunities for livestock products. Dissemination of improved multipurpose forages will contribute to more efficient use of family labor at the household level, to more income and to intensification of livestock-based systems.

To address the issues of scarcity of feed resources for livestock encountered by small producers, the research portfolio of CIAT includes the Mega Project entitled "Tropical Grasses and Legumes: Optimizing Genetic Diversity for Multipurpose Use" which is housed in the Agrobiodiversity Research for Development Challenge Program. The goal of the work on forages is to exploit the genetic diversity of tropical grasses and legumes to improve the livelihoods of poor rural livestock producers and to contribute to greater access of poor urban consumers to safe high quality animal products, while taking advantage of the potential of forages to enhance natural resource base management and provide environmental services.

To accomplish the objectives of the Forage Project, the research is organized around 4 major outputs: 1) Defined forage quality attributes, 2) Defined plant interactions with parasites (insects, bacteria, and fungi), 3) Defined mechanisms of plant adaptation to environmental constraints and 4) Delivered superior grasses and legumes to partners for further evaluation, adaptation and innovation in crop/livestock productions systems and eventual release and adoption by farmers.

Partnerships are formed with ARIs, universities and NARS to carry out strategic research on improving forage quality (output 1), on developing screening methods based on improved knowledge on mechanisms of adaptation of forage species to biotic (output 2) and abiotic stresses (output 3) and on developing improved feeding systems using an innovation approach (output 4).

The delivery of superior forage genotypes is accomplished through partnerships with NARS, NGO's, farmer groups and the private seed sector. To better target forage options to different environments and production systems (output 4) databases and decision support tools are being developed for use by researchers, development workers and for capacity building. Finally, as part of the delivery process we form partnerships with different groups to document on-farm performance of released grass and legume cultivars and quantify the impact of selected forages (output 4) in LAC and in Southeast Asia.

Changes:

Considerable progress was made in 2005 to meet the Output Targets for 2006 included in the MTP for 2006-2008. A fast method to screen large number of grass genotypes for quality (crude protein and *in vitro* digestibility) was developed and validated in 2005. Thus in 2006 we will use this method to screen an advanced sexual population for quality parameters and select genotypes with superior quality that will then be used in the breeding program. In 2005 we selected *Brachiaria* genotypes with resistance to several species of spittlebug and validated a field screening method for Rhizoctonia, which were output targets for 2006. Consequently in 2007 we aim to have available sexual and apomictic *Brachiaria* genotypes that combine resistance to more than 3 species of spittlebug with improved adaptation to low fertility - acid soils with toxic levels of Al. In addition, new sexual genotypes of *Brachiaria* with resistance to Rhizoctonia will be selected.

In 2006 the annual core budget of the Forage Project was significantly reduced. As a result in 2007 some research activities will be either transferred to other projects or will be phased out. Research on fungal endophytes and nitrogen- fixing endophytic bacteria will be transferred to the Crop and Agroecosystem Health Management Project (PE-1). On-going collaborative work with TSBF –LAC (PE-2) and with JIRCAS, Japan on characterizing and exploiting nitrification inhibition (NI) in *B. humidicola* will be stopped. The research priority on NI will be on identifying genes in *B. humidicola* that are associated with the phenomenon so that these genes could be transferred to crops of commercial importance. Finally, work on antinutritional factors in grasses and legumes will be phased out.

CGIAR System Priorities:

Among the CGIAR Research Priorities (2005-2015), livestock is recognized as being crucial to improve the livelihoods of many poor rural and peri-urban farmers in tropical regions. It is recognized however, that for poor farmers to capitalize on evolving commodity markets, there is a need to improve the availability and access of improved feed resources in areas of low and high potential. This implies the challenge of developing forages capable of producing high quality biomass to feed ruminant animals in environments characterized by having pest and disease pressures, low fertility soils, long dry seasons or poorly drained soils. Development of forage-based feeding systems for monogastric animals to complement existing home grown feed resources and replace expensive commercial concentrates is also seen as an important research output to assure improved productivity and competitivity of pig, poultry and fish in smallholder systems.

To address the priorities of the CGIAR on livestock, the Tropical Forage Project of CIAT has the global mandate of developing forage-based technologies suitable for extensive and intensive crop-livestock systems in contrasting environments. Selected forages are expected to perform well in infertile soils and to contribute to reduce seasonal variation in both feed quality and quantity and as a result reduce livestock mortality and increase productivity. In addition, grasses and legumes with broad adaptation to soils and climate in sub-humid and humid environments can contribute to better use of family labor (specially children and women) and to recuperate degraded soil/pastures in pastoral and crop-livestock systems through the enhanced capacity of grasses with deep rooted systems to improve physical structure of soils and of legumes to improve soil fertility through their contribution via biological N_2 fixation. Furthermore improved forages contribute to soil improvement through improved soil organic matter quality thereby enhancing soil biological activity and belowground biodiversity. The benefits of legumes are captured by forming strong research linkages with the Research for Development Challenge (RDC) dealing with Agroecosystems Management and with TSBFI (Tropical Soil Biology and Fertility Institute) of CIAT.

Specific activities carried out by the Forage Project to contribute to the CGIAR Priorities are:

- Development of methodologies for screening forages for quality and for major abiotic and biotic constraints
- Characterization of the genetic diversity in legume collections from the Gene Bank of CIAT, other CG Centers and research institutions to select new alternative with superior forage quality, yield and resistance to biotic and abiotic constraints
- Breeding to develop superior grasses (*Brachiaria*) that combine quality attributes with adaptation to major abiotic and biotic constraints
- Development of methods for evaluating forages in different production systems with farmer participation
- Development of Data Bases and Decision Support Tools to help target forages to different environments and production systems

Impact Pathways:

To contribute to the improvement of livelihoods of poor rural livestock owners through high quality forages (output 1) adapted to major biotic (output 2) and abiotic (output 3) constraints, forage researchers rely on natural genetic diversity from core germplasm collections housed in the GRU of CIAT and other international and national centers. Artificial hybridization to create novel genetic combinations is used when major limitations in successful commercial cultivars have been identified and where evaluation of large germplasm collections has failed to identify the required character combinations (e.g. spittlebug resistance and acid soil tolerance in *Brachiaria*). Screening methods and selected genotypes with superior forage quality, with resistance to major pest and diseases and with adaptation to acid, low fertility soils, to poorly drained soils and to drought are the output targets to be used by different partners engaged in research and development activities. To improve the efficiency of partners to better target forages to diverse environments and production systems in defined target areas, the forage team develops methods on participatory evaluation of forages and decision support tools

(output 4). Selected forage genotypes are evaluated by partners in different environments and production systems. The superior grass and legume genotypes are released by NARS and private seed companies and tested and adopted by farmers to intensify and diversify their production systems. Adoption of new forage varieties results in more income to livestock farmers through more efficient use of land, labor and more animal products for urban consumers.

International Public Goods:

In the past there were a number of strong organizations in developed countries (i.e. Australia, USA) involved in development of forages for sub-tropical and tropical environments. However, currently there are only few suppliers of improved forages with an international mandate as is the case for CIAT, ILRI and ICARDA. The forage work carried out by the CGIAR centers is complementary. For example, forages developed at ICARDA are mostly for the arid and semi-arid regions, while forages being developed by ILRI are for areas with better soils and cooler environments while forages developed by CIAT are for lowlands to mid-altitudes. An additional important participant in Forage R&D is EMBRAPA in Brazil but with a national mandate.

The research outputs of CIAT's Tropical Forage Project are in line with the mandate of the CGIAR of producing international public goods (IPGs). The IPGs of the research outputs of the Forage Project can be grouped into the following categories:

1. Mechanisms/Processes (to assist in the development of screening methods)
   - Understanding how forages adapt to acid soils with high levels of Al
   - Understanding how forages adapt to soils with low levels of P
   - Understanding how grasses resist pests (spittlebug) and diseases (Rhizoctonia)

2. Screening and evaluation methods (to select improved genotypes)
   - Forage quality (i.e. crude protein and *in vitro* digestibility)
   - Biotic constraints (i.e. Spittlebug and Rhizoctonia)
   - Abiotic constraints (i.e. adaptation of grasses to low soil nutrients status and high Al; adaptation to drought and to poorly drained soil conditions)
   - Selection of forages by farmers using participatory methods

3. Superior grass and legume genotypes and cultivars (to contribute to increased livestock productivity)
   - Grasses and legumes selected from germplasm collections that have broad adaptation to environmental factors prevailing in target areas and with multiple uses in crop/livestock production systems.
   - Grasses with high forage quality and combined resistance to biotic and abiotic constraints

4. Databases and Tools (to better target forages)
   - Forage databases on adaptation of forage species to diverse edaphic and climatic conditions

- Decision Support Tool with information on adaptation, uses and management of different forage species

Partners:

Through partnerships with different organization from developed and developing countries, the Forage Project conducts research to develop improved grasses and legumes as feed resources. In what follows we present some key partnerships and the nature of the work being done as it relates to the 4 outputs of the Forage Project shown in parenthesis.

1. Australia- CSIRO and QDPI; Germany- U of Hohenheim and ILRI: (output 4). Development of a tool- Selection of forages in the tropics (SoFT). Funds from ACIAR, DFID and BMZ.

2. Australia- CAMBIA: (output 3). Mechanisms of resistance of *Brachiaria* to Al. Funds from BMZ.

3. Brazil- EMBRAPA: (output 3). Development of a multidisciplinary network for research on acid soils involving different systems, crops and forages. Funds from Brazil to the CG.

4. Costa Rica – SIDE; Guatemala – ICTA and MAGA; Honduras- DICTA; Nicaragua- IDR, IICA and ILRI: (Output 4). Analysis of the Beef Chain in Central America. Funds from CFC.
5. Colombia- CORPOICA and Mexico- PAPALOTLA -Seed Company: (output 4). On-farm evaluation of selected *Brachiaria* hybrids. Funds from PAPALOTLA.
6. Germany- U of Hohenheim; Colombia -CORPOICA and U del Cauca: (outputs 1 and 3). Development of multipurpose forage legumes for smallholder crop-livestock systems in the hillsides of Latin America Funds from Volkswagen Foundation

7. Germany – U of Goettingen: (output 3). Genotypic variation in P acquisition and utilization in Arachis. Funds from the University.

8. Germany—U of Hohenheim; Nicaragua- INTA; Honduras- DICTA: (outputs 1 and 4). Demand-Driven Use of Forages in Fragile, Long Dry Season Environments of Central America to Improve Livelihoods of Smallholders. Funds from BMZ.
9. Germany- U of Hohenheim: (outputs 1and 3). Genetic diversity of multipurpose legumes (*Flemingia* and *Cratylia*). Funds from the University.
10. Guatemala- ICTA and Mexico- PAOLOTLA- Seed Company: (output 4): On- farm evaluation of selected *Brachiaria* hybrids. Funds from PAPALOTLA.
11. Honduras- DICTA and Mexico- PAPLOTLA -Seed Company: (output 4). On- farm evaluation of selected *Brachiaria* hybrids. Funds from PAPALOTLA.
12. Lao PDR- National Agriculture and Forestry Research Institute, Australia- Department of Primary Industry and Forestry (DPI & F), Queensland and Canada-

Nutrition Prairie Swine Centre, Saskatoon (Output 1 and 4) – Forage legumes for supplementing village pigs in Lao PDR. Funded by ACIAR

13. Japan- JIRCAS: (output 3). Nitrification inhibition in *Brachiaria humidicola*. Funds from Ministry of Agriculture of Japan.
14. Japan- Hokkaido University: (Output 3). Mechanisms of plant adaptation to low P and high Al in contrasting forages. Funds from the University
15. Japan- Yamagata University: (Output 3). Mechanisms of Al resistance in *Brachiaria*. Funds from the University
16. Switzerland – ETHZ; and Colombia- CORPOICA, Universidad Nacional de Colombia- Bogotá: (output 1). The forage potential of tannineforus legumes. Funds from ZIL- SDC
17. Switzerland –ETHZ; and Colombia- CORPOICA: (output 3). Adaptation of *Brachiaria* grasses to low-P soils. Funds from ZIL- SDC
18. Switzerland- ETHZ; and INTA- Nicaragua: (output 1). Improved feeding systems for dairy cattle in tropical smallholder farms. Funds from ZIL-SDC
19. United States- U of Kentucky: (output 2). Endophytes in grasses- Alkaloid detection. USAID linkage fund
20. United States- U of Florida- (Output 2). Biochemical mechanisms of resistance of *Brachiaria* to spittlebug. USAID linkage fund

Project Funding:

Budgeting 2005-2009

Year	2005 (actual)	2006 (estimated)	2007 (proposal)	2008 (plan)	2009 (plan)
US Dollars (millions)	3.586	2.801	2.354	2.271	2.240

CIAT PROJECT IP5: TROPICAL GRASSES AND LEGUMES: OPTIMIZING GENETIC DIVERSITY FOR MULTIPURPOSE USE (2007-2009)

Targets	Outputs	Intended User	Outcome	Impact
Output 1	Grasses and legumes with high forage quality attributes developed	CIAT and NARS researchers and seed companies	New cultivars of *Brachiaria* and legumes with high quality are released and adopted by farmers in LAC, Asia and Africa	Increased production of livestock through feeding high quality grasses and legumes
Output 1 Targets 2007	Developed at least 5 *Brachiaria* sexual hybrids that combine resistance to 5 species of spittlebug with high leaf digestibility (>60%) and crude protein (>10%) Defined the effect of location and soil fertility on forage quality of 5 shrub legumes	CIAT researchers CIAT and NARS researchers	New genotypes incorporated into the *Brachiaria* breeding program to develop high quality cultivars Environmental niches to grow shrub legumes with tannins in LAC and Africa better defined	
Output 1 Targets 2008	Identified at least 3 legume varieties with high nutritional quality, capable of improving village pig production in extensive production systems by at least 30%	CIAT and NARS researchers	Small pig producers in extensive production systems in Asia evaluate and adopt forage legumes as supplementary feed	Improved pig production (improved growth, reduced mortality) and increased return from labor in extensive village pig production
Output 1 Targets 2009	Developed at least 2 apomictic *Brachiaria* hybrids that combine high digestibility (<60%) and crude protein (<10%) with spittlebug resistance	NARS researchers, and seed companies	New cultivar of *Brachiaria* with potential to increase livestock production are released and adopted by farmers in LAC and Asia	

Targets	Outputs	Intended User	Outcome	Impact
Output 2	Grasses and legumes with known reaction to pest and diseases and interactions with symbiont organisms developed	CIAT and NARS researchers, and seed companies	New cultivars of *Brachiaria* and legumes with resistance to prevalent pests and diseases are released and adopted by farmers in LAC	Increased profitability and sustainability of livestock production through planting grasses and legumes resistant to major pests and diseases
Output 2 Targets 2007	Developed at least 5 apomictic *Brachiaria* hybrids that combine resistance to 3 species of spittlebug with tolerance to high levels of Al	NARS researchers	Selected *Brachiaria* hybrid with resistance to spittlebug and adaptation to acid, infertile soils tested in different regions in LAC	
Output 2 Targets 2008	Developed at least 5 *Brachiaria* sexual hybrids with resistance to *Rhizoctonia* foliar blight as high as that of the commercial *B. decumbens* cv Basilisk	NARS researchers	*Brachiaria* hybrids with resistance to *Rhizoctonia* are evaluated in multilocational trials in humid areas of LAC and Asia	
Output 2 Targets 2009	At least 5 *Brachiaria* hybrids that combine resistance to spittlebug with adaptation to acid soils tested in regional trials	NARS researchers	*Brachiaria* hybrids with superior traits available for multilocational testing in LAC	
Output 3	Grasses and legumes with adaptation to edaphic and climatic constraints developed	CIAT, ARIs and NARS researchers, and seed companies	New cultivars of *Brachiaria* and legumes with adaptation to low fertility soils, drought and poorly drained soils released by partners and adopted by farmers in LAC, Asia and Africa	Increased livestock/crop production and improved NRM through planting multipurpose forage species adapted to low fertility soils, drought and waterlogged soils

Targets	Outputs	Intended User	Outcome	Impact
Output 3 Targets 2007	Developed a screening method for selecting *Brachiaria* hybrids for adaptation to poorly drained soils	CIAT researchers	New genotypes incorporated into the *Brachiaria* breeding program to develop cultivars with adaptation to poor soil drainage	
Output 3 Targets 2008	Developed a screening method for selecting *Brachiaria* hybrids for combined adaptation to drought and aluminum toxicity	CIAT researchers	New genotypes incorporated into the *Brachiaria* breeding program to develop cultivars with combined adaptation to drought and aluminum toxicity	
Output 3 Targets 2009	Developed at least 5 *Brachiaria* hybrids with combined resistance to spittlebug and poorly drained soils	NARS researchers	*Brachiaria* hybrids with resistance to spittlebug and adaptation to poorly drained soils evaluated in multilocational trials in LAC	
Output 4	Superior and diverse grasses and legumes evaluated in different production systems are disseminated	NARS researchers, development programs and farmers	New cultivars of grasses and legumes with adaptation to biotic and abiotic stresses are adopted by farmers in LAC, Africa and Asia	Livelihoods of small livestock farmers improved through adoption of forages that result in more efficient use of family labor and higher income from crop and animal products
Output 4 Targets 2007	Elite accessions (4) of shrub legumes (*Flemingia macrophylla* and *Desmodium velutinum*) selected for high quality and yield in the wet and dry seasons.	NARS researchers and development programs	Researchers in LAC, Asia and Africa select new shrub legume alternatives for on-farm testing	

Targets	Outputs	Intended User	Outcome	Impact
Output 4 Targets 2008	Identified perennial and annual herbaceous legume accessions (5) that perform well under residual soil moisture, that are suited for hay and silage production and/or to maintain soil fertility and recuperate degraded lands	NARS researchers and development programs	Livestock and non-livestock farmers in dry hillsides adopt annual legumes to make high quality hay and silage	
Output 4 Targets 2009	Released a revised version of SoFT (Selection of Forages for the Tropics) to target forages to different niches	NARS researchers and development programs	Large number of researchers and development workers use SoFT to identify and promote best-bet forage species for different environments and uses. Educational institutions utilize SoFT in teaching Forage Science	

CIAT PROJECT IP-6: TROPICAL FRUITS

NARRATIVE PROJECT DESCRIPTION

Rationale and Changes

Rationale

The tropical fruits fall within the definition of High Value Agricultural Products (HVAP) '*crop, fish, livestock or non-timber forest products that return a higher gross margin per unit of available resources (land, labour, capital, human capacity) than other products within a given location and context*'. It is recognized that growing demand for HVAP in the domestic and international markets represent economic opportunities for competitive and skilled producers in every major region of the world. Considering the steady decline of staple commodity prices and that income generation using staple crops is becoming more difficult for small-scale farmers, the tropical fruits offer an alternative for crop diversification and income generation. These opportunities are challenged by diverse constraints that vary from one region to another depending on the species of fruits, agro-ecological conditions, market conditions, political will and infrastructure.

The Tropical Fruits project aims to increase incomes in the rural areas either through increasing farmers' income or employment opportunities to the landless. However, small-scale farmers should be linked to the market chain so their products could be marketed in the domestic, regional or global markets. A good understanding of market requirements and development of technologies and practices to comply with market demands are essential for facilitating access of the poor to the HVAP markets. This can be achieved by creating solid public-private partnerships, new technologies, policy and interventions that consider the complexity of HVAP markets and make small-scale farmes more competitive, productive, and sustainable. The Tropical Fruits project will take advantage of the broad genetic diversity observed in tropical fruits and develop research activities conducting to improve production systems for they become socially, environmentally and economically sustainable. Within CIAT, the Tropical Fruits project will collaborate with other projects to address these issues on a case by case basis on each output target.

Within this context the mission of the CIAT tropical fruits program is *"to use science, technology and modern information technology to support partners in the public and private sector that promote production, processing and marketing of tropical fruits by rural communities which leads to increased wealth and improved welfare in the countryside."*

Output 1: Tropical Fruits Information Center.

Information management and knowledge sharing systems for the horticultural supply chain is highly needed for a more efficient operation and modernization. . A survey conducted by CIAT in 2003 indicated a strong interest by countries in Latin America (Region 1 Central America, Region 2, Andean Zone and Region 3, Mercado común del Sur (Mercosur) to belong to a Thematic Network on Tropical Fruits. The highest interest was observed in countries from the Andean Region (70%) (Colombia, Ecuador, Peru and Bolivia) followed by countries in Central America with 27% (Mexico, Guatemala, Honduras, El Salvador,

Nicaragua, Costa Rica and Panama). The academic sector, nongovermental institutes, and international and national research organizations demonstrated the highest interest (70%) in belonging to the Thematic Network. CIAT aims to promote research and information exchange on tropical fruits through the development of an Information Center for Tropical Fruits. This need, besides being identified during the Global Horticulture Assessment, has also been identified by partners in the region.The Center will focus mainly to serve fruit growers, researchers, development agencies and funding bodiesin Latin America and will seek collaboration with partners in the region to become part of this initiative. CIAT is conducting a feasibility and market study in Colombia which will be completed in 2006 and will result in a proposal to be submitted for funding to national and international donors. This is a pilot study and it will be extended to other countries in the region if funding is secured. The objective of the Center is to make accessible published information, and also to bring up to circulation the numerous final reports from projects financed by several donors and to capture local expert knowledge. At the moment, that information is not readily available and as a consequence, (a) research dollars invested have less return as some research is being duplicated because of lack of publicizing the results, (b) technical information does not reach farmer groups or extension officers, (c) easy to implement horticultural practices are not adopted.

Output 2: Selection, propagation and targeting methodologies for tropical fruits.
Little if any breeding has occurred in many of the tropical fruit species in developing countries. Consequently planting material is not of the best quality and will result in variable quality of fruits. This is mainly because sexual seeds are still used as planting material in many of the species. This offers an opportunity for using participatory selection processes for identification of elite clones with consumer demanded characteristics. Methodologies for clonal propagation of elite materials need to be developed, adapted for low cost, and transferred to either farmers groups or commercial nurseries. Increased genetic variability will be required to speed long term solutions to many of the problems affecting tropical fruits. This implies not only access to existing variability but effective tools for proper evaluation and screening, as well as the generation of new genetic variability for several key traits. Traditional tropical fruit breeding is either in infant stage or not existing at all. Introducing inbreeding in genetic improvement has many advantages, which facilitates and expedites the generation of diversified improved breeding lines. Breeding of the most important crops generally relies on the use of inbreeding at one stage or another of the process. Introducing inbreeding in genetic improvement has many advantages. Among them: a) homozygous lines are genetically fixed, and therefore, their genetic superiority (as progenitors) can be better exploited, than genetically unstable heterozygous parents; many of the tropical fruits are higly heterozygous b) the identification of useful recessive mutants (or their induction) would be greatly facilitated; c) germplasm exchange based on botanical seed is much easier than that of vegetative cuttings; d) the production of genetic stocks for basic and applied research would now be feasible; e) the backcross breeding scheme could be implemented; f) inbred parents would allow designing better performing hybrids rather than just finding them by trial and error as is currently being done; g) by definition, inbreeding reduces the undesirable effects of the genetic load of a given population. However, developing inbred lines through self-pollinations may require several generations (years) depending on the species. In contrast, rapid and complete homozygous can be

reached by using *in vitro* haploid technology generating doubled haploids lines. Doubled-haploids (DH) would significantly reduce the time span to generate genetically fixed lines, accelerating inbreeding while unmasking recessive traits at early generations, and gaining efficiency when selecting for qualitative and quantitative traits. The most important advantage of using DH is the rapid and complete achievement of homozygosity. In turn, this implies a reduction of costs and faster genetic improvement (by reducing the time involved in the production of inbred lines). Doubled-haploids are also frequently used in the production of segregating populations utilized for basic molecular research. The advantage of the technology is higher the longer the time required attaining complete homozygosity through successive self-pollinations. The relative efficiency in the production of DH affects the costs of their production and their relative advantage over materials produced by the traditional method.

The risk of losing a variety in short-cycle species (2 or 3 years) is higher than in perennial species when propagated using vegetative cuttings. Small farmers rotate their production systems and could easily abandon plants that could die due to watershortages or pest pressure. New varieties could be preserved storing seeds of hybrids generated using *in vitro* double haploid technologies.

Output 3: Disease resistance identified in fruit species.
Disease and pest control amounts to almost 50 to 60% of the production cost in several tropical fruits. Due to pathogen pressure, farmers apply fungicide to the point of creating fungicide resistance and fruits with high pesticide residues.
Access to new domestic and international markets will be seriously jeopardized unless production practices are improved, including reduced use of pesticides.
Existing diversity of several neo tropical fruit species will be used to identify disease resistance genes in cultivated species. Introduction of elite clones bearing disease resistance will have a significant impact in human health of growers and consumers alike, and will result in implementation of best agricultural practices. Rapid assessment methodologies using molecular markers linked to disease resistance genes will be developed and tested.

Changes:
New leadership has been brought into the project, new partnerships and activities are being initiated. So far some unrestricted resources have been invested in developing tools for predicting where a crop could grow well (**Homologue**). This important topic will remain in the research agenda of Tropical Fruits; however, it is now at the stage of developing case studies to demonstrate the proof of concept before further development is needed. The Tropical Fruits project is now putting more emphasis into developing technologies and knowledge for improving the economic profitability of growing fruits by using improved planting material, selected elite varieties with high quality attributes and pest and disease resistance traits, and better and more efficient practices for disease and pest managementof production systems. The selected species of fruits CIAT will focus on must be grown by a significant number of families, have a local and/or regional market with potential to grow onto international markets, be important to small-scale growers in the hills of Latin America, and be of interest to partners in the National Agricultural Research Institutes.

CG System Priorities:

The Mission of Tropical Fruits aligns with the System Priorities 2005-2015 of the Consultative Group on International Agricultural Research (CGIAR). It explicitly asks to incorporate research on 'reducing poverty through agricultural diversification and emerging opportunities for high value commodities and products'. Tropical Fruits are High Value Agricultural products (HVAP) and has been identified as an opportunity to generate income in the rural communities.

- Many of the commercially grown tropical Fruits fall within the category of under-utilized species. CIAT is engaged with NARS in promoting the commercial use of these species and is facilitating the adoption of new cropping systems aiming to generate direct income as a grower or to implement agricultural bussiness in the rural areas. (**Priority 1b, Promoting conservation and characterization of under-utilized plant genetic resources to increase the income of the poor**)

- Characterisation of sites where selected species or selected clones are succesfully grown will help to identify other places with similar characteristics where that clone could perform well. Application of ***Homologue*** is directed towards saving time and minimizing risk of chosing particular varieties to be grown on a particular site. In Tropical Fruits business, chosing the right variety at time of planting is critical because of the long waiting period before performance of the variety is known. (**Priority 2b Tolerance to abiotic stressess**)

- Selecting individual clones with more marketable characteristics will maximize the top grade products that farmers can market, and will help them to comply with the quality standards of new markets (**Priority 2d: Genetic enhancement of selected species to increase income generation by the poor**)

- Promoting best agricultural practices, introduction of new technologies (clones, better varieties), identification of genetic resources with disease resistance attributes will help farmers to maximize their income through better and cleaner products to be sold in the markets. Tropical Fruits project is working closely with the Rural Agroentreprise to help growers engaging in fruit production, identify markets or create new market opportunities for fruit products. (**Priority 3a: Increasing income from fruit and vegetables**)

Impact Pathways:

Output 1: Tropical Fruits Information Center. Production practices of Tropical Fruits and other high value products require expert knowledge. Sometimes this knowledge exists but is not readily available to users, such as farmers groups, research agencies, extension officers etc. The Information Center will aim to make information more visible and accessible to all those interested in Tropical Fruits and to funding bodies in the developing countries so that new research will advance previous results rather than duplicating it. Readily available information will have a positive impact on production practices and the quality of research conducted by NARs, local universities and international centers.

Output 2: Selection, propagation and targeting methodologies for tropical fruits. Access to new domestic and international markets impose new quality standards to small-scale producers that will be difficult to achieve unless new technologies are incorporated into their production systems. Quality standards are demanded by fresh fruit consumers and processing industries which require specific varieties, often lacking in many of the locally grown crops. There is opportunity for using participatory selection protocols for identifying and multiplying elite clones from farmer's fields, which will likely be adopted. Aiming at conserving genetic diversity in the farmer's fields, garden of clones with similar quality characteristics will be promoted. Methodologies for developing *in vitro* double haploids would facilitate breeding by NARS and will short the time to produce better varieties of tropical fruits.

Output 3: Disease resistance identified in fruit species. Research agencies would be the intended users of this technology and information, to be used in their own breeding efforts or for rapid screening of large populations of segregating hybrids or populations from farmer's fields. Within the same family, related species could benefit from information gathered from model species and could speed the process of identifying sources of disease resistance among large populations by screening using molecular markers. CIAT will play a role as primary research provider, and in certain cases will catalyze the release and testing of existing populations for multi-site assessment of variety performance.

International Public Goods.

The Tropical Fruits Project in CIAT seeks support and collaboration assistance from the diverse projects that are the basic work units of the centre. The success of the Tropical Fruits Project depends on the degree of integration and collaboration with other CIAT projects. Therefore, international public goods developed within the Tropical Fruit Projects are shared with many of the collaborating projects within CIAT.

The research outputs of the IP-6 Project are aligned with the mandate of the CGIAR of producing international public goods (IPGs). The IPGs of this Project are summarized in categories as follows:

1. Methods:
   a) Methodologies for clonal propagation of woody species
   b) Standarization and transfer of *in vitro* tissue culture techniques to farmers for selection and multiplication of their own planting material.
   c) Identification of sources of genetic resistance to major pests and diseases in existing populations of tropical fruits.
   d) Rapid screening methodologies for disease resistance in populations of tropical fruits

2. Products:
   a) Tropical fruits genotypes with resistance to pests and diseases identified.
   b) Tools for identification of where a Tropical Fruit crop will grow well (Homologue; CropIdent)

c) Use of biopesticides as alternative crop protection for use in fruit production systems.

3. Mechanisms:

a) Information Center on Tropical Fruits will connect end users to sources of information.

Because many of the fruits are not part of the Multilateral Treaty on Plant Genetic Resources for Food and Agriculture, working with local partners is essential for the Tropical Fruits Project. The Tropical Fruits project aims to reach its goals of improving the welfare and increasing the incomes of rural communities by working with local partners.

Partners:

- **Farmer groups**: Work in collaboration with farmers for implementing participatory selection (**output 2**) of elite clones in targeted fruit species. Test performance of elite clones in their farms and help in evaluating and collecting data in remote locations.
- **Developed and developing country universities**: Provide students and co-advising of thesis of masters and Ph.D students, facilities and laboratory analysis not available at CIAT.
- **IPGRI**: coauthor of the Neotropical Fruits database, provide scientist time and knowledge of genetic resources distribution and taxonomy.
- **Max Planck Institute**: Collaborative work in the Rockefeller funded project on control of flowering in Cassava and Mango. The institute will provide the genetic construct to be inserted in mango tissue, once methodologies for transformation and regeneration are worked out.
- **CORPOICA**, local partner providing genetic resources, scientists and technician's time. Several ongoing projects include Corpoica as co-executor of the projects.
- **MADR**, main funding body for existing projects in Lulo and Avocado**.**
- **ASOHOFRUCOL**, funding body for special projects and development of the proposal to create an Information Center of Tropical Fruits.
- **Corporación Biotec**, leader and co-executor of Precision Agriculture Project aiming at developing models for performance of tropical fruits using fuzzy logic.
- **CIRAD**, collaboration in progress with the Fruits program and the Library for sharing information on tropical fruit species. CIRAD coauthored the existing Neotropical Fruits Database.
- **Universidad Catolica del Oriente**. Developed methodologies for clonal propagation of tree tomato. Major player in scaling up propagation methodologies of several fruit species.
- **INIAP (Ecuador)**. local partner providing genetic resources, scientists and technician's time. Co-executor in proposals submitted for funding.

Project Funding:

Budgeting 2005-2009

Year	2005 (actual)	2006 (estimated)	2007 (proposal)	2008 (plan)	2009 (plan)
US Dollars (millions)	0.438	0.381	0.656	0.899	1.149

CIAT PROJECT IP-6: TROPICAL FRUITS (2007-2009)

Targets	Outputs	Intended User	Outcome	Impact
OUTPUT 1	Tropical Fruits Information Center	Farmer groups, research institutes, development agencies, and entrepreneurs growing Tropical Fruits.	Information on tropical fruits generated in the developing countries becomes available to all users. Better use of money invested in new research projects.	Rural communities producing fruits based on most updated information and practices. New research moves forward as previous research information becomes available and is not repeated.
Output Targets 2007	Proposal for development of a Tropical Fruits Information Center submitted to potential donors for funding.	Research agencies, donors.	Consortium of potential national and international partners identified and engaged in the initiative.	
Output Targets 2009	Tropical Fruits Information Center developed, functional and accessible to the public	Farmer groups, research agencies, development agencies, and entrepreneurs growing Tropical Fruits.	At least 1000 documents containing information on Tropical Fruits collected, digitized and made available via web based technologies.	Small-scale fruit growers improve their competitiveness through better farming practices and quality produce based on local and updated scientific knowledge. Capacity of NARs enhanced.

Targets	Outputs	Intended User	Outcome	Impact
OUTPUT 2	Selection, propagation and targeting methodologies for tropical fruits	Local research and development agencies and farmers groups	Producers planting uniform quality elite fruit materials, selected from existing natural variation, well adapted to specific ecological conditions on their farms.	Increased rural income through increased yield and reduced production costs of high value readily marketed products.
Output Targets 2007	Selected at least 10 elite clones from 3 fruit species with desirable attributes to growers and consumers. (lulo, andean raspberry and avocado)	Local research and development agencies and farmers groups	Producers using selected and propagated elite materials	
Output Targets 2008	Elite clones of selected species species identified, multiplied and transferred to growers and nurseries	Local research agencies	Propagation methodologies adapted to individual species (or clones) of local interest	
Output Targets 2009	Technology based on *in vitro* double haploid developed for a semi-perennial fruit species.	Local research, private seed industry and farmers groups.	Elite clones of semi-perennial fruit trees conserved and propagated using seeds of double haploid plants.	Varieties of semi-perennial species propagated using commercially available seeds that produce true to type plants. Disease dispersion minimized and production of better planting material.

Targets	Outputs	Intended User	Outcome	Impact
OUTPUT 3	Populations of fruit species with disease resistant traits identified.	Research agencies	Reduce fungicide input in production systems	Clean production practices. Healthier fruits with less chemical residue and easier access to new markets.
Output Targets 2007	At least 6 populations of three fruit species (lulo, andean rasbberry and avocado) tested for resistance to most limiting diseases	Research agencies	Breeders of tropical fruits could add identified lines to their breeding program	
Output Targets 2008	Develop molecular markers for major disease resistance genes in at least one fruit species.	Research agencies, farmers groups.	Identified lines propagated for fruit quality attributes	
Output Targets 2009	Test use of molecular markers for disease resistance genes in related species.	Research agencies	Useful genes used to tag similar genes in closely related species.	

CIAT PROJECT PE-1: CROP AND AGROECOSYSTEM HEALTH MANAGEMENT

NARRATIVE PROJECT DESCRIPTION

Rationale and Changes

Rationale:

Most cultivated plant species are susceptible to a wide range of fungal, bacterial, and viral pathogens, and arthropod pests, particularly in tropical climates. These problems are compounded by the lack of resources and technical assistance to poor farmers in developing countries. Under these conditions, crop losses can often be significant or even total, affecting the livelihoods and food security of millions of poor rural and urban communities. In view of this situation, we could expect that the application of improved and intensive crop protection measures would contribute to the sustainability and enhancement of food production in these regions of the world. The development and application of integrated pest and disease management (IPDM) strategies is the basis of the Crop and Agroecosystem Health Management Project activities. Some of these methods include the development of resistant cultivars, including transgenic plants, and a variety of control measures developed for specific plant diseases/pests and agroecosystems. Biotechnology and/or conventional tools perform essential roles in our research activities dealing with crop and agroecosystem health management.

The Project's research activities are organized around four major outputs: 1) Pest and disease complexes described and analyzed, 2) Pest-and-disease management components and IPM strategies developed, 3) NARS' capacity to design and execute IPM research and implementation, and applications of molecular tools for pathogen and pest detection, diagnosis, diversity studies as well as novel disease and pest management strategies strengthened, 4) Global IPM networks (Integrated Whitefly Management Technology) and knowledge systems developed.

Output 1: Pest and disease complexes described and analyzed.

The difficulty of accurately identifying pathogens and pests of tropical crops is often a bottleneck to their control. We, together with various collaborators, have developed several molecular and conventional diagnostic tools to detect, identify, and characterize pathogens and other pests affecting its mandated crops, that is, beans, cassava, tropical forages, and rice, as well as several high value crops currently grown by small-scale farmers in the tropics.

Extensively characterized pathogen populations at CIAT, with substantial practical implications for their management, include *Xanthomonas axonopodis* pv. *manihotis*, *Colletotrichum gloeosporioides*, *Phaeoisariopsis griseola*, *Pyricularia grisea*, *Sphaceloma manihoticola*, *Colletotrichum lindemuthianum*, species of *Pythium*, *Xanthomonas campestris* pv. g*raminis*, Rice *hoja blanca* virus (RHBV), and begomoviruses and potyviruses that infect important crops found in the tropics. Pests that are well-characterized include species of mealybugs, species of spittlebugs, whiteflies and their parasitoids, biotypes of the whitefly *Bemisia tabaci*, bruchids, white grubs

Output 2: Pest-and-disease management components and IPM strategies developed.

Resistance (conventional breeding): Managing diseases and pests through host resistance is economically attractive and practical. To develop cultivars resistant to diseases and insect pests, a common strategy, known as 'gene pyramiding', is to incorporate as many resistance genes into a single plant genotype as possible, in the hope that it will be statistically unlikely for a pathogenic race or insect pest to evolve that can overcome all the resistance genes simultaneously. However, combining several resistance genes simultaneously in one background becomes difficult without using markers for each gene. In this context, the use of marker-assisted selection to contain pest damage becomes essential.

Transgenic crops as components of IPDM strategies: Genomic approaches are increasing our understanding of the genetic basis of plant disease and pest resistance by enabling us to better understand resistance genes themselves, other genes, and the pathways they regulate. While fully recognizing the controversy on transgenic organisms, we value the potential role they can play in arthropod pest, disease, and virus management strategies across several crops. The role of transgenic organisms in IPDM will increase in the future and has already been shown as a way of drastically decreasing pesticide use.

Transgenic crops developed at CIAT include *Stylosanthes guianensis* containing a rice-basic chitinase gene for resistance to the fungal pathogen *Rhizoctonia solani*; rice, for resistance to Rice *hoja blanca* virus (RHBV), containing the RHBV nucleocapsid protein (*N*) gene. As the possibilities of combining genes from various sources expand, the need for biosafety regulations and risk assessment increases. Our studies on the effect of transgenic (Bt) varieties on non-target soil organisms showed that no statistical differences were detected in abundance and diversity of soil organisms in conventional versus genetically modified cotton [Bollgard ® Bt Cry 1A ©] during the 2003-05 period in the Cauca Valley, Colombia.

Bio-pesticides:

The concerns on excessive pesticide use and the threat to human health and the environment, coupled with increasing regulatory and market pressures, along with pest and pathogen resistance to synthetic chemicals, have led to a reappraisal of approaches to pest and disease control strategies that include the development of safer "biological pesticides." This excessive use of pesticides threatens to weaken the competitiveness of many Latin American countries' agriculture by: 1) threatening to disqualify export products especially in those countries that have stringent food safety regulations, 2) increasing production cost, 3) degrading the general ecosystem, making their soils less productive over time, 4) contaminating water supplies, 5) causing health problems among agricultural workers and thus affecting the labor force. In this context, we believe natural plant and microbial compounds will play a major role in pest and disease control in both developed and developing countries.

Biological control is an important component of integrated pest and pathogen management. Endophytic microbes, fungi, bacteria, nematodes, viruses, plant-derived compounds are all identified and characterized for use as biocontrol agents against a wide range of pathogens and pests attacking various crops. Biopesticides developed and currently made commercially

available in collaborative projects with the private sector include: 1) Biocanii, based on a strain of the fungus *Verticillium lecanii* for the control of whiteflies and thrips on flowers, beans, avocado, cotton, onion, citrus, asparagus, papaya, tomatoes and other horticultural crops; 2) Biorhizium**,** based on two strains of the fungus *Metarhizium anisopliae* for the control of various insects such as spittlebugs in pastures; 3) Biovirus**,** based on a baculovirus and used for the control of cassava hornworm, 4) Ecoswing®,. a biofungicide formulated from extracts of the plant swinglia (*Swinglia glutinosa*).

Plant-derived compounds: We have identified plant-derived compounds that are effective in controlling diseases and pests. These include: 1) fique (*Furcraea cabuya*), 2) swinglia (*Swinglia glutinosa*), 3) *Clitoria ternatea*.

Legumes have been used as cover crops and as sources of green manure. The use of cover crops (e.g. *Canavalaia ensiformis*, *Crotalaria rahamiana*, *Crotalaria juncea*, *C. ochroleuca*, *Desmodium intortum*, *D. unicanatum*, *Lablab purpureus*, *Tagetes patula, Mucuna pruriens*) has been associated with a decrease in incidence of soil-borne pathogens and pests in several cropping systems.

Output 3: NARS' capacity to design and execute IPM research and implementation, and applications of molecular tools for pathogen and pest detection, diagnosis, diversity studies as well as novel disease and pest management strategies strengthened.

The purpose of this output is to strengthen our national partners' capacity to diagnose and detect pests and diseases; develop and execute IPDM strategies that would contribute to the reduction of losses caused by pests and diseases through effective targeting, dissemination and adoption of integrated pest management strategies that are acceptable to smallholder farmers in eastern, central and southern Africa and Latin America. Useful practical experiences have been gained, successes achieved and lessons learnt during the promotion of technologies at target sites. We will help to develop plant diagnostic networks to combat invasive pests, promote regional collaboration, and strengthen local diagnostic and outreach capabilities.

Through strong partnerships with national programs, universities, farmer groups, and the private sector we develop and evaluate diagnostic tools, disease and pest management methods including resistant materials, cultural methods and biopesticides. Capacity building and training of students, farmers and professionals at various levels is a major activity of the project staff.

Output 4: Global IPM networks (Integrated Whitefly Management Technology) and knowledge systems developed.

One of our main research areas is the management of whiteflies as pests and vectors of plant viruses attacking a broad range of crops throughout the tropics. In the1990s, new inter-center initiatives including the System-wide Program on Integrated Pest Management (SP-IPM) were created by the CGIAR. Due to the importance of whiteflies and the viruses they transmit, the Tropical Whitefly IPM Project (TWFP) was the first inter-center project within

SP-IPM. The Project was developed in three phases to be carried out over a 10-year period, and launched in 1997 with CIAT as the convening Center. Five IARCs (CIAT, IITA, AVRDC, ICIPE, CIP), 12 advanced research institutes, and 31National Agricultural Research and Extension Systems in Latin America, Caribbean, Africa and Asia are included. This extensive partnership was made possible through the financial support of six major donors: Danish International Development Agency (DANIDA), Australian Center for International Agricultural Research (ACIAR), United States Agency for International Development (USAID), Ministry of Foreign Affairs and Trade (MFAT, now New Zealand Aid), U.S. Department of Agriculture-Agricultural Research Service (USDA-ARS), Department for International Development (DFID, UK)

Changes:
No significant changes would be made in 2006.

CGIAR System Priorities:
The Crop and Agroecosystem Health Management Project contributes essentially to all the 5 CGIAR Research Priorities (2005-2015). Specific activities conducted by the Project to contribute to the CGIAR priorities are:

- Developing molecular and conventional methods for screening of germplasm for resistance to diseases and pests- (Priority 1)
- Characterization of germplasm and identification of sources of resistance to diseases and pests-(Priority 1)
- Developing phytosanitory methods and protocols for the safe movement of germplasm--(Priority 1)
- Identification, characterization and conservation of beneficial microorganisms associated with plant germplasm (eg. endophytic bacteria and fungi), and predators of harmful pets--(Priority 1)
- Enhancing yields of crops through pest and disease resistance- (Priority 2)
- Reduction of pesticide use in various crops including high value crops, thus reduction of pesticide residue and improving food safety- (Priority 2)
- Monitoring pathogens and pests that develop resistance to pesticides- (Priority 2)
- Screening high value crops for resistance to key pathogens and pests- (Priority 3)
- Management of diseases and pests in fruits and vegetables- (Priority 3)
- Developing methods to prevent post harvest losses- (Priority 3)
- Improving water quality through pesticide use reduction- (Priority 4)
- Enhancing soil health through improved and integrated disease and pest management strategies-(Priority 4)
- Development and implementation of integrated disease and pest management strategies for sustainable management of agroecosystems- (Priority 5)
- Development of phytosanitary protocols and certification systems to facilitate international trades- (Priority 5)

Impact Pathways:
The project contributes to improved crop productivity and improved livelihoods through development of efficient and accurate tools for disease and pest diagnosis (output 1), and cost-effective disease and arthropod pest management strategies (output 2). We screen for host plant resistance and identify important sources of resistance to a wide range of pests and pathogens. These sources of resistance are used in the breeding programs to incorporate the resistance genes with a number of other genes of agronomic importance. We develop other components of integrated pest and disease management strategies including biopesticides and cultural practices. The capacity of our national partners to diagnose and detect pathogens and pests and to implement effective disease and pest management strategies is enhanced through our activities in output 3. We communicate our results through publications in international and regional journals, books and manuals, articles presented in conferences and workshops, websites, and in English, Spanish and other major local languages. Other communication outlets are newspaper articles and other journals intended for the general public. Global networks on sustainable management of key pests, such as whiteflies, which attack staple crops, high value crops and industrial crops are established (output 4). The outputs of the Project benefit NARS scientists, farmers, and consumers by increasing crop yields, crop quality, agro-ecosystem health and stabilizing production systems. The judicious use of pesticides results in clean harvests with little or no pesticide residues, leading to increased income and market access through healthier products, and cleaner environment.

International Public Goods:
The project works on diseases and pests of rice, beans, cassava, tropical forages and tropical fruits. In addition to the research activities involving CIAT's commodity crops, the Project scientists are also involved in projects that expand their expertise to other agricultural and industrial crops. These include maize, cotton, onions, asparagus, other vegetables, potatoes, cut flowers and oil palm.

The Project has played a major role in the formation and development of the CGIAR Systemwide Program in IPM (SP-IPM). CIAT is the Convening Center for the major ongoing project in the SP-IPM, The Tropical Whitefly IPM Project. A draft SP-IPM proposal on "Soil Biota, Fertility and Plant Health" is available. The Project staff as well as the TSBF Institute of CIAT have played major roles in this proposal. If funded, CIAT will most likely be the convening center for this project.

The Instituto Agronómico de Colombia (ICA) invited the Project and its scientists to apply for, and acquire accreditation to evaluate the quality and effectiveness of biological pesticides. The CIAT laboratories and scientists would become registered with ICA to perform quality control analysis of biopesticide products of commercial producers seeking ICA registration. Furthermore, the Project is invited to participate in major activities of ICA involving phytosanitary issues. The citrus virus certification work that the Project has conducted in collaboration with ICA and CORPOICA is now considered as a model for expansion to other crops, diseases and regions.

The science dealing with the identification, naming and classification of organisms, is a vital component in a pest management program. An inaccurate identification of a pest organism

can result in an acute loss of time and resources and delay the most appropriate response to pest attack. The Project provides a service for the identification of arthropod pests and pathogens collected from various crops, but especially from CIAT's mandated crops, and related activities. The Project maintains a working collection, now totaling over 20,000 specimens, of arthropod pests and their natural enemies for cassava, beans, rice, tropical pastures and tropical fruits, as well as those collected from related agroecosystems. A database containing information on individual specimens accompanies this collection and this is made available to collaborating institutions, museums, universities and national research and extension programs. The project also maintains large collections of fungal and bacterial pathogens, and beneficial microorganisms including nitrogen fixers, plant growth promoters, biocontrol agents. In addition, a collection of entomopathogenic fungi, bacteria and nematodes is also maintained. These potential biological control agents have been isolated from crop pests through field surveys, or have been received from other research institutions (e.g. CENICAFE) in collaborative exchange projects.

The project uniquely works on endophytic fungi and bacteria, multiple resistances to spittlebugs, microbial and plant-derived biopesticides. Several biopesticides have been commercially made available through collaborative projects with the private sector. The project staff in Africa provide capacity building in molecular tools for disease diagnosis and pathogen characterization, marker assisted selection methods to improve the efficiency of breeding for disease resistance, participatory evaluation and implementation of disease and pest management methods, as well as supervision of graduate student thesis.

The research outputs of the PE-1 Project are in line with the mandate of the CGIAR of producing international public goods (IPGs). The IPGs of the research outputs of this Project are summarized as follows:

1. Mechanisms:
    a) Understanding mechanisms of resistance to fungal, bacterial and viral pathogens leading to the development of screening methods
    b) Understanding mechanisms of resistance to arthropod pests thus, leading to development of methods for resistance screening.
    c) Understanding mechanisms of how pathogens and pests evolve and overcome host resistance
    d) Understanding mechanisms of hoe pathogens and pests evolve and develop resistance to pesticides

2. Methods:
    e) Techniques and methodologies for mass rearing of arthropod pests for resistance screening and biopesticide testing
    f) Standardized protocols for risk evaluations of genetically modified organisms (GMOs) on non-target soil organisms.
    g) Genetic transformation methods for pathogenic and non-pathogenic fungi and bacteria.
    h) Methods for long-term storage of microbes.

i) Methods for artificial inoculation/infestation and for resistance measurement for a number of pathogens and pests.
j) An improved greenhouse inoculation method to detect quantitative differences for genetic studies and breeding, and evaluation, eg. sheath blight resistance (*Rhizoctonia solani*) in rice
k) Methods for screening potential biopesticides
l) Protocols for the safe movement of germplasm within and across regions

3. Products:
   d) Genotypes with resistance to pests and diseases identified among the collection of beans, cassava, rice, tropical forages and tropical fruits
   e) High yielding disease and pest resistant breeding lines
   f) Microbial-derived biopesticides
   g) Plant-derived biopesticides
   h) Improved biocontrol agents
   i) Microbial and arthropod pest databases.

Partners:

- **Bolivia-** PROIMPA: Management of whitefly.
- **Brazil**- EMBRAPA- CNPMF, - CNPGC, IAC – Development of host plant resistance to spittlebugs
- **Canada**- Agriculture & Agri-Food- *Pythium* species identification
- **China-** Yunnan Academy of Agricultural Sciences – Development of runner bean project
- **Colombia-** CORPOICA, ICA, Universidad Nacional de Colombia-Palmira and Bogotá, Life Systems Technology (LST) S.A, Universidad del Valle, Universidad de Caldas, Universidad Católica, Universidad de la Amazonía, Universidad de los Andes, Profrutales Ltda, BIOTROPICAL, Palmar del Oriente: provide samples, validation of control and management practices); Corporación BIOTEC, FEDEPLATANO: farmers groups, and many more; graduate and undergraduate thesis of students, development of disease and pest diagnosis tools, evaluation of pest and disease management methods, quarantine pests and diseases, certification programs; - Biotropical: development, evaluation and formulation of biopesticides.
- **Denmark -** The Royal Veterinanry and Agricultural University: induced resistance and training
- **Ecuador-** Instituto Nacional Autónomo de Investigaciones Agropecuarias (INIAP), Escuela Politécnica del Ejército (ESPE): pest and pathogen resistance to pesticides, research on soil arthropods. Manrecur : management of whitefly.
- **France**- IRD: insect physiology and biochemistry.
- **Germany-** Institut für Pflanzenkrankheiten und Pflanzenschutz, Fachbereich Gartenbau, Universität Hannover, Agrar- undErnährungswissenschaftliche Fakultät, Universität Kiel, Federal Biological Research Centre for Agriculture and Forestry (BBA): soil arthropod pests, entomopathogens.
- **Honduras**- PROMIPPAC: biopesticides
- **Kenya**- International Centre of Insect Physiology and Ecology (ICIPE): insect physiology.

- **Nicaragua**- MAGFOR: capacity strengthening in disease and pest diagnosis, disease and pest management.
- **Nigeria**-IITA: System –wide program on IPM, management of whiteflies.
- **Peru**-CIP: management of whiteflies.
- **Rwanda**- Institut des Sciences Agronomiques du Rwanda (ISAR): integrated disease and management and soil fertility management for enhancing soil health
- **Taiwán**- AVRDC: management of whiteflies in tropical crops.
- **Tanzania**- Agricultural Research Institute, African Highlands Ecoregional Program, Adventist Development and Relief Agency, Ministry of Agric.-Armyworm project, Farm Africa, Farm Africa, World Vision, farmers groups, and others: Evaluation of disease and pest management methods.
- **Uganda**- National Agricultural Research Organization (NARO), African Highlands Ecoregional Program, Makerere University, Uganda National Agricultural Advisory services, farmers groups, and others: Evaluation of disease and pest management methods, thesis students.
- **United Kingdom**- Commonwealth Agricultural Bureaux International (CABI), Horticulture Research International (HRI), Natural Resources Institute: management of whiteflies. Scottish Crop Research Institute: Isolation and conservation techniques.
- **United States**-University of Kentucky, Cornell University, Iowa State University, Kansas State University, University of Georgia, University of Florida, University of California-Davis, Michigan State University, Texas A& M, United States Department of Agriculture (USDA): insect taxonomy, analysis of alkaloids from endophytes, diagnosis and detection tools.
- **Venezuela**- Instituto Nacional de Investigación Agrícola (INIA): pesticide use and resistance of pathogens and pests to agrochemicals.

Project Funding:

Budgeting 2005-2009

Year	2005 (actual)	2006 (estimated)	2007 (proposal)	2008 (plan)	2009 (plan)
US Dollars (millions)	1.782	2.049	1.926	1.858	1.833

CIAT PROJECT PE-1: CROP AND AGROECOSYSTEM HEALTH MANAGEMENT (2007-2009)

Targets	Outputs	Intended User	Outcome	Impact
Output 1	Pest and pathogen complexes in key crops described and analyzed.	NARIs, universities, NGOs, IARCs	Molecular and conventional tools for disease and pest diagnosis, detection and characterization developed, evaluated and disseminated to researchers.	Improved crop productivity from more efficient and accurate tools for disease and pest diagnosis, and cost-effective disease and insect pest management strategies. Improved livelihoods of small farmers through higher yields of crops obtained by better disease and insect pest management
Output 1 Targets 2007	Molecular tools for detection, diagnosis and diversity studies of key pathogens and pests of CIAT commodities made available	NARIs researchers in LAC, Asia and Africa, IARCs	Disease and pest characterization tools developed and adopted by researchers.	
Output 1 Targets 2008	Two plant- growth promoting bacteria and one biological control agent characterized.	NARIs researchers in LAC, Asia and Africa	New options for disease and pest management and plant health enhancement developed and tested by researchers.	
Output 1 Targets 2009	Diagnosis and certification programs expanded to countries in Latin America	NARIs researchers in LAC, policy makers	Facilitation of trades, mainly exports of high value crops	
Output 2	Pest-and-disease management components and strategies developed for key crops.	Researchers in LAC, Asia and Africa	Integrated disease and pest management strategies developed and adopted by farmers.	Increased and stable income of small farmers through increased crop yields and enhanced quality of products

Targets	Outputs	Intended User	Outcome	Impact
Output 2 Targets 2007	At least 2 *Brachiaria* genotypes with spittlebug resistance, a whitefly resistant cassava variety, and 50 blast and sheath blight resistant rice lines developed.	Researchers in LAC, Asia and Africa; CIAT scientists; farmers	Selected genotypes of *Brachiaria,* cassava and rice tested for resistance to insects and pathogens in different regions.	
Output 2 Targets 2008	Three biological pesticides, and angular leaf spot and *Pythium* resistant bean varieties made available	Researchers in LAC, Asia and Africa; farmers	Disease /pest resistant crops developed and adopted; biopesticides formulated and adopted.	
Output 2 Targets 2009	- Biopesticides relevant to Africa developed and tested - Advanced rice lines/populations with stable blast resistance developed - Development of fungicide resistance by major rice pathogens detected - Method available to quantify *Pythium ultimum,* as a tool to assess disease management strategies, and to refine management of resistance breeding nurseries.	Researchers in Africa; farmers Researchers, farmers Extension agents, rice farmers, regulatory offices Researchers in LAC, Asia and Africa	Cost-effective biopesticides made available to be tested by African farmer groups Rice lines with more durable blast resistance for blast prone areas Control and management of fungicide resistance problems in rice, environment and human protection, reduced application of fungicides Improved efficiency in genetic improvement and control of the disease	

Targets	Outputs	Intended User	Outcome	Impact
Output 3	Strengthened capacity of NARS to design and execute IPM R&D, to apply molecular tools for pathogen and pest detection, diagnosis, diversity studies and to device novel disease and pest management strategies	NARIs in LAC, Asia and Africa; farmers	Improved capacity of NARS partners to disseminate to farmers disease and pest management strategies	More income to farmers by using; environmentally-friendly disease and pest management strategies.
Output 3 Targets 2007	Management strategies for soil-borne pests (white grubs and burrowers bugs) evaluated with farmers	NARIs and farmers in LAC, Africa	Soil pest management methods adopted by farmers.	
Output 3 Targets 2008	Combination of whitefly resistant cassava varieties and biological control agents made available to farmers	NARIs, NGOs and farmers	Improved cassava varieties together with improved disease and pest management practices adopted.	
Output 3 Targets 2009	- Management of key diseases and pests affecting high value crops evaluated by farmers in Latin America and Asia - Management strategies for fungicide resistance problems available to farmers and extension agents in Latin America	NARIs, NGOs and farmers NARIs, farmers, extension agents	Disease and pest management methods which will lead to reduction of pesticides tested by farmers Reduced application of fungicides in rice	

Targets	Outputs	Intended User	Outcome	Impact
Output 4	Global IPM networks (Integrated Whitefly Management Technology) and knowledge systems developed.	NARIs, Universities, NGOs, IARCs, farmers	Sustainable food and cash crop production systems with reduced environmental impact and production costs adopted.	Improved livelihoods, rural and urban health standards, and increased farm/household income
Output 4 Targets 2007	Farmer participatory research conducted in selected pilot sites of sub-Saharan Africa, S.E. Asia and Latin America.	NARIs, Universities, NGOs, IARCs, farmers	Methods in lower pesticide use resulting in lower production costs and environmental contamination adopted.	
Output 4 Targets 2008	Impact assessment and Policy guidelines implemented for the benefit of farmers.	Government Institutions, NARs, NGOs, farmers	Food production and income-generating strategies for small-scale farmers facilitated by official decrees	
Output 4 Targets 2009	Manuals, bulletins, and other publications that will benefit farmers and others prepared. Global networks on sustainable management of anthracnose diseases of tropical fruits initiated.	Government Institutions, NARs, NGOs, farmers	Food production and income-generating strategies for small-scale farmers facilitated by official decrees	

CIAT PROJECT PE-2: INTEGRATED SOIL FERTILITY MANAGEMENT IN THE TROPICS

NARRATIVE PROJECT DESCRIPTION

Rationale and Changes

Rationale:

Soil fertility degradation has been described as one of the major constraints to food security and income generation in developing countries. Despite proposals for a diversity of solutions and the investment of time and resources by a wide range of institutions it continues to prove a substantially pervasive problem. The rural poor are often trapped in a vicious poverty cycle between land degradation, fuelled by the lack of relevant knowledge or appropriate technologies to generate adequate income and opportunities to overcome land degradation. Intensification and diversification of agricultural production on smallholdings is required to meet the food and income needs of the poor, and this cannot occur without investment in soil fertility. Investing in soil fertility management is necessary to help households mitigate many of the characteristics of poverty, for example by improving the quantity and quality of food, income, and resilience of soil productive capacity to environmental change.

The integrated soil fertility management (ISFM) is a holistic approach to soil fertility research that embraces the full range of driving factors and consequences of soil degradation — biological, physical, chemical, social, economic and political. There is a strong emphasis in ISFM research on understanding and seeking to manage the processes that contribute to changes in soil fertility. The emergence of this paradigm, very closely related to the wider concepts of integrated natural resource management (INRM), represents a significant step beyond the earlier, narrower, nutrient replenishment approach to soil fertility enhancement.

Research on natural resource management has been criticized for not addressing the real needs of rural people and hence has often been judged irrelevant. In the march to generate solutions to farmers' problems, research has generated a wide variety of technologies, such as fertilizers, improved legume germplasm and crop rotations. ISFM arose because of the recognition that addressing the ***interactions*** between components (e.g., water, pests and soils) is as important as dealing with the components themselves. However, improving the natural resource base without addressing issues of marketing and income generation (e.g. the resource-to-consumption logic) seems sterile and is often the reason for a lack of adoption of improved farming practices.

To address the soil fertility related issues and to contribute to sustainable land management in the tropics, the research for development portfolio of CIAT includes the Mega Project entitled "Integrated soil fertility management in the tropics" which is housed in the Research for Development Challenge "Improving Management of Agroecosystems in the Tropics". The goal of the project is to strengthen national and international capacity to manage tropical ecosystems sustainably for human well-being, with a particular focus on soil, biodiversity and primary production; to reduce hunger and poverty in the tropical areas of Africa and Latin America through scientific research leading to new technology and knowledge; and to ensure environmental sustainability through research on the biology and fertility of tropical soils, targeted interventions, building scientific capability and contributions to policy. The

main objectives are: (1) to support the livelihoods of people reliant on agriculture by developing profitable, socially-just and resilient agricultural production systems based on Integrated Soil Fertility Management (ISFM); (2) to develop Sustainable Land Management (SLM) in tropical areas of Africa and Latin America through reversing land degradation; and (3) to build the human and social capital of all TSBF-CIAT stakeholders for research and management on the sustainable use of tropical soils.

To achieve these objectives, the work is organized into five major outputs:

1. Biophysical and socioeconomic processes understood, principles, concepts and methods developed for protecting and improving the health and fertility of soils;
2. Economically viable and environmentally sound soil, water, and nutrient management practices developed and tested by applying and integrating knowledge of biophysical, socio-cultural and economic processes;
3. Partnerships and tools developed and capacity enhanced of all stakeholders for improving the health and fertility of soils;
4. Improved rural livelihoods through sustainable, profitable, diverse and intensive agricultural production systems;
5. Options for sustainable land management (SLM) for social profitability developed, with special emphasis on reversing land degradation.

Each of these outputs has specific output targets for each year to contribute towards output level outcomes and output level impacts. The outcomes and impacts are conceptualized using seven strategic pillars:

1. Improving fertilizer efficiency and developing soil and water management practices;
2. Improved germplasm as an entry point for managing soil fertility;
3. Managing the genetic resources of soil for enhanced productivity and plant health;
4. Understanding farm level social dynamics;
5. Linking farmers to markets, nutrition, and health;
6. NRM strategies to move from plot to landscape scales; and
7. Strengthening scientific and institutional capacity of partners for integrated soil fertility management.

The project has a major focus on developing and extending technologies that support sustainable intensification of cropping systems, especially in the dry and moist savanna, hillside, and forest and forest margin agro-ecological zones (AEZs) in Africa and Latin America. In these AEZs, poverty, population growth and a rising demand for food is driving expansion of cropped area into increasingly marginal lands and/or remnant forest zones. Under these circumstances, sustainable intensification of agriculture on already cultivated land represents the most promising solution to achieving food security and protecting against natural resource degradation.

Changes:

Reduced core support to CIAT by donors resulted in elimination of 3 senior staff positions (Soil Physics, Soil Ecology and Biodiversity, Systems Agronomy) and 10 support staff positions in the TSBF-Latin America team during 2006. Because of this drastic reduction in

core support, the output targets for 2007 and 2008 for the work in Latin America have been revised and scaled down.

CGIAR System Priorities:

CIAT's PE-2 Project (TSBF Institute) on Integrated Soil Fertility Management in the Tropics is housed mainly under CGIAR System Priority Area 4: Promoting poverty alleviation and sustainable management of water, land, and forest resources. Majority of the efforts are dedicated to System Priority Area 4A: Promoting integrated land, water and forest management at landscape level. The project contributes to Specific goals 1 (To develop analytical methods and tools for the management of multiple use landscapes with a focus on sustainable productivity enhancement), 2 (To enhance the management of landscapes through changing stakeholder awareness and capacity for social-ecological planning at landscape and farm levels) and 5 (Creating multiple benefits and improved governance of environmental resources through the harmonization of inter-sectoral policies and institutions). Considerable efforts are also dedicated to System Priority Area 4D: Promoting sustainable agro-ecological intensification in low- and high-potential areas. The project contributes to Specific goals 1 (To improve understanding of degradation thresholds and irreversibility, and the conditions necessary for success in low productivity areas), 3 (To identify domains of potential adoption and improvement of technologies for improving soil productivity, preventing degradation and for rehabilitating degraded lands), 5 (To improve soil quality to sustain increases in productivity, stability, and environmental services through greater understanding of processes that govern soil quality and trends in soil quality in intensive systems), and 7 (To optimize productivity at high input use (e.g. labor, nutrients, pest control practices, water, seed, and feed) through understanding and managing spatial and temporal variation).

Impact pathways:

The 5 major outputs outlined above in the rationale section articulate the logical relationship of activities within the project logframe. Output 1 (*Biophysical and socioeconomic processes understood, principles and concepts developed for protecting and improving the health and fertility of soils*) encompasses our research developing principles and concepts that transcend the classical boundaries of the biophysical sciences through integration with economics, sociology and anthropology. Local and scientific knowledge interact to develop integrated "hybrid" knowledge for soil fertility management, improved food security, and environmental protection. The intended users of the ISFM principles and concepts are CGIAR, ARIs, researchers from NARS and local universities, NGOs, farmers, and regional consortia. These intended users are applying the principles, concepts and methods to improve technologies and system understanding. The final impacts of this output are resilient production systems and sustainable agriculture based on improved soil health and fertility.

The process and integrated knowledge generated under Output 1 activities is therefore applied as sustainable soil fertility and land management practices, shaped by and responding to the socio-cultural and economic environment. Research activities from Output 2 (*Economically viable and environmentally sound soil, water, and nutrient management practices developed and tested by applying and integrating knowledge of biophysical and socioeconomic processes*) address the social, economic, and gendered dynamics of local

knowledge generation and exchange, the nature of the interface between research-extension, local community institutions/social networks, and evaluate the economic and environmental impacts of current or proposed practices. These activities provide general principles and methodologies for TSBF-CIAT and partners to enhance farmers' capacity for applying best principles for sustainable soil, water and land management practices.

At the center of the research-outcome-impact chain, Output 3 (*Partnerships and tools developed and capacity enhanced of all stakeholders for improving the health and fertility of soils*) addresses the building of human and social capital of all TSBF-CIAT stakeholders for effective research and sustainable management of tropical soils. This is particularly necessary since the managing soil fertility for improved livelihoods requires an approach that integrates technical, social, economic and policy issues at multiple scales. To overcome this complexity, research and extension staff need the capacity to generate and share information that will be relevant to other stakeholders working at different scales (i.e., policy makers, farmers).

Output 4 (*Improved rural livelihoods through sustainable, profitable, diverse and intensive agricultural production systems*) represents the application of human and social capital and sound, socio-culturally and economically relevant biophysical principles for ISFM. The challenge of intensification and diversification of smallholder agricultural production is that meeting the food and income needs of the poor cannot occur without investment in natural resource management, especially soil fertility. Investment in improving soil fertility is not constrained by a lack of technical solutions *per se* but is more linked to lack of access to information for improved decision making and analyzing trade-offs, inputs and profitable markets.

The highest scale for our research-for-development activities is found within Output 5 (*Options for sustainable land management (SLM) practices for social profitability developed, with special emphasis on reversing land degradation*). These activities are dedicated to applying the findings of all the previous outputs for restoring degraded agricultural lands to economic and ecological productivity, enhancing ecosystem health and improving livelihoods by generating technology, institutional, and policy innovations. Since soils play a central role for the provision of ecosystem services (e.g. regulation of water quality and quantity, carbon storage and control of net fluxes of greenhouse gases to the atmosphere), appropriate soil management at the landscape level should result in enhanced provision of environmental services.

The key assumptions for these 5 outputs are: security and political stability does not restrict access to target sites and continuation of on-going activities; poverty reduction strategies remain central to human development support and funding; TSBF-CIAT stakeholders remain engaged with TSBF-CIAT strategic priorities and/or TSBF-CIAT management continues to adapt and innovate in response to changing priorities; funding for research on globally-important issues continues; and linkages maintained among research and development organizations. The expected beneficiaries, target ecosystems and end users are principally small-scale crop-livestock farmers and extension workers, NGOs and NARES in tropical agroecosystems of Sub-Saharan Africa, Latin America and South-east Asia. The target

ecoregions are East and Central African highlands (Kenya, Uganda, Ethiopia, Tanzania, Rwanda, DR Congo); Southern African savannas (Zimbabwe, Malawi, Mozambique, Zambia); West African region (Burkina Faso, Niger, Cote d'Ivoire, Nigeria, Benin, Togo, Mali, Senegal, Ghana); Central American hillsides (Honduras, Nicaragua); Andean hillsides (Colombia, Ecuador, Peru, Bolivia); Tropical savannas of south America (Colombia, Venezuela); and Amazon rainforest (Brazil, Colombia, Peru).

International Public Goods (IPG):

The IPG of the PE-2 project include:

- Improved knowledge on soil processes;
- Global inventory of below-ground biodiversity;
- Improved knowledge on nutrient and other resource flows;
- Improved knowledge on how different stakeholders use and manage landscapes;
- Tools and indicators to assess soil quality;
- Improved approaches and practices for managing soil, water and land resources;
- Innovative diversification options within farms;
- Decision support tools and models to analyze trade-offs among food productivity, ecosystem services and land conservation;
- Methods and tools for promoting effective collective action for improved soil fertility management and improved livelihoods;
- Novel forms of institutional innovations and policy options to reduce land degradation and to restore degraded lands.

The Institute's comparative advantage is in conducting IPG research on ISFM in farming systems where soil degradation undermines local livelihoods and market opportunities. However, while TSBF-CIAT will focus primarily on strategic research, it is also ready to support technology dissemination and development activities with partners via regional networks and global projects. TSBF-CIAT will continue research on below-ground biodiversity as a means of beneficially managing soil biology, through the GEF-UNEP funded global project on below-ground biodiversity (BGBD) which has successfully completed its Phase I and is about to start its Phase II activities. Much of the applied research and dissemination of findings, as well as NARSs capacity building, will be done via the Institute's regional partner networks/consortia — the African Network for Soil Biology and Fertility (AfNet), the Latin American Consortium on Integrated Soil Management (known by its Spanish acronym, MIS), and the Consortium for Sustainable Development of the Andean Region (CONDESAN). TSBF-CIAT also collaborates with the South Asian Regional Network (SARNet) on soil fertility research in that region.

Partners:

NARES: These are important local partners that contribute staff time and operational resources to all 5 outputs of the project. The staff time of NARES partners is indicated for each country. East and Central African highlands (Kenya-10, Uganda-4, Ethiopia-1, Tanzania-1, Rwanda-5, DR Congo-5); Southern African savannas (Zimbabwe-3, Malawi-1 Mozambique-1, Zambia-1); West African region (Burkina Faso-1, Niger-3, Cote d'Ivoire-2, Nigeria-2, Benin-1, Togo-1, Mali-1, Senegal-1, Ghana-2; Central American hillsides (Honduras-4, Nicaragua-3); Andean hillsides (Colombia-2, Ecuador-1, Peru-1; Bolivia-1);

Tropical savannas of south America (Colombia-3, Venezuela-1); Amazon rainforest (Brazil-3, Colombia-1, Peru-1).

ARIs: These are important international partners that contribute to mostly to strategic research in output 1 on biophysical and socioeconomic processes and output 2 on natural resource management strategies. These include CIMMYT-1, ILRI-1, CIP-1, IFDC-1 ICRAF-2, IITA-2, ICRISAT-2, IRD (France-1), CIRAD (France-2), ETHZ (Switzerland-1), and JIRCAS (Japan-2).

Universities: These are local and international partners that participate mostly in co-supervision of students that work on ISFM related aspects. Nacional (Colombia-6), UNA (Nicaragua-5), UNA and EAP Zamorano (Honduras-6), Uberlandia (Brasil-1), University of Nairobi (Kenya-2), Maseno University (Kenya-1), Makerere University (Uganda-2), Kenyatta University (Kenya-2), Zimbabwe (Zimbabwe-2), Sokoine (Tanzania-1), Universidade Federal de Lavras (Brazil-1), Universidade Regionale de Lavras-FURB (Brasil-1), INPA (Brasil-1), UFAM (Brasil-1), Universidade De Brasilia (Brasil-1), Jawaharlal Nehru University (India-1), University of Agricultural Sciences (India-1), Kumaon University (India-1), Sambalpur University (India-1), Universitas Lampung (Indonesia-1), Brawijaya University (Indonesia-1), Gadjah Mada University (Indonesia-1), Bogor Agricultural University (Indonesia-1), Université de Cocody (Cote d'Ivoire-1), Universite D'Adobo-Adame (Cote d'Ivoire-1), Universidade Veracruziana (Mexico-1), Instituto Polytecnico (Mexico-1, Leuven (Belgium-2), Paris (France-1), Bayreuth and Hohenheim (Germany-3), SLU (Sweden-3), NAU (Norway-1), Cornell (USA-2), Wisconsin-Madison (USA-1), U.C. Davis (USA-1), Ohio State (USA-1), Colorado State University (USA-1), East Anglia (UK-1), Queen Mary University (USA-1), Michigan State University (USA-1), ITC (The Netherlands-1) University of Exeter (UK-1), and Wageningen University and Research Centre (Netherlands-3).KU-Leuven University (4).

Regional Consortia: These partners play a key role in building capacity in the regions for ISFM research and also for dissemination of tools and technologies to promote ISFM. These include AFNET for Sub-Saharan Africa, African Highlands Initiative for African highlands, MIS for Central America, and CONDESAN for the Andean region of South America.
NGOs: These partners play a key role in dissemination of tools and technologies for ISFM in the regions. These include CARE-Kenya, World Vision, CIPASLA and CIPAV.

In addition to the above partners, PE-2 project also participates with Systemwide Programs (AHI, PRGA) and Challenge Programs (Water and Food CP, SSA-CP).

Project Funding:

Budgeting 2005-2009

Year	2005 (actual)	2006 (estimated)	2007 (proposal)	2008 (plan)	2009 (plan)
US Dollars (millions)	6.405	7.253	6.012	5.710	5.538

CIAT PROJECT PE-2: INTEGRATED SOIL FERTILITY MANAGEMENT IN THE TROPICS (2007-2009)

Targets	Outputs	Intended User	Outcome	Impact
OUTPUT 1	Biophysical and socioeconomic processes understood, principles, concepts and methods developed for protecting and improving the health and fertility of soils	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Principles, concepts and methods inform technology and system development	Improved soil health and fertility contribute to resilient production systems and sustainable agriculture
Output Targets 2007	At least three indicators of soil quality at plot and farm scales in acid soil savannas identified	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Partners begin validating indicators of soil health and fertility	
	Land use intensity impact on BGBD evaluated in seven tropical countries participating in the BGBD project	Scientists participating in the BGBD project, ARIs, CGIAR, researchers from NARS and local universities, and farmers	Links between BGBD and land use management established and used as basis for developing sustainability in tropical farming systems	
	At least two indicators of soil quality used for farmer's decision making in hillsides agroecosystem	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Partners incorporate farmer decision making in new proposals and on–going activities	
Output Targets 2008	Practical methods for rapid assessment and monitoring of soil resource base status developed	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Partners are using the methods with farmers	
	The social, gender, and livelihood constraints and priorities affecting the sustainable use of soils have been identified, characterized, and documented through case studies using innovative methods	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Partners are working to overcome the identified constraints with new proposals and on-going research	

Targets	Outputs	Intended User	Outcome	Impact
Output Targets 2009	Decision tools for soil biota and nutrient management developed and disseminated to stakeholders	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Partners involved in research for development are using the decision tools	
	Knowledge on relationships between soil fertility status and the nutritional quality of bio-fortified crops is used by development partners to target production of these crops	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Stakeholders in research for development focus on food quality in addition to production	
	Sufficient knowledge on mechanisms driving tolerance to drought and low soil P is available to guide breeding efforts	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Breeders involve soil scientists in the breeding program	
OUTPUT 2	Economically viable and environmentally sound soil, water, and nutrient management practices developed and tested by applying and integrating knowledge of biophysical, socio-cultural and economic processes	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Technologies, systems and soil management strategies adopted and adapted through partnerships	Adapted technologies contribute to food security, income generation and health of farmers
Output Targets 2007	Banana, bean and cassava-based systems, with the relation between pest, diseases and ISFM as entry point, including novel cropping sequences, tested and adapted to farmer circumstances in Africa	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Banana, bean and cassava-based systems and soil management strategies adopted and adapted through partnerships	
	Benefits of agropastoral systems on crop productivity and soil quality quantified in acid soil savannas	CGIAR, ARI, researchers from NARS and local universities	Agropastoral systems and soil management strategies adopted and adapted through partnerships	

Targets	Outputs	Intended User	Outcome	Impact
Output Targets 2008	Communities in at least three countries demonstrate and test direct or indirect management options that enhance locally important ecosystem services using BGBD	BGBD network, CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, policy makers and global conservation organizations	Researchers, farmers, land users and policy makers and global conservation organizations increase their awareness of the benefits of conserving and managing BGBD	
	Quesungual and other related agroforestry systems, with soil and water conservation as entry point, including crop diversification strategies, tested and adapted to farmer circumstances in Central America	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Quesungual system and soil management strategies adopted and adapted through partnerships	
Output Targets 2009	Local baselines and interviews show that farmers' understanding of soil processes is demonstrably enhanced within community-based experimentation in at least 5 benchmark sites	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Scientists blend local and new scientific knowledge in the experimental design	
	The potential for occurrence of positive interactions between organic and mineral inputs is evaluated for the most common cropping systems in each mandate area.	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Stakeholders appreciate the complementary role of both inorganic and organic inputs and use them judiciously	
	Throughout the Institute project life, new questions generated in the evaluation efforts of the different target outputs are addressed and fed back to these evaluation activities	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	PM&E is institutionalized and used by all project partners	

Targets	Outputs	Intended User	Outcome	Impact
OUTPUT 3	Partnerships and tools developed and capacity enhanced of all stakeholders for improving the health and fertility of soils	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	Strengthened and expanded partnerships for ISFM facilitate south-south exchange of knowledge and technologies	Improved institutional capacity in aspects related to ISFM and SLM in the tropics contribute to agricultural and environmental sustainability
Output Targets 2007	Strategy for building capacity for SLM is developed with partners	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	TSBF-CIAT scientists and partners lead globally-funded research on at least three topics of key relevance to the international community (as identified in GEF, MDG, MEA, CGIAR mission and goal statements)	
	At least three capacity building courses on ISFM held by AfNet and MIS	AfNet, MIS	Partners incorporating new knowledge and skills in new proposals and on-going research efforts	
	Books, web content and papers produced by partners in BGBD project both north and south in seven tropical countries	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	Partners incorporating new knowledge and skills in new proposals and on-going research efforts	
Output Targets 2008	Farmer-to farmer knowledge sharing and extension through organized field trips and research activities result practices in at least two sites	Researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	Farmers realize benefits of knowledge sharing	

Targets	Outputs	Intended User	Outcome	Impact
	Web content in the BGBD website enhanced to contain data and information on BGBD taxonomy and species identification	Researchers, CGIAR, ARI, local universities	Increased number of biodiversity scientists use the website for proper identification and classification of soil biota to species level	
Output Targets 2009	Profitable land use innovations scaled out beyond pilot learning sites through strategic alliances and partnerships, and application of alternative dissemination approaches.	Researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	Partners incorporating new knowledge and skills in new proposals and on-going research efforts	
	At least three capacity building courses on ISFM held by AfNet and MIS	Researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	Partners use the T shape approach that enhance efficiency in R4D	
	Strategies for institutionalization of participatory NRM approaches and methodologies established	Researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	New institutional arrangement catalyse multidisciplinary work and enhance scaling up of technologies and best practices	
OUTPUT 4	Improved rural livelihoods through sustainable, profitable, diverse and intensive agricultural production systems	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	Partners promoting resilient production systems with multiple benefits (food security, income, human health and environmental services)	Improved resilience of production systems contribute to food security, income generation and health of farmers

Targets	Outputs	Intended User	Outcome	Impact
Output Targets 2007	Crop-livestock systems with triple benefits tested and adapted to farmer circumstances in hillsides	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	Farmers are testing and adapting improved production systems in at least 15 sites across five countries	
	Strategies of BGBD management for crop yield enhancement, disease control, and other environmental services demonstrated in seven tropical countries participating in the BGBD project	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	Farmers and governments adopting BGBD technologies in crop production and ecosystems services	
Output Targets 2008	Improved production systems having multiple benefits of food security, income, human health and environmental services identified	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	Market-led hypothesis is incorporated in systems experimentation; Different partners linking food security, environmental sustainability and income generation to health	
Output Targets 2009	Validated intensive and profitable systems are being demonstrated, promoted by partners and adopted by farmers in 10 countries	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	Increased sustainable productivity and profitability of major cropping systems	
	The contribution of multiple stress adapted germplasm in driving overall system resilience is understood for the conditions occurring in all mandate areas	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	Farmers pay more attention to the sustainability of their farming system in addition to productivity	

Targets	Outputs	Intended User	Outcome	Impact
	Products of the trade-off analysis are guiding the introduction and evaluation of alternative NRM options, better suited to the farmer production objectives and the environment of the actions sites	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	Farmers use results of trade off analysis to make appropriate choice	
OUTPUT 5	Options for sustainable land management (SLM) for social profitability developed, with special emphasis on reversing land degradation	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	Principles of sustainable land management integrated in country policies and programs	Reversing land degradation contribute to global SLM priorities and goals
Output Targets 2007	Decision tools (GEOSOIL; Decision Tree) available for land use planning and targeting production systems in acid soil savannas	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, policy makers	Local organizations using the decision tools for land use planning	
	Biophysical, social and policy niches in the landscape for targeting SLM technologies and enhanced ecosystem services identified and prioritized	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, policy makers	Methods of SLM are incorporated in the design of landscape research	
Output Targets 2008	Methods developed for socio-cultural and economic valuation of ecosystem services developed and applied for trade-off and policy analysis in at least in 1 humid and 1 sub-humid agroecological zones	CGIAR, ARI, researchers from NARS and local universities, BGBD network, NGOs, farmers, regional consortia, policy makers	Methods of SLM are incorporated in the design and evaluation of landscape research	

Targets	Outputs	Intended User	Outcome	Impact
	In at least four of the countries participating in the BGBD project, policy stimulated to include matters related to BGBD management, and sustainable utilization.	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, policy makers	Policy issues related to BGBD acquisition, exchange, intellectual property rights (IPR), benefits sharing, etc. included in local, national and regional government policies	
Output Targets 2009	30% of partner farmers in pilot sites used SLM options that arrested resource degradation and increased productivity in comparison with non-treated farms	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, policy makers	Increased productivity and conservation of degraded landscape	
	75% of stakeholders in target areas have an improved capacity for collective action and local policy negotiation and implementation of integrated land use practices using integrated agricultural research for development	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, policy makers	Improved knowledge sharing and exchange to empower stakeholder to innovate with respect to technologies and best land conservation practices	
	The benefits of community-based watershed management innovations quantified and disaggregated by wealth and gender	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, policy makers	Increased investment in beneficial conservation	

CIAT PROJECT SN-1: RURAL AGROENTERPRISES DEVELOMENT

NARRATIVE PROJECT DESCRIPTION

Rationale and Changes

Rationale:

Given that there is only a decade left to achieve the Millennium Development Goal of halving the number of people living under one dollar per day and that seventy percent of people living in extreme poverty are located in rural areas of developing countries, greater attention is needed on finding ways of improving marketing and income options for the rural poor. CIAT's Rural Agro-enterprise project is designed to contribute towards this goal by working with partners to improve smallholder's market access.

However, the marketing context for smallholder farmers is challenging. External global trends, such as globalisation and market concentration combined with internal changes caused by liberalisation, urbanisation and privatisation have led to rapid changes in the marketing environment. Many smallholder producers are becoming increasingly marginalised due to their lack of assets, skills and competitiveness and inability to join the modernisation of markets. The consequences of these changes are profound, as smallholder incomes fall, supply and prices are more prone to volatile movements, thin margins lead to lack of investments in natural resources, business services cannot be supported and the result is that poorly managed farming systems are spreading. In many developing countries the effects of market and government failure are locking millions into poverty. Given the magnitude of the marketing challenge faced by smallholders and poor urban communities, there is both considerable scope and a pressing need to find approaches to "make markets work better for the poor".

CIAT's Rural Agro-enterprise Development Project (RAeD), aims to support pro-poor growth by enhancing the entrepreneurial development needs of institutions that facilitate business development with rural communities. The products of our research focus on "how" to achieve better market engagement for the rural poor, with an emphasis on realising outputs that (i) facilitate business support services, (ii) foster new institutional arrangements to enhance market led interventions and investment (iii) evaluate policy options that lead to more effective design of agricultural based interventions.

The project's evolution from a commodity focus to agro-enterprise was made in response to demands from partners requiring a methodical process for shifting from production based approaches, to identifying and responding to market demands. The aim was to enable service providers[6] to assist communities in increasing the competitiveness of their existing products and to facilitate a systematic approach for diversification into alternative and higher value products.
The outputs of RAeD's research aim to promote a "market chain" perspective to agricultural interventions such that partners and agencies that use our products can

[6] The term "service providers" refers to public agencies for research, extension and local administration and private sector actors and agencies involved in extension, business planning and market facilitation.

support the development of enterprises and services and strengthen business relationships between producer groups, traders, processors and buyers. RAeD is advocating that development agencies and investors adopt methods that foster systemic change in markets rather than only focussing "on farm". The methods and tools developed by RAeD emphasis the need to design interventions that can scale up rapidly and encourage a continual process of innovation as a means to tackle the dynamic nature of markets and to shift from pilot projects to broader impact in a competitive manner.

Although simple in nature, the challenge of incrementally building marketing skills and facilitating pro-poor market interventions rather than simply providing unsustainable goods and services is a serious challenge. A challenge that applies to resource poor farming communities, their public and private sector support services, donors and large scale commercial buyers interested in improving the supply of quality agricultural products with smallholder farmers.

Experience shows that for marketing approaches to be effective, service providers and investors, from the public or private sector will need to find new ways of doing business that have a less distorting effect on markets, acquire new skills and develop new types of relationships. These changes generally require more time to implement that traditional safety net approaches, finances need to be addressed with a view to promoting growth rather than churn. These changes require careful planning and flexibility if they are to make markets work better for the poor. RAeD intends to play a catalytic role in this process.

Changes:

The project has and will have to make a number of changes due to the difficult financial situation within CIAT. We are attempting to shift staff from core onto non core funding. This may slow down some of the core activities but hopefully will make the project more sustainable in the future. Staffing problems and management transitions in Asia have affected our ability to support the project in Vietnam and Lao PDR.

The strategy of RAeD is changing in terms of our positioning. Whilst many project activities 5 years ago were undertaken directly with farmer groups, our role is shifting towards supporting higher order service providers and incorporating a greater emphasis on working with private sector buyers and agencies such as supermarkets.

This shift is being made for several reasons, where possible, we charge for our services to clients and therefore we need to operate at a higher level of intervention. Also, in order to operate in the high value market area, we need to be interacting directly with larger, more commercial operations, so that we better understand, higher value market opportunities and are therefore able to facilitate this area for smallholders.

Through this process, we are segmenting the work and developing IPG's that focus on poor smallholders with service providers and on higher value markets with commercial partners.

It is also envisaged that RAeD activities will in the future also place greater emphasis on services rather than "on-farm" activities, so as to facilitate and foster changes in the market place rather than be involved in localised activities.

CG System Priorities:

The emphasis of this project is on priorities (i) 5B making markets work for the poor, (ii) 5C strengthening rural institutions, and (iii) 5D developing options for reducing poverty. RAeD is also developing activities in 2C, Genetic improvement of nutritional quality and 3A market development for high value fruits and vegetables.

The project is working with a range of partners including farmer associations, development projects, NGO's, private sector and donor support groups to develop ways to improve market efficiency and enable poor smallholder farmers and rural traders to better understand market dynamics and engage in markets more effectively.

The products from RAeD aim to support non market distorting processes that will assist the poor in their market engagement as outlined in SCP[7] 5B. A critical part of this process is to move away from the direct provision of goods and services, by Governments and NGO's to a more systemic approach to changing the "rules of the game" and enhance the ability of poor farmers and traders to "enter the game". This requires working with service providers and investors, to consider how poor farmers and traders can work within markets and incrementally develop the skills required, rather than benefit from short term interventions that often undermine their ability to engage with markets in a sustainable manner.

Rural institutions include "farmer organisations" that are strengthened by taking on new skills that will assist them in making the transition from opportunistic marketing of occasional surpluses towards a more systematic approach to producing a specific product, for an identified market, at a specified price to an identified buyer, SCP 5C. These skills specifically aim to increase incomes over the longer term, and through this process create the demand and ability to pay for new technologies and support services. Technology drives will not work on hand out approaches; technologies will only be adopted if it is embraced by the market.

This work also includes the development of local market information services, that builds the capacity for sharing knowledge and fosters better business decision making. In Uganda, 70% of 4 million rural households listen to market information that is provided through a RAeD supported market information service at a price of US 1.5 cents per household, per year. This is fostering change.

The enterprise tools and skills that have been developed are mainly gender neutral, in which case they can be promoted for use by women, men or combinations. The language of our IPG's however, attempts to encourage to women to play a more active role in decision making with farmer enterprise groups and in particular with financial issues. Many of our "learning alliance" partners work with communities in extreme poverty and often with those emerging from disaster. For these communities, small incremental changes in income can rapidly elevate people from absolute poverty to being able to manage their futures and most importantly prepare for short term

[7] SCP – Science Council Priority

economic shocks. Based on the findings from self help groups in India, we are encouraging savings led approaches to enterprise and it is often women that have the discipline and drive to lead such processes, as indicated in SCP 5D.

At the trade level, RAeD is seeking to develop national market information services that assist and encourage arbitrage of goods and the development of additional local business services that will foster more sustainable business development. Additional work is also investigating how to foster better business relations with public and private sector partners and through this mediation how to enable poor women and special needs groups, such as those suffering from HIV / AIDs, and those emerging from disaster to prepare for the market, SCP 5D.

New activities being developed with commodity project partners include the work on providing iron rich bean varieties to poor rural and urban consumers. Beans are a rapidly expanding commercial crop for the poor in developing countries and RAeD is aiming to develop tagging systems so that produce can be traced through market channels to target specific end users. Through this type of mechanism, improved nutritional traits can be embedded in low value, high volume commercial products, SCP 2C.

Finally, RAeD is working with other CIAT projects to enable poor farming communities to benefit from expanding high value product markets including fruits and vegetables, as outlined in SCP 3A.

Impact Pathways:

Output 1 – Enhancing Rural Business Development Services: This area of activity includes the development best practice (IPGs) for market development and poverty reduction. The guides aim to enable service providers to facilitate increased marketing competence of smallholder farmers. The first generation of guides were used in collaboration with partners in Latin America and more recently with partners in Africa and S.E. Asia as a resource to support their marketing intervention with farmers.

Typically, RAeD operates on a cascade system whereby, RAeD interacts with large or international service providers. Activities are undertaken by the partners of these leading service providers, who in turn interact directly with beneficiary groups. Interventions undertaken in this manner include:- (i) Project site resource evaluations and establishing relationships with other agencies and actors in the project to support scaling activities; (ii) evaluating market opportunities, at local, national and export levels, and (iii) developing new enterprises and business development services within selected chains.

There are a number of partners using the RAeD guides in Latin America, Africa and Asia. These activities are ongoing in more than 40 countries. Feedback from the experiences of our partners at the market level, are then used to develop and refine the tools and to develop new a better ways of engaging markets. In addition the service providers also translate and change the guides to suit their needs.

In other cases, RAeD staff will work directly with a private sector partner to develop a new information management software package or knowledge systems, which are

then distributed through the private sector or through the web to beneficiaries and their service providers. Examples of this type of distribution can be viewed on the agro-enterprise website. www.ciat.cgiar.org/agroempresas/ingles/index.htm

Output 2 – Facilitating institutional arrangements to increase rural investment and business expansion: This work integrates products from output 1 with new organisational approaches that foster relationships between public and private sector actors so as to maximise their effectiveness in rural enterprise development.
As an example, the best practice guides developed in output 1 are being used by the RAeD team through "action research partnerships" and "learning alliances". These partnerships are based on the development of long term capacity building programs that include integrated research and testing of the methods.

This approach enables the team to out scale the agro-enterprise methods and tools rapidly and also to test and compare how the CIAT methods perform. Through this process, the learning is accelerated and the tools and methods and refined more quickly.

RAeD is working on a number of approaches to fostering better research and development partnerships. These methods include:- (i) learning alliances, (ii) public private partnerships, (iii) action research partnerships for rural businesses and (iv) more recently with tools to develop business partnerships between large commercial industries and smallholder associations.

The learning alliance provides an example of a new type of partnership that is working with a number of partners from NGO's and private sector. This relationship enables the RAeD team to develop initiatives on many of the Science Council Priorities, with agencies that have considerable resources. Our role is therefore to catalyse the way development is implemented through sound research methodologies. Currently partners are taking on these approaches and further refining the way activities are undertaken, which further accelerates the rate of spread. A process of use and abuse is encouraged.

New areas of research include how to integrate micro-finance instruments, such village savings schemes into agro-enterprise processes and how to develop methods for investment in major NRM impediments, so as to foster enterprise options.
Output 3. Strengthening pro-poor policy options for rural communities: This is an area in which RAeD is developing new activities. Early results in this area include the development of the Marketing and Agro-processing Strategy for the Government of Uganda's Plan for the Modernization of Agriculture. This strategy document provides an outline of the priority marketing areas to foster the commercialization of the smallholder farming sector, where new investments should be made to support marketing and the institutions that partners should link with or are already working in identified areas.

The strategy enables policy makers to define budget allocations and resources to priority areas and also for donor organization to target where they want to place investments.

In other areas, the RAeD team is investigating includes developing strategies for CIAT and GFAR on how to enable the poor to benefit from high value markets. Given that most poor farmers have failed to benefit considerably from lower risk, low value markets, the process of benefiting from high value markets is a challenging task. RAeD is working with leading agencies already operating in this area with a view to develop IPG's that will provide methods to mitigate the risks involved in such markets and foster greater investment for smallholder farmers.

International Public Goods:

The RAeD project is investing considerable time in developing a portfolio of public goods, which includes, research papers, student theses, improved methods and capacity building materials, University and specialist agency courses and knowledge systems for sharing information. These knowledge based goods are being applied to increase the marketing and entrepreneurial competence of service providers. Similarly, RAeD is developing private sector products and services to support better market engagement and decision making for rural smallholders and their local business support services.

The team is undertaking impact studies on behalf of donors to assess the value of market led interventions and working with policy makers to develop better strategies and policy frameworks to facilitate the activities of the private sector. Through this process, we aim to contribute towards future interventions that have less market distorting and are better able to support local entrepreneurial needs. These public goods are being developed on a demand basis and there are a steadily increasing number of direct and indirect partners that are using and adapting these materials. RAeD is well positioned to develop these types of public goods, due to our presence in-developing countries, our strong links with a range of partners including (i) centres of advanced learning, (ii) national and international research, NGO's and the private sector. Through learning based partnerships, we can undertake action based research to test new ideas, undertake more strategic studies to understand and refine ongoing interventions and also work with partners to design and innovate new methods, tools and business models in a collaborative manner.

Partners:

RAeD is working through an expanding range of partners and clients made up from technical personnel of GOs, NGOs in rural development, policy makers from public and private sector and private sector. For a more exhaustive partner list please see RAeD's 2005 annual report.

Our business partners include farmer groups (men and women), entrepreneurs, local business support service who benefit from co-innovation and information based applications that enhance access to high volume and high value market opportunities, and, in some cases, selected large-scale private firms interested in assessing and improving the sustainability of their supply chains.

Examples of private sector partners:

- Busylab working to develop a national market information software platform. Current investment is approximately $100,000 per year with a research group of 3 software specialists and MIS services in 14 countries. *This work links to Output 1.*

- Green Mountain Coffee and Organica are engaged in supporting marketing of niche speciality coffee into export markets in USA. *This work links to Output 2.*

Examples of civil society partners:

- The Catholic Relief Service is a key partner in developing the global agro-enterprise learning alliance. To date there are 33 country programs from CRS involved in implementation of market led project work. These countries are investing 2-300,000 in capacity building through the learning alliance and implementing this work in projects worth more than $10M. *This work links to Output 2.*
- Traditional Irrigation Project (TIP): In Tanzania, TIP is working with CIAT to adapt best practise guides for agro-enterprise with the Governments program of agricultural marketing development. TIP is currently working with 27 other agencies in developing marketing skills and local marketing projects.
- SNV are working with CIAT in devising new ways of assisting poor farmers to engage with higher value markets. SNV work started in Central Latin America, with market chain support, links are now spreading to Eastern and Western Africa through the learning alliance.
- CATIE are working with CIAT to mainstream agro-enterprise methods into their diploma course. Through such linkages the project aims to develop educational materials that will be available to other centres of learning to integrate these methods into student curriculum.

Project Funding:

Budgeting 2005-2009

Year	2005 (actual)	2006 (estimated)	2007 (proposal)	2008 (plan)	2009 (plan)
US Dollars (millions)	2.336	4.030	3.637	3.508	3.461

PROJECT SN-1: RURAL AGRO-ENTERPRISES DEVELOPMENT (2006-2009)

Targets	Outputs	Intended User	Outcome	Impact
CIAT- SN-1 Agro-enterprise				
OUTPUT 1 – Enhancing Rural Business Development Services	Alternative rural agro-enterprise methods, strategies, and applications that effectively link smallholder farmers and rural services with value chain opportunities widely adopted by research and development partners, State organizations and private sector. (5 years)	Development agencies and service providers including NGOs, Gov extension workers, local business support providers, private sector, farmer organizations.	More effective identification and exploitation of market opportunities by poor rural communities.	• Increased and more diversified incomes for poor rural communities.
Output targets 2007	• Agro-enterprise methods and strategies, market based software applications validated and contextualized with development partners. • Products published in print and disseminated in electronic formats. Methods available in English, Spanish, French, Vietnamese and Lao.	• Development partners and service providers linked to selected market chains, enhance through Local ICT providers, and CBO's	• Market based software and ICT market information applications will open new opportunities for commercial investment.	• Significantly increased use of marketing tools by service providers leading to more diversified and measurable gains in incomes for poor rural communities.
Output targets 2008	• Training materials for agro-enterprise completed, software applications commercialized, web based marketing portals expanded through partners with emphasis on private sector business development partners, available in 10 languages.	• Marketing services in East and Western Africa linked to private sector software houses. NGO's, farmer associations, Micro-finance, NGO's, farmer associations	• Private sector invest in services and farmers link services and financial investments in higher levels of innovation and market engagement.	
Output targets 2009	• Partners leading expansion and adaptation of first generation marketing methods and tools. • Methods for linking farmers to higher value markets through business partnerships, available in 3 languages.	• Farmer groups linked to International NGO's, companies, and national service providers.	• Private sector and farmers co-invest in higher value market chains. • Service providers facilitate process, rather than providing goods and services	
	Realization of new institutional arrangements	Strategic partners from	New business approaches and	Increased and more

Targets	Outputs	Intended User	Outcome	Impact
OUTPUT 2 – New Institutional Innovations for increased rural investment and business expansion	and innovations to facilitate market linkage, collective action and financial support for improved market entry and business development among segmented rural agro-enterprises evaluated and tested with partners in selected sites (10 years)	NGOs, Gov extension, private enterprise, donor agencies and farmer organizations	financial instruments enable institutions to extend enterprise opportunities deep into rural communities targeting both high volume and high value markets, with scaling opportunities realized through ICT expansion and co-investment between public and private sector partners	diversified incomes for poor rural communities
Output targets 2007	• Learning alliance partnerships established for impact, action research and strategic studies. • ICT based knowledge management systems and first level enterprise "tool box" for learning alliance completed to support selected sites in LAC, SE Asia and Africa, scaled up to 30 countries.	• Clients: Strategic partners from NGOs, Gov extension, private enterprise, donor agencies and farmer organisations	• Strategic partners invest in learning process and integrate marketing skills into project development and implementation	• Increased partner skills, more effective rural development projects and inputs for improved public, private and donor policies
Output targets 2008	• Expansion of ICT related knowledge management systems in 30 countries, with second order learning alliances established. University courses mainstream agro-enterprise concepts with partners in Latin America and Africa and rural finance mechanisms linked with non-financial BDS	• Strategic partners involved with co-innovation of new processes and products	• Strategic partners invest in new areas for co-innovation, such as linkage between HIV and enterprise, Gender and market chain equity, local policy reform and enterprise	
Output targets 2009	• High value agro-enterprise methods integrated into social corporate responsibility projects with partners in at least 5 countries in Latin America, Africa, and Asia and available in at least 3 major languages.	• Strategic partners from private enterprise, donor agencies and farmer organizations	• Strategic partners integrate marketing skills into value chains.	
	Policy options evaluated to make markets and marketing services work better for the poor.	National and regional policy makers in Asia, Africa and	Partners using national and cross continental data to	Increased and more diversified incomes

Targets	Outputs	Intended User	Outcome	Impact
OUTPUT 3 – Pro-poor enterprise policy options for rural communities	Studies on markets and rural business development services undertaken and policy recommendations advocated with partners at local, national and international levels. (5 years)	Latin America; donors and private sector, NGOs, advocacy groups.	formulate better policy options for smallholder farmers in LDC countries to enhance access to selected high volume, higher value and value added markets.	for poor rural communities
Output targets 2007	• Research outcomes lead to projects that enable differentiated clients and service providers to achieve better access to markets and services. • New models in place that link private sector firms with smallholder farmers based on principles of business equity and sustainable NRM. • Impact studies of BDS service options for small-scale producers undertaken in selected sites to support pro-poor market improvement.	• Advocacy groups, NGO's, Policy and economics researchers, National – regional trade policy groups, Private sector firms	• Initial model for linking smallholders with major private sector firms in a sustainable fashion.	
Output targets 2008	• Guide on policy mechanisms to link small-scale farmers effectively to regional, national and international agri-chains, and to improve governance and equity in the production chain approach validated and adjusted.	• Policy groups as above	• Broader understanding of impact of current policies on CGIAR clients and beneficiaries	
Output targets 2009	• Processes for "non market distorting" rural intervention planning and investment initiated with partners in at least 3 countries in Latin America, Africa, and Asia and available in at least 3 major languages.	• Strategic partners from NGOs, Gov extension, private enterprise, donor agencies and farmer organizations	• Strategic partners invest in learning processes and integrate non market distorting approaches into private sector development programs.	

PROJECT SN-3: PARTICIPATORY RESEARCH APPROACHES

NARRATIVE PROJECT DESCRIPTION

Rationale & Changes

Goal:
To conduct research and develop methods, approaches and technologies for improving local innovation systems and market linkages in resource-poor rural economies

Objective:
Community-managed participatory research methodologies for organizational and technological innovation in agriculture co-developed, tested and widely disseminated, benefiting poor farmer groups and their members (with emphasis on ethnic minorities and women).

Important Assumptions:
Institutional economic stability. Participatory research approaches remain a priority in the CG. Donors allocate sufficient resources to participatory research approaches. NARS and other stakeholders remain supportive and receptive to participatory research approaches.

Beneficiaries and End Users:
IPRA's research is directed at improving national agricultural innovation systems by developing and disseminating institutional innovations that better articulate local needs to R&D service providers, leading to pro-poor technological change. R&D organizations and personnel will increase their use of innovative participatory approaches thereby making technology development more relevant and useful to the poor. The use of participatory approaches and the innovation systems perspective will drive adoption of technologies and innovations that improve institutional efficiency, better delivery of quality services, uptake of research results and feedback to research priorities. IPRA develops participatory research approaches and methodologies that include social network analysis, community-driven participatory monitoring and evaluation and farmer-led experimentation in farmer organizations and for linking farmers' organizations to markets. The project's research products are international public goods (participatory approaches, methods, and tools) that are broadly applicable by a variety of international R&D stakeholders.

Rationale:
Since the late 1980s, CIAT has developed and promoted a wide variety of approaches and methodologies for participatory research and development. These participatory approaches emerged as an alternative to coping with poverty and complexity of farming systems, and for strengthening the adaptive capacity of farmers and other local stakeholders to generate new knowledge, and learning to share existing knowledge. Such approaches emphasize the iterative, adaptive nature of innovation in complex systems, which is achieved through systematic inquiry combined with learning based on action. IPRA's goal is to conduct research and develop methods, approaches and technologies for improving local innovation systems and market linkages in resource-poor rural economies. The objective is to develop, test and evaluate community-driven participatory research methodologies for organizational and technological

innovation in agriculture co-developed, tested and widely disseminated, benefiting poor farmer groups and their members (with emphasis on ethnic minorities and women). An important component of which is generating knowledge and developing research products to meet local priorities and adapted to changing conditions. The participation of all stakeholders, alongside scientists in a jointly managed process of investigation and learning based in action-research is a central feature of research for development.

In recent years, IPRA's efforts have been geared increasingly towards consolidating lessons and institutionalizing participatory research approaches in agricultural research and development organizations. A key finding is that having impact on rural livelihoods requires an integrated research agenda. In this regard, IPRA is focusing more on research for enabling rural innovation (ERI) aimed at applying the most effective elements from CIAT's expertise and experience to build more robust livelihood strategies within the rural community. Research emphasis is on understanding how to catalyze and support rural innovation processes.

Changes:

Our research will continue to focus on understanding the dynamics of rural innovation systems and developing more effective ways of organizing and working with farmers' groups and building their capacity to innovate, and strengthen the interaction between rural communities and the wider innovation systems in which they are embedded *to make research more relevant, more effective, more decentralized in ways that fuel local innovation.*

In Africa, our research will continue to test and refine the resource to consumption (R-to-C) framework, and particularly to examine the hypothesis that better market opportunities provide incentives for demand and investment in agricultural innovations. We will investigate the contextual factors (institutional, social, policy, historical, contested knowledge) that enable or constrain innovation processes in rural communities; and what conditions or incentives are necessary for women and other marginalized groups to invest in agricultural and NRM innovations? IPRA will play an important role in the implementation of the research agenda of the Sub-Saharan Africa Challenge Programme by coordinating a multi-institutional Task Force in the Lake Kivu Pilot Learning Site. Research will identify, test and promote differentiated strategies for different socio-ecological niches to foster market-oriented agriculture for equitable wealth creation. It is hypothesized that improving market access and diversifying agro-enterprises will have equitable and positive impacts on all livelihood dimensions, including the natural resource base.

Through partnerships with the African Soil Fertility Research Network (AfNet) of TSBF and funding from IDRC, IPRA will develop innovative approaches and methods for strengthening the potential of research and development to enhance NRM and improve rural livelihoods in sub-Saharan Africa. The overall research hypothesis guiding this project is that successful innovation processes require research integrated into learning processes. Therefore investments in strengthening human and social capital and institutionalizing participatory approaches will lead to profitable and sustainable natural resources management innovations (institutional, technology, human, social, and policy, amongst others) and improvement in rural livelihoods.

In 2005 IPRA took on the leadership of a project to carry out ex-ante impact assessment of projects in the Challenge Program on Water and Food (CPWF). As part of this work IPRA is researching and developing concepts related to "impact pathways", that is, the implicit models that people use when planning pro-poor interventions in rural innovation systems. We are developing participatory methods that help make these implicit models explicit and help improve them. Research and development on impact pathways is critical because project impact (be it a project implemented by a CG Centre or an NGO) depends largely on how well it is conceptualized.

CG System Priorities:

IPRA directly contributes to priority 5: improving policies and facilitating Institutional innovation to support sustainable reduction on poverty and hunger. Our research explicitly focuses on the general goal of enhancing the role that rural organizations and innovative institutional partnerships play in maximizing impact from agricultural research and in creating marketing platforms for smallholder producers. It seeks to identify mechanisms for the strengthening of producers' organizations and for modes of participatory research (specific goal 1); and to identify new forms of partnership with NARS, the private sector, NGOs and producers' organizations, and public agencies (specific goal 2). In addition, our research also contributes to promoting sustainable agro-ecological intensification in low and high potential areas (priority area 4d), and reducing rural poverty through agricultural diversification and emerging opportunities for high value commodities and products (priority area 3). The work on impact pathways contributes to Priority 5a, specific goal 5 "Enhancing the structure, conduct and performance of knowledge intensive institutions", particularly with respect to benefiting poor farmer groups.

Impact Pathways:

IPRA will research, develop and strategically disseminate participatory research methodologies for organizational and technological innovation in agriculture, benefiting poor farmer groups and their members (with emphasis on ethnic minorities and women). The research strategy involves co-development and adaptation of prototype methodologies with R&D partners so that these methodologies will be assimilated by the institutions as part of their working practice as R&D service providers. The successful uptake of the methodologies will be supported by collaborative evaluation of the outcomes of using them and through impact studies that document the benefit to the users of the methodology in terms of their capacity to call-down R&D services and to bring their influence to bear on the agricultural R&D agendas. IPRA will produce knowledge necessary to empower important actors in national innovation systems to influence policy. Scaling-up within and beyond research sites will occur through strategic partnerships with networks of farmers' associations, entrepreneurs, NGOs and GOs, national, regional and international research and development organizations to promote learning, sharing, uptake promotion and spill-overs of research results to other areas and institutions. Results will assist national and regional bodies to develop and promote appropriate policies and institutional arrangements that will help to contribute to the achievement of the Millennium Development Goals and poverty eradication strategies. Ultimately, these results will enhance opportunities for income generation, employment, and business opportunities that will equitably benefit male and female farmers, farmers' organizations, rural communities, entrepreneurs and other actors (producers, processors, consumers, transporters, traders, policy makers etc) in rural innovation

systems. IPRA has a strong focus on carrying out research and developing approaches that benefit rural women and the poor to generate and use agricultural technologies to their own advantage.

International Public Goods:

To develop IPGs, IPRA conducts action research and applied comparative research that responds to problems and opportunities that have local relevance with national, regional and global application. The research leads to the development of methodologies, approaches and tools to make research more relevant to the needs of small-scale poor farmers, and to increase relevance, effectiveness and impacts of agricultural research. We use a combination of social and biophysical sciences through an integrated approach to develop innovations and technological options that lead to increased market access and diversified agro-enterprise options, innovative institutional arrangements and supportive policies.

Our IPGs include:

- Methodologies, conceptual frameworks, approaches and tools for strengthening farmers' organizations and rural innovation systems.
- Organizational procedures, institutional mechanisms and policies for using participatory methodology in the co-development of technologies with rural innovation systems in Latin America and Africa
- The resource-to-consumption (ERI) framework to strengthen farmer organizations and rural women's capacity allowing transition from semi-subsistence to competitive market-orientated production in Africa and Latin America
- Methodology for establishing community-driven participatory monitoring and evaluation systems (CD-PM&E)
- Generic guidelines and a set of principles for strengthening the organizational capacity of farmers organizations;
- Methods and tools for diagnosing and tracking social capital and for strengthening the organizational capacity of farmers' groups and linking farmers' organizations to service providers, and the private sectors;
- Methods and tools for helping service providers better conceptualize and monitor their impact pathways in rural innovation systems;
- Handbooks and training resource materials for producers, entrepreneurs and their market chain actors;
- Web-based databases of farmers' and entrepreneurs organizations (Diagnosis and characterization, GIS, Livelihood assets, market access, different markets/products, farmers' associations, trade intelligence systems); and (v) Publications (journal articles) on social capital and market linkages.

Partners:

IPRA works with stakeholders along the resources-to-consumption continuum, using an innovation system approach. These include

- National Agricultural Research and Extension and Systems (NARES) in Bolivia, Colombia, Ecuador, Nicaragua, Uganda, Malawi, Kenya, Tanzania, Ghana, Burkina Fasso, Rwanda, DR Congo, etc. provide co-ordination of project activities at the country

level, conduct adaptive research, support farmers' experimentation and provide scientific and technical support to NGOs and private sector. Universities are involved in specific studies and supervision of students' research, capacity building and development of training materials and curricula.

- NGOs are responsible for managing social processes and strengthening local innovation systems that enable rural communities to benefit from the technologies and market opportunities. They help to ensure wide promotion, dissemination and uptake of project results beyond the action learning sites
- Farmers' organizations are involved in the entire research process, designing and conducting experiment with technology and institutional innovations
- The private business sector in Uganda facilitate access to domestic, regional and international markets, and provide advisory and mentoring services on entrepreneurship, and support technology development.
- Regional Networks, System Wide Programmes and Challenge Programmes: African Highlands Initiative, African Soil Fertility Research Network, The Challenge Program on Food and Water (CPWF); Institutional Learning and Change (ILAC) Initiative, ASARECA, PRGA, Sub-Saharan Africa Challenge Programme (SSA CP).
- IARCs: including ICRAF, CIP, ICRISAT participate in collaborative research, training and other joint events.
- Policy and Government organizations in Uganda, Kenya, Malawi and Tanzania
- Donors: IPRA receive funding from a number of donors including DFID, Kellogg Foundation, Rockefeller Foundation, Belgian Directorate General of Development Cooperation, CIDA, the donors who fund the Challenge Program on Food and Water (CPWF), as well as from other national R&D partners in Africa and LAC.

Project Funding:

Budgeting 2005-2009

Year	2005 (actual)	2006 (estimated)	2007 (proposal)	2008 (plan)	2009 (plan)
US Dollars (millions)	2.236	3.121	2.904	2.802	2.764

PROJECT SN-3: PARTICIPATORY RESEARCH APPROACHES

Targets	Output / Output Target	Intended User	Outcome	Impact
OUTPUT 1	Methodologies developed for strengthening farmers' organizations and rural innovation systems[8]	NARES and other organizations and actors involved in rural innovation processes, e.g., IARCs, NARS, NGOs, private sector companies, farmers organizations	Increased capacities of organizations / institutions to develop and promote integrated agricultural and natural resources management innovations	Increased productivity and multiple use of resources (social, financial, natural, human) through integrated agricultural and natural resource management interventions
Output Target 2006	Participatory methodologies developed for: 1) strengthening rural planning, 2) mapping and strengthening social networks; and 3) identification and monitoring of impact pathways	Ditto	Increased efficiency and number of actors including vulnerable/ disadvantaged farmers participating in rural innovation systems	
Output Target 2007	Methodologies and approaches for diagnosis, tracking and strengthening social capital outcomes for improved NRM documented	Ditto	Ditto	Ditto
Output Target 2008	Results of research on strengthening farmers organizations and rural innovation systems published	Ditto	Changes in decision-making and policies in partner organizations to better foster rural innovation occur in at least two innovation systems in Latin America or East Africa	Ditto

[8] By rural innovation system we mean the network of organizations that influence rural innovation. Rural innovation systems can include: farmer groups; NGOs, financial organizations; national and international research institutes; and, local and national government agencies.

Targets	Output / Output Target	Intended User	Outcome	Impact
Output Target 2009	Mechanisms and processes for resilience and maturation of farmers organizations understood and analyzed	NARES, Networks of farmers organizations, IARCs, Donors, Policy makers, Government organizations and private sector	Increased efficiency and number of actors including vulnerable/ disadvantaged farmers participating in rural innovation systems	Ditto
OUTPUT 2	Organizational procedures, institutional mechanisms and policies for using participatory methodology in the co-development of technologies designed and tested with rural innovation systems in Latin America and Africa		Stakeholders form alliances and multi stakeholder platforms for joint learning, participatory M&E, knowledge and information sharing	
Output Target 2007	At least 10 active partnerships developed with national and international organizations in 4 Latin American countries, for action research on organizational procedures, institutional mechanisms and policies for co-development of technologies	NARS in Latin America	Rural innovation systems strengthened through co-development of technologies, and the creation of a more nurturing environment for innovation.	Faster development and adaptation of more appropriate technologies leading to improved sustainable livelihoods, especially for the rural poor
Output Target 2008	An approach consisting of a set of procedures, institutional mechanisms and policies for the co-development of technologies with at least on community-managed innovation system (CAIS) validated	Ditto	Ditto	Ditto

Targets	Output / Output Target	Intended User	Outcome	Impact
OUTPUT 3	The resource-to-consumption (ERI) framework developed, tested and applied to strengthen farmer organizations and rural women's capacity allowing transition from semi-subsistence to competitive market-orientated production in Africa and Latin America	NARES and other organizations and actors involved in rural innovation processes, e.g., IARCs, NARS, NGOs, private sector companies, farmers organizations.		
Output target 2006	A regional symposium in Africa on ERI held to synthesis and share results, and finalize the ERI methodology	Organizations and actors involved in rural innovation processes, e.g., IARCs, NARS, NGOs, private sector companies, farmers' organizations policy makers.	. Stakeholders form alliances and multi stakeholder platforms for joint learning, participatory M&E, knowledge and information sharing	Faster development and adaptation of more appropriate technologies, motivated by better links to markets, leading to improved sustainable livelihoods, especially for the rural poor
Output target 2007	At least 40% of NARS professionals trained in the ERI framework are using it in at least four African countries, and as a result at least 25 farmers' groups are using the ERI approach	Ditto	Increased capacities of organizations / institutions to develop and promote integrated agro-enterprise development solutions for wealth creation Increased efficiency and number of actors including vulnerable/ disadvantaged farmers participating in marketing chain	Ditto
Output target 2008	At least half of participating farmers in the ERI pilot sites have increased their income and productivity by at least 20%	Ditto	Increased number of farmer associations successfully linked to markets and conducting innovative research	Increased income from new and diversified market / agro-enterprise opportunities for the rural and vulnerable communities

	Output / Output Target	Intended User	Outcome	Impact
OUTPUT 4	Methodology for establishing community-managed participatory monitoring and evaluation systems (PM&E) tested, applied and widely disseminated		More promising strategies, mechanisms, and approaches for institutional change, knowledge management, and communication identified	Improved relevance and impacts of R&D products through strengthening the capacity of farmers' groups and organizations to articulate their objectives and visions for the future monitor and evaluate the relevance of R&D services and products to their needs and priorities.
Output target 2006 (1)	Results of research on incorporating participatory monitoring and evaluation (PM&E) into the Bolivian national agricultural research system are presented for consideration by stakeholders	Members of the Bolivian national agricultural research system; other organizations implementing rural R&D projects in Bolivia	Improved implementation of rural R&D projects through better expression of user-demands; community ownership of projects; project monitoring and evaluation, and better targeting of interventions to meet the needs of the poor	Faster development and adaptation of more appropriate technologies leading to improved sustainable livelihoods, especially for the rural poor
Output target 2006 (2)	PM&E systems researched and tested in 10 rural communities in countries in Africa and Latin America	Farmer organizations, CBOs, Latin American and African NARS, including GOs; NGOs; and the private sector	Ditto	Ditto
Output target 2007	At least three teams of facilitators are formed in Africa and Latin America for wider capacity building, dissemination and application of community managed PM&E systems	Ditto	Ditto	Ditto

	Output / Output Target	Intended User	Outcome	Impact
Output target 2008	At least 6 organizations have adopted community-managed PM&E	Ditto	Ditto	Ditto
Output target 2009	At least 40% of R&D partners with skills in PM&E are using gendered local and technical indicators to monitor and evaluate progress on key outputs, livelihood impacts, and environmental sustainability	Ditto	Increased social and human capital in communities as a result of applying PM&E to their projects	Ditto

PROJECT SW-3: SYSTEMWIDE PROGRAM ON PARTICIPATORY RESEARCH AND GENDER ANALYSIS FOR TECHNOLOGY DEVELOPMENT AND INSTITUTIONAL INNOVATION

NARRATIVE PROJECT DESCRIPTION

Rationale and Changes

Rationale:

Phase two (2003–2007) of the Systemwide Program on Participatory Research and Gender Analysis for Technology Development and Institutional Innovation (PRGA Program) builds on the lessons and experiences from phase one (1997–2002). These lessons can be broadly summarized as:

- An absence of a critical mass of participatory research (PR) and gender analysis (GA) practitioners in agricultural research, particularly in the CG System;
- Little or no focus on gender analysis;
- An unmet demand for capacity development in GA and PR methods;
- While learning and change through methods development is widespread, it does not extend beyond the project life and into the organization.

Clearly, these lessons necessitate the need for renewed focus on gender analysis with its inextricable linkage to participatory research. This calls for continued focus on building capacity for the use of GA, PR and impact assessment (IA) methods, and demonstrating the impacts of using such methods. Additionally, and in order to sustain, enhance and extend learning and change to the level of the organization, it is necessary to focus on developing capacity for mainstreaming such approaches, combined with action-research to document 'best practices' for organizational learning and change.

Thus, the major goal in phase two of the PRGA Program is to mainstream gender analysis and equitable participatory research to promote learning and change through partnerships with CG Centers, NARS and civil society groups, so that they can better target the demands of beneficiary groups, particularly poor rural women.

Mainstreaming refers to the following activities: (a) developing capacity for GA, PR, IA and organizational development; (b) establishing a cadre of change agents versed in GA, PR, IA and organizational development skills, which is networked for support and exchange of experiences; (c) establishing internal working groups to facilitate adaptation of organizational structures and practices to initiate a demand-driven agenda within their organizations; (d) having a high-level external support group that represents the interests of clients, particularly poor rural women, and functions as a body to ensure accountability for instituting a demand-driven agenda in participating institutions.

The objective of the Program is to improve the competencies of the CG System and collaborating institutions to mainstream the use of gender-sensitive participatory approaches in plant breeding and natural-resource management research.

Important Assumptions:

The success of the PRGA Program is dependent on the following.

- CGIAR Centers and partner institutions are willing to become involved in learning and change by committing staff and budget to using PR&GA methods, contributing to capacity development of their members, and making the necessary organizational adjustments for integrating such approaches into their organizations.
- Donor commitment to the PRGA Program is constant over the period.
- IARCs and other institutions collaborating with the PRGA Program are able to include results in their institutional reports and annual reviews.
- Stakeholders are willing to contribute actively to PRGA Program planning and evaluation.

Changes:

There are no major changes in the PRGA Program plan since the beginning of Phase 2 in 2003. However, the International Workshop included under Output 3 is now scheduled for February 2007.

CG System Priorities:

The PRGA Program fits primarily into CG System Priority area 5 "Improving policies and facilitating institutional innovation to support sustainable reduction of poverty and hunger," and more specifically Priority 5D "Improving research and development options to reduce rural poverty and vulnerability." However, the use of gender-sensitive participatory research-for-development by the CG System and its partners, as promoted by the Program, should improve the efficiency of effort in all five Priority areas.

Impact Pathways:

Output	Logical chain	Outcome	Ultimate benefits	Key assumptions	Expected beneficiaries and end-users	Project role
1. Capacity developed for mainstreaming gender analysis and equitable participatory research — Improved competencies of the CG System and collaborating institutions to mainstream the use of gender-sensitive participatory approaches in plant breeding, and natural-resource management research	Partners internalize learning, resulting in institutional change; more specifically, partners utilize appropriate elements of PR and GA whenever appropriate	CG System and collaborating institutions routinely use gender-sensitive participatory approaches in plant breeding, and natural-resource management research	Improved targeting of R&D	Institutional support for learning and change, mainstreaming	Selected CG Centers and NARS; NGOs, regional networks, other IARCs, other institutions interested in mainstreaming PR and GA; ultimate beneficiaries poor rural farmers	Catalyzer, facilitator, enabler, advocate

Output	Logical chain	Outcome	Ultimate benefits	Key assumptions	Expected beneficiaries and end-users	Project role
2. Impact of PR and GA methods assessed and published; methods and frameworks for IA developed, and capacity built among partners to conduct and interpret IA	Partners see value of PR and GA in R&D, and incorporate PR and GA into their own R&D processes; and have increased capacity to conduct IA for PR and GA	Partners use PR and GA, and conduct their own IA of PR and GA work	Improved R&D decision-making	Recognition of value of IA data; Institutional support for integrating PR and GA into R&D	CG Centers, other IARCs, NARS, NGOs; ultimate beneficiaries poor rural farmers	Primary research provider (IA methods); facilitator, advocate
3. Communication strategies for learning and change with partners — PRGA Program communicates effectively with partners, donors, and other interested parties	Partners learn from published outputs	Agricultural R&D practitioners utilize appropriate elements of PR and GA in their work, thereby generating gender-sensitive results for equitable development	Improved R&D	Institutional support to learning and change	CGIAR, IARCs, NARS, donors, anyone interested in PR and GA; ultimate beneficiaries poor rural farmers	Advocate, enabler

International Public Goods:

Output 1. Capacity developed for mainstreaming gender analysis and equitable participatory research — Improved competencies of the CG System and collaborating institutions to mainstream the use of gender-sensitive participatory approaches in plant breeding, and natural-resource management research: IPGs in the form of methods for and approaches to mainstreaming made available through publication. This is the only Program working on mainstreaming with the CG Centers and their NARS partners.

Output 2. Impact of PR and GA methods assessed and published; methods and frameworks for IA developed, and capacity built among partners to conduct and interpret IA: IPGs in the form of PR, GA and IA methodologies and empirical results made available through publication. The Program provides a CG System focal point for, and is also the only Program dedicated to, the systematic assessment of the impact of PR and GA *methods*.

Output 3. Communication strategies for learning and change with partners — PRGA Program communicates effectively with partners, donors, and other interested parties: Relevant information on PR, GA, IA, mainstreaming, etc., goes into the public domain (i.e. becomes IPGs). As a focal point for all these issues, PRGA Program has the only information and communications group dedicated to PR and GA.

Partners:

CGIAR System

- *CIAT:* Impact-assessment study of CIALs; Impact-assessment of CIAT's Rural Agro-enterprise Development Project (learning alliances) in Central America. PRGA providing staff time and research funds; CIAT providing funds and staff time.
- *CIMMYT:* Collaboration on mentoring researchers in writing research papers. PRGA and CIMMYT both provide staff time.
- *CIP:* Small grant allocated (from PRGA) for GA mainstreaming. (Output 1)
- *ICARDA:* PRGA is providing staff time to discuss ICARDA's follow up to the PRGA-funded institutional assessment (mainstreaming); Contribution of senior staff time for impact-assessment studies; Capacity-development support (social-science backstopping) for the Challenge Program on Water and Food (CPWF, Eritrea project). ICARDA is leading the WCP in Eritrea.
- *ICRAF:* PRGA is providing staff time to discuss ICRAF's follow up to the PRGA-funded institutional assessment.
- *ILRI:* Joint PRGA–ILRI appointed senior staff member; ILRI staff conducting institutional analysis of constraints to and opportunities for GA mainstreaming; PRGA is providing staff time to discuss ILRI's follow up to the institutional assessment.

NARS:

- *ECAPAPA/ASARECA:* Follow up on 2006 evaluation of PRGA-funded capacity development of 10 NARIs in the Eastern, Central and Southern Africa (ECSA).

- *Eritrea:* Social-science support to CPWF (with ICARDA) project. PRGA is providing staff time and funds; the Eritreans are conducting the impact-assessment studies, and doing the monitoring and evaluation.

NGOs:

- *Eastern Himalayan Network/Women Organizing for Change in Agriculture and NRM (WOCAN)/CARE-Laos:* Institutionalizing social and gender analysis through organizational change. PRGA is providing capacity-development; partners are doing research and moving towards institutional change.
- *Corporación PBA:* Joint organization of International Seminar (early 2007). PRGA and PBA both providing funds and staff time.

Universities:

- *National University of Laos:* Small grant for study documenting the development and implementation of a participatory monitoring and evaluation (PM&E) process with the national agricultural extension services. PRGA is providing funds, capcity-development and research framework; NUL are implementers.
- *China Agricultural University (CAU):* Small grant for designing and implementing a study to assess the mainstreaming of participatory research approaches with its various stakeholders; Joint seminar on how to institutionalize PR on national scale. PRGA is providing funds, capacity-development and research framework; CAU are implementers.

Others:

- *FAO:* (Co-)Publication of PPB book: PRGA providing technical editing; FAO producing and distributing copies.
- *S. Biggs:* Social inclusion impact study: PRGA providing funds, staff time and network of case-study partners; private consultant providing time–expertise.
- *Impact Assessment Network:* Developing partnerships.

Project Funding:

Budgeting 2005-2009

Year	2005 (actual)	2006 (estimated)	2007 (proposal)	2008 (plan)	2009 (plan)
US Dollars (millions)	1.056	1.094	0.894	0.894	0.894

PROJECT SW-3: SYSTEMWIDE PROGRAM ON PARTICIPATORY RESEARCH AND GENDER ANALYSIS FOR TECHNOLOGY DEVELOPMENT AND INSTITUTIONAL INNOVATION

Targets	Outputs	Intended users	Outcome	Impact
OUTPUT 1	Capacity developed for mainstreaming gender analysis and equitable participatory research— Improved competencies of the CG System and collaborating institutions to mainstream the use of gender-sensitive participatory approaches in plant breeding, and natural-resource management research	Selected CG Centers and NARS	CG System and collaborating institutions routinely use gender-sensitive participatory approaches in plant breeding, and natural-resource management research	Institutions have mainstreamed PR and GA to better target R&D to the benefit of all end-users, especially poor women
Output Targets 2007	• Field training manual for PR and GA, IA of ILAC, and organizational development (OD) developed and widely disseminated, including a brief review of existing PR and GA, IA, and OD methods, drawing on best practices in developing guidelines	CGIAR, NARS, NGOs, regional networks	• Researchers previously unexposed to PR and GA adopt methodologies	
Output Targets 2008	• Research results published and disseminated on the process of mainstreaming through organizational change	Other CG Centers, IARCs and NARS; other institutions interested in mainstreaming PR&GA	• Researchers previously unexposed to PR and GA adopt methodologies	

Targets	Outputs	Intended users	Outcome	Impact
Output Targets 2009	• Impact study of mainstreaming work to date complete and published	CG Centers, IARCs and NARS; other institutions interested in mainstreaming PR and GA	• Adoption of mainstreaming agenda by organizations beyond current partners	
OUTPUT 2	Impact of PR and GA methods assessed and published; methods and frameworks for IA developed, and capacity built among partners to conduct and interpret IA	CG Centers, other IARCs, NARS, NGOs	Partners use PR and GA, and conduct their own IA of PR and GA work	Institutions have mainstreamed PR and GA to better target R&D to the benefit of all end-users, especially poor women
Output Targets 2007	• Eritrean NARS trained in IA planning and methodologies, and IA and M&E work is initiated • Social inclusion and learning alliance studies published • Learning session on IA held at PRGA International Seminar • Special issues of international journals publish papers from IA Workshop (2005)		• Partners (and others) convinced of the value of PR and GA approaches (on the basis of published empirical IA studies)	

Targets	Outputs	Intended users	Outcome	Impact
Output Targets 2008	• Discussion paper on methods of IA for ILAC is published and disseminated to Program partners and collaborators • Workshop held for capacity-building of IA Network members		• Researchers utilize the tools and methods made available via PRGA to assess the impact of gender-sensitive participatory research process, which contributes to enhanced ILAC	
Output Targets 2009	• Lessons from IA Network capacity-building workshop published • Results from Water Challenge Program project (Eritrea) published		• More partners adopt PR and GA approaches, conducting their own IA of their work; also more "non-partners" (via publications)	
OUTPUT 3	Communication strategies for learning and change with partners — PRGA Program communicates effectively with partners, donors, and other interested parties	CGIAR, IARCs, NARS, donors, anyone interested in PR and GA	Agricultural R&D practitioners utilize appropriate elements of PR and GA in their work, thereby generating gender-sensitive results for equitable development	Institutions have mainstreamed PR and GA to better target R&D to the benefit of all end-users, especially poor women

Targets	Outputs	Intended users	Outcome	Impact
Output Targets 2007	• International workshop held on integrating gender-sensitive participatory research through organizational change • Membership of PRGA Info listserv reaches 800; Mailing list built • Research results packaged into 1- to 2-page brief forms, and disseminated both as hard copy and in electronic form • Report on feasibility of PRGA Program acting as 'information hub' on global agricultural PR and GA	IARC and NARS scientists, NGO practitioners, civil society organizations, policy-makers		
Output Targets 2008	• Mechanism set up for PRGA Program to source and redistribute 50% of relevant global agricultural PR and GA results (primarily through listservs and website; bibliographic database)—*if deemed feasible (in 2007)*	All agricultural R&D practitioners	• Members, partners and other interested parties source all relevant information on PR and GA from PRGA Program, particularly through its website	
Output Targets 2009	• Review of strategies, procedures and mechanisms	PRGA and partners		

PROJECT BP-2: SPATIAL AND ECONOMIC ANALYSIS FOR DECISION AND POLICY SUPPORT IN AGRICULTURE AND THE ENVIRONMENT

NARRATIVE PROJECT DESCRIPTION

Rationale and Changes

Rationale:

In the heterogenous landscapes of the tropics, there is huge potential to enhance the welfare of rural communities by improving the way that agricultural and natural resources are managed. Rural communities could improve their welfare and derive greater benefits in a number of ways: greater productivity in current agricultural systems; more profitable and sustainable systems; value-adding industries and services related to agriculture; provision of environmental or ecological services.

Realizing these benefits requires that decision makers recognize and seize opportunities offered by new technologies, policies, markets and other innovations. To do this, they need relevant and accurate information on which to base their decisions. In recent years, explosive growth in the availability of biophysical and socioeconomic data has vastly improved quality of such analyses. However these advances won't lead to real change in rural welfare unless they are in the hands of the right decision maker(s), at the appropriate scale(s), and the moment that the decision is being made.

The goal of this project is to improve the targeting of investments in agricultural and NRM research and development through economic and geographic analysis, by providing analysis, information and tools to improve decisions about where, when and how innovations can be implemented to enhance rural livelihoods in a sustainable and equitable manner. Our outputs are analyses, tools and data.

Our clients include the rural population in general, and farmers and rural entrepreneurs in particular, as well as researchers, policy makers and any person or agency working in the field of rural development with and for the rural population. Our clients will be able to: (i) evaluate *ex ante* the probable consequences of decisions they make to directly change land use or to influence those that make the decisions and (ii) to monitor the effects of any decisions they make. Our analysis seeks to inform key policy debates on issues of national and global importance. Our methods and tools are designed to be used at the local or regional scale, where site specificity rules out generic approaches but can be the basis for unique solutions if local diversity is understood and maximized. Our data consist mainly of climate, soils, crop performance, infrastructure and socio-economic variables that are processed and combined to form land resource indicators organized in mega data bases that cover the tropical world. These mega databases, analogous to the germplasm banks that have been the basis of the CG germplasm development efforts to date, are expected to provide similar raw material for a revolution in how agricultural and other natural resources are managed.

The major research themes of BP2 are:

Theme 1. Understanding spatial and temporal variability of plant-environment interactions within and across landscapes.
Theme 2. Realizing the potential of spatial and temporal variability of plant-environment interactions.
Theme 3. Identifying the conditions under which environmental goods and services contribute to equitable and sustainable development.
Theme 4. Estimating the magnitude and distribution of socio-economic and environmental impacts of agricultural R&D on poverty and vulnerability in rural communities.
Theme 5. Obtaining, developing, and managing data and information

Changes:
The BOT, the Science Council, and an internal CIAT task force of scientists have all expressed a preference to simplify CIAT project structures in order to reduce administrative overheads and enhance synergies between the currently decentralized projects. The Land Use (PE4) and Impact and Policy (BP1) projects have very similar goals and objectives and are therefore currently merging in order to help both projects improve their research implementation and thereby better achieve their shared goals and objectives. As a direct outcome of this process we adjusted the output targets of both projects. The here presented targets are therefore slightly different from the individual output targets presented in the previous 2006 – 2008 midterm plan.

CG System Priorities:
The project contributes to the following system priorities:

- Integrated land & water management at landscape level
- Science and technology policies and institutions
- Improving water productivity
- Sustainable agro-ecological intensification in low and high potential environments
- Conservation and characterization of staple crops
- Promoting conservation and characterization of underutilized crops
- Options to reduce rural poverty through agricultural diversification, specifically fruit and vegetables and forest and trees

Impact Pathways:
The analysis, methods and data generated by BP2 are meant to be used by a range of stakeholders—farmers and other resource users, farmer and community organizations, private companies, NGOs, researchers, and policymakers. These users have common interests managing tropical landscapes, however their capacities and incentives are likely different. This implies multiple impact pathways, and multiple modes of engagement between BP2 and its partners and end users.

At the policy level—broadly defined to include e.g. local and national legislation, multilateral agreements, and priorities of aid agencies or research institutes—use of BP2 outputs is expected to result in technologies, programs and policies that are more effective and equitable because they are based on a more accurate understanding of the size and the distribution (spatial and socio-economically) of the benefits and costs.

Other end users such as farmers, producer groups, resource management organizations or private companies will use outputs directly for their own use. Increasingly these types of end users, who in the past looked to the international and national research systems for technologies and analysis, are now using data and tools from research providers like BP2 to conduct their own analyses of which combinations of technological, management, and institutional innovations are most beneficial for their constituents given their specific ecological and socio-economic conditions.

Working with such organizations brings challenges since their goals may not always be totally aligned with those of the CG, however the potential impact they can generate via the adoption profitable, equitable and sustainable innovations can far outweigh the risks, if properly managed. This project suggest a triple mechanism for achieving impact:

Research is focused on compiling and processing information on climate, soils, crop performance, infrastructure and socio-economic variables into land resource indicators organized in mega data bases and that cover the tropical world. These mega databases are analogous to the germplasm banks that were established as the basis of the germplasm development efforts which have been the pillars of the CGIAR system until now.

The databases and information held in them are of little use *per se*, but they are the key to providing our clients with valid information pertaining to their specific circumstances. As was the case in germplasm, much of the knowledge already exists in the hands of local populations and agencies but not in a readily accessible form: it now needs to be collected, compiled and systematized.

Research is focused on the generation of tools and methodologies that can determine what data and information is relevant to a particular case, and then analyze and interpret that data in such a manner that our clients can use it to resolve problems and explore new opportunities. The users may be farmers groups, development agencies, governmental or non-governmental organizations or researchers.

Research is conducted in the manner in which rural communities and other actors involved in the provision of products and services can best utilize the information and information management tools that are being developed, and apply them to their particular circumstances. This research provides hands on experience with the tools and methodologies to ensure that they are applicable to real life situations and can be taken up immediately by organizations similar to those with whom they were developed. The research identifies the social and organizational alliances that are prerequisites for successful use and adoption.

International Public Goods:

This project generates and makes available analysis, methods and tools for geographic information management and analysis that supports decision making of our partners and clients. The international public goods produced by the project include knowledge, technologies, and data. Knowledge is mainly used as an input into policy processes, though sometimes more local analyses are conducted as proof or concept or as part of

methodological development. Tools and methods are designed to be applicable by a range of stakeholders in diverse tropical ecosystems.

Partners:

The project collaborates with the following types of partners:

- Advanced research institutes (e.g. Bonn University, CIRAD, Michigan State University, Vienna University, East West center, Universidad de Los Andes). We generally work with students and their university supervisors. BP2 provides information for joint analyses. Collaborating centers provide the time of their staff and access to their infrastructure. Field work takes place in South America and Southeast Asia or Africa.
- Growers associations (e.g. Organica in Colombia). The project usually transfers in these case resources to growers that enable their participation in research projects. Growers normally provide access to the infrastructure, project relevant information about their agricultural systems and provide their time if required for meetings, interviews, and other participatory activities.
- Organizations that represent growers (e.g. National Federation of Colombian Coffee Growers, ARD Consulting, Conservation International). This project currently engages in two types of collaboration. (a) The project is contracted by the organizations in order to conduct research on specific issues. The organization transfers financial resources to the project. (b) The project collaborates with the organizations in jointly developed initiatives. In this case the lead actor transfers resources to the collaborating party.
- Private industry partners (e.g. Green Mountain Coffee Roasters, CostCo). In this type of collaboration the industry partner transfers resources to the project and / or provides the expertise at no cost in order to solve specific research problems.
- Non-governmental organization (NGOs) (eg Catholic Relief Services, WWF-Colombia, Fundación Humedales,). NGO partners are diverse in their interests and capacities. Some have a strong focus on evidence-based interventions and will conduct research, especially participatory methods. Others are more focused on dissemination and capacity building. Smaller NGOs usually receive funding via BP1 however larger NGOs often provide resources when a particular activity falls within their mandate.
- National agricultural research systems (NARs) (eg. Corpoica, Colombia; Kenyan Ministries of Agriculture and Water)- Collaboration with NARs is mainly technical and focuses on adapting methods and tools to local conditions. In general BP2 provides operational funds, and NARS contribute staff time and facilities.
- CGIAR Centers (eg IFPRi, CIP, IBPRI, ILRI, ICRAF) – we often work with scientists from other centers to expand the technical or geographical scope of a project. Collaboration is usually technical, though their may be transfer of resources to or from the other center depending on the specific research being conducted.
- CGIAR systemwide and challenge programs (HarvestPlus, CPWF, CAPRi, Consortium for Spatial Information, SPIA). BP1 receives resources from these programs for research or dissemination activities. The project provides expertise, data and information, and facilities.

Project Funding:

Budgeting 2005-2009

Year	2005 (actual)	2006 (estimated)	2007 (proposal)	2008 (plan)	2009 (plan)
US Dollars (millions)	2.801	3.645	2.926	2.823	2.784

PROJECT BP-2: SPATIAL AND ECONOMIC ANALYSIS FOR DECISION AND POLICY SUPPORT IN AGRICULTURE AND THE ENVIRONMENT

Targets	Outputs	Intended User	Outcome	Impact
OUTPUT 1	Implications of alternative R&D investments analyzed	Scientists and research managers; development planners and practitioners; policymakers; donors and others who make decision about how R&D resources are invested.	Decision-makers informed regarding potential tradeoffs resulting from the allocation of research or development funds, either directly or indirectly via changes in policy	Impacts to R&D investments are more efficient, equitable, sustainable
Output Targets 2007	Potential of payment for environmental services schemes to provide incentives for adoptions of better soil and water management practices in catchments assessed.			
Output Targets 2008	Potential impact of high value crops research on poverty in producing communities estimated Analysis of impact of high-iron beans in one country in Africa	CIAT, CG and NARS researchers; policy makers; donors	Policies and programs on high value crops confirmed/revised	Potential of high value crops to contribute to poverty alleviation enhanced.
Output Targets 2009	Feasibility of site sensitive natural hazard insurance documented in 2-3 case studies.	Organizations that work for and with producers.	Cost effective insurance schemes that enable NGO and private sector provision to more smallholder farmers	More resilient income streams for smallholders and improved (longer-term) land management

Targets	Outputs	Intended User	Outcome	Impact
OUTPUT 2	Frameworks and tools for evaluating and targeting technology and/or management alternatives in agriculture and NRM R&D	Researchers and analysts in CIAT and partner organizations	Researchers use their better conceptual and empirical understanding of how impact occurs and is measured to design more impact-oriented projects.	R&D efforts more effective, equitable and sustainable.
Output Targets 2007	Canasta and Homologue tools adapted to a range of crops. Concepts expanded to Africa.	Decision makers in producer associations, NGOs, and GOs.	Tools are used for identification of environmental niches that support the implementation of supply chains high value crops.	More effective locating and targeting of germplasm leads to higher welfare and environmental benefits
Output Targets 2008	Methodology and tools to target higher value products to environmental niches developed and applied to a range of crops. Analytical framework for assessing the costs and risks of GMOs, as required in CBD, for LAC countries	Decision makers in producer associations, NGOs, and GOs.	Tools are used for identification of genetic resources that are deployed to support agricultural development.	More effective locating and targeting of germplasm leads to higher welfare and environmental benefits
Output Targets 2009	Protocols for screening and selecting medicinal plants developed, published and applied. Improved methods for incorporating soils data into landscape scale models developed	Decision makers in producer associations, NGOs, and GOs.	Method is widely adopted to establish high value product supply chains for medicinal plants.	More effective locating and targeting of germplasm leads to higher welfare and environmental benefits

Targets	Outputs	Intended User	Outcome	Impact
OUTPUT 3	Spatial, economic and other information and data developed, maintained and made available to internal and external users.	Researchers internal and external to CIAT, agricultural decision makers.	Researchers and decision makers have readily-accessible accurate and appropriate information from which to conduct analysis and base actions.	Better analysis and decisions are made thereby enhancing impacts
Output Targets 2007	Disaggregated data on food consumption, and production and nutritional outcomes for key HarvestPlus target countries.	Researchers internal and external to CIAT.		
Output Targets 2008	Indicator maps of vulnerability to natural hazards at regional and national scale in GEF project countries	Decision makers in producer associations, NGOs, and GOs.	Decision makers use information for identification and targeting of site-specific land use and management options.	More effective locating and targeting of measures to combat land degradation leads to significant environmental benefits
Output Targets 2009	Data bases for accessions and performance of high market value, underutilized crops and tropical fruit species established	National agricultural and environmental NGOs and GOs. Researchers internal and external to CIAT.	Identification of environmental niches that support the implementation of supply chains high value crops enabled.	More effective locating and targeting of germplasm leads to higher welfare and environmental benefits

Appendix I

Financial Tables 2007-2009

Appendix II

List of Acronyms and Abbreviations (June 2006)

LIST OF ACRONYMS AND ABBREVIATIONS

Acronyms

ACERG	Asociación de Centros Educativos del Cañón del Río Garrapatas, Colombia
ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank
AfNet	African Network for Soil Biology and Fertility
AHI	African Highland Initiative
APC	Association for Progressive Communications
ARI	Agricultural Research Institute, Tanzania
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
ASOBOLO	Asociación de la Cuenca del Río Bolo, Colombia
ASOCOLFLORES	Asociación Colombiana de Exportadores de Flores
AVRDC	Asian Vegetable Research and Development Center
BBA	Federal Biological Research Centre for Agriculture and Forestry, France
BCP	Biofortification Challenge Program
Bean/Cowpea CRSP	Bean/Cowpea Collaborative Research Support Program (*of the* Univ. Georgia, USA)
BOT	Board of Trustees (*of* CIAT)
CA	Département des Cultures Annuelles (*of* CIRAD)
CAAS	Chinese Academy of Agricultural Sciences
CAMBIA	Centre for the Application of Molecular Biology to International Agriculture, Australia
CAPRi	Collective Action and Property Rights
CARDER	Corporación Autónoma Regional de Risaralda, Colombia
CARE	Cooperative for American Relief Everywhere, USA
CATIE	Centro Agrónomico Tropical de Investigación y Enseñanza, Costa Rica
CBN	Cassava Biotechnology Network
CEGA	Centro de Estudios de Ganadería y Agricultura, Colombia
CENIBANANO	Centro de Investigaciones del Banano, Colombia
CENICAFE	Centro de Investigaciones del Café, Colombia
CENIPALMA	Centro de Investigación en Palma de Aceite, Colombia
CENTA	Centro Nacional de Tecnología Agropecuaria, El Salvador
CFP	Centro Fitogenético Pairumani, Bolivia
CIAT	Centro de Investigación Agrícola Tropical, Bolivia
CIDA	Canadian International Development Agency
CIFOR	Centre for International Forestry Research, Indonesia
CIMMYT	Centro Internacional para Mejoramiento de Maiz y Trigo, Mexico
CIP	Centro Internacional de la Papa, Peru
CIPASLA	Consorcio Interinstitucional para una Agricultura Sostenible en Laderas, Colombia
CIPAV	Fundación del Centro para la Investigación en Sistemas Sostenibles de Producción Agropecuaria, Colombia
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement, France
CLAYUCA	Consorcio Latinoamericano y del Caribe de Apoyo a la Investigación y Desarrollo de la Yuca, *based in* Colombia
CLODEST	Comité Local para el Desarrollo Sostenible de la Cuenca del Río Tascalapa, Honduras
CNPMF	Centro Nacional de Pesquisa de Mandioca e Fruticultura Tropical (*of* EMBRAPA)
CODESU	Corporación para el Desarrollo Sostenible de Ucayali, Peru
COLCIENCIAS	Instituto Colombiano para el Desarrollo de la Ciencia y la Tecnología "Francisco José de Caldas"
CONDESAN	Consorcio para el Desarrollo Sostenible de la Ecorregión Andina, Peru
CORPOICA	Corporación Colombiana de Investigación Agropecuaria
CRCTPP	Cooperative Research Centre for Tropical Plant Pathology, Australia
CRI	Crop Research Institute, Ghana
CRS	Catholic Relief Services, USA

CSIRO	Commonwealth Scientific and Industrial Research Organisation, Australia
CTCRI	Central Tuber Crops Research Institute, India
CURLA	Centro Universitario Regional del Litoral Atlántico, Honduras
CVC	Corporación Autónoma Regional del Valle del Cauca, Colombia
DANAC	La Fundación para la Investigación Agrícola—Danac, Venezuela
DANIDA	Danish International Development Agency, Denmark
DBT	Department for Biotechnology and Biological Control (*of the* Univ. Kiel, Germany)
DFID	Department for International Development, UK
DGIS	Directorate-General for International Co-operation, the Netherlands
DICTA	Dirección de Ciencia y Tecnología Agropecuaria, Honduras
DNP	Departamento Nacional de Planeación, Colombia
EAP-Zamorano	Escuela Agrícola Panamericana *at* Zamorano, Honduras
EARO	Ethiopian Agricultural Research Organization
EC	Economic Commission (*of the* European Union)
ECABREN	Eastern and Central Africa Bean Research Network
ECLAC	Economic Commission for Latin America and the Caribbean
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária
EPMR	External Program and Management Review (*of* CIAT)
ETH	also ETHZ; Eidgenössische Technische Hochschule—Zürich, Switzerland
E-TIP	Ecologia's Environmental Technical Information Project (online service)
FAO	Food and Agriculture Organization of the United Nations
FCRI	Field Crop Research Institute, Thailand
FEDEARROZ	Federación Nacional de Arroceros, Colombia
FIDAR	Fundación para la Investigación y el Desarrollo Agroindustrial Rural, Colombia
FLAR	Fondo Latinoamericano y del Caribe para Arroz de Riego, *based at* CIAT
FONAIAP	Fondo Nacional de Investigaciones Agropecuarias, Venezuela
FPR-IPM	Farmer Participatory Research for IPM Project (*of the* SP-IPM *and* SP-PRGA)
GEF	Global Environment Facility (*of the* UNDP, UNEP, *and* World Bank)
GRU	Genetic Resources Unit (*of* CIAT)
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (German Agency for Technical Cooperation)
GWG	Gender Working Group (*of the* SP-PRGA)
HAP	Hillside Agricultural Program, Haiti
IAEA	International Atomic Energy Agency, Austria
IAR&T	Institute for Agricultural Research and Training, Nigeria
IBSRAM	International Board for Soil Research and Management, Thailand
ICA	Instituto Colombiano Agropecuario
ICARDA	International Center for Agricultural Research in the Dry Areas, Syria
ICER	Internally Commissioned External Review (*of* CIAT)
ICIPE	International Centre of Insect Physiology and Ecology, Kenya
ICRAF	International Centre for Research in Agroforestry, Kenya
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics, India
ICTA	Instituto de Ciencia y Tecnología Agrícola, Guatemala
ICWG—CC	Inter-Center Working Group on Climate Change (*of the* CGIAR)
IDEAM	Instituto de Hidrología, Meteorología y Estudios Ambientales, Colombia
IDIAP	Instituto de Investigación Agropecuaria de Panamá
IDRC	International Development Research Centre, Canada
IDS	Institute for Development Studies, UK
IER	Institut d'Economie Rurale du Mali
IFDC	International Fertilizer Development Center, USA
IFPRI	International Food Policy Research Institute, USA
IGAC	Instituto Geográfico "Agustín Codazzi", Colombia
IGDN	Inter-American Geospatial Data Network
IGER	Institute of Grasslands Environment Research, UK

IIA	Instituto de Investigaciones Avícolas, Cuba
IIA	Instituto de Investigaciones Agropecuarias, Venezuela
IIASA	International Institute for Applied Systems Analysis, Austria
IICA	Instituto Interamericano de Cooperación para la Agricultura, Costa Rica
IILA	Instituto Italo-Latino Americano, Italy
IITA	International Institute of Tropical Agriculture, Nigeria
ILAC	Institutional Learning and Change
ILRI	International Livestock Research Institute, Kenya
INBIO	Instituto Nacional de Biodiversidad, Costa Rica
INERA	Institut de l'Environnement et de Recherches Agricoles, Burkina Faso
InforCom	Information and Communications for Rural Communities
INIA	Instituto de Investigaciones Agropecuarias, Chile
INIA	Instituto Nacional de Investigación Agraria, Peru (*now* INIAA)
INIA	Instituto Nacional de Investigación Agropecuaria, Uruguay
INIA	Instituto Nacional de Investigaciones Agrícolas de Venezuela
INIAA	Instituto Nacional de Investigación Agraria y Agroindustrial, Peru (*formerly* INIA)
INIAP	Instituto Nacional Autónomo de Investigaciones Agropecuarias, Ecuador (*formerly* Instituto Nacional de Investigaciones Agropecuarias)
INIFAP	Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Mexico
INIVIT	Instituto de Investigaciones de Viandas Tropicales, Cuba
INPA	Instituto Nacional de Pesquisas da Amazônia, Brazil
INPE	Instituto Nacional de Pesquisas Espaciais, Brazil
INRAB	Institut National des Recherches Agricoles du Bénin
INRAN	Institut National des Recherches Agronomiques du Niger
INTA	Instituto Nacional de Tecnología Agropecuaria, Argentina
INTA	Instituto Nicaragüense de Tecnología Agropecuaria
IPCA	Proyecto de Investigación Participativa en Centroamérica, *based in* Honduras
IPGRI	International Plant Genetic Resources Institute, Italy
IPP	Institute for Plant Protection, Germany
IPRA	Investigación Participativa en Agricultura/*Participatory Research in Agriculture, based at* CIAT
IRD	Institut de Recherche pour le Développement, France (*formerly* ORSTOM)
IRRI	International Rice Research Institute, the Philippines
ISABU	Institut des Sciences Agronomiques du Burundi
ISAR	Institut des Sciences Agronomiques du Rwanda
ITRA	Institut Togolais de Recherche Agronomique
IVITA	Instituto Veterinario de Investigaciones Tropicales y de Altura, Peru
IWMI	International Water Management Institute, Sri Lanka (*formerly* International Irrigation Management Institute)
JIRCAS	Japan International Research Center for Agricultural Sciences
KARI	Kenya Agricultural Research Institute
KEMRI	Kenya Medical Research Institute
KSU	Kansas State University, USA
Lempira Sur	FAO project in Honduras to change slash-and-burn agriculture
LSU	Louisiana State University, USA
MADR	Ministerio de Agricultura y Desarrollo Rural, Colombia
MinAmbiente	Ministerio del Medio Ambiente, Colombia
MIS	*also* MIS Group; Management and Information Systems Research Group (*of the* Univ. York, UK)
MSU	Michigan State University, USA
MT	Management Team (*of* CIAT)
NARO	National Agricultural Research Organization, Uganda
NCAR	National Center for Atmospheric Research, USA
NCGR	National Center for Genome Resources, USA

NEN	North East Network
NLH	Norges Landbrukshøgskole (Agricultural University of Norway)
NRCRI	Natural Root Crops Research Institute, Nigeria
NRI	Natural Resources Institute, UK
NRMG	Natural Resource Management Group (*of the* SP-PRGA)
OFI	Oxford Forestry Institute, UK
ORE	Organization for the Rehabilitation of the Environment, Haiti
ORSTOM	L'Institut Français de Recherche Scientifique pour le Développement en Coopération (*now* IRD)
PABRA	Pan-Africa Bean Research Alliance
PASOLAC	Programa de Agricultura Sostenible de Laderas en Centro América
PBA	Corporación PBA, Colombia
PBG	Plant Breeding Group (*of the* SP-PRGA)
P*h*Action	Global Post-*h*arvest Forum
PRGA	Participatory Research and Gender Analysis
PRI	Plant Research International, Netherlands
PROCITROPICOS	Programa Cooperativo de Investigación y Transferencia de Tecnología para los Trópicos Suramericanos
PRODAR	Programa de Desarrollo de la Agroindustria Rural para América Latina y el Caribe, *based in* Costa Rica
PROFRIJOL	Programa Cooperativo Regional de Frijol para Centro América, México y el Caribe
PROFRIZA	Proyecto Regional de Frijol para la Zona Andina
PROINPA	Fundación Promoción e Investigación de Productos Andinos, Bolivia
PRONATTA	Programa Nacional de Transferencia de Tecnología Agropecuaria, Colombia
RDA	Rural Development Administration, Korea
REDCAPA	Red de Instituciones vinculadas a la Capacitación en Economía y Políticas Agrícolas en América Latina y el Caribe
RII	Rural Innovation Institute
RIVM	Rijksinstitut voor Volksgezondheid en Milienhygiene (National Institute of Public Health and Environmental Protection), the Netherlands
SABRN	South Africa Bean Research Network
SACCAR	Southern Africa Center for Cooperation in Agricultural Research and Training
SARNET	Southern Africa Root Crops Research Network
SDC	Swiss Agency for Development and Cooperation
SEA-CIAS	Secretaria de Estado de Agricultura – Centro de Investigaciones Agrícolas del Sureste, Dominican Republic
SEARCA	Southeast Asia Regional Center for Graduate Study and Research in Agriculture
SENA	Servicio Nacional de Aprendizaje, Colombia
SIBTA	Bolivian Agricultural Technology Development
SINCHI	Instituto Amazónico de Investigaciones Científicas, Colombia
SINGER	The CGIAR System-wide Information Network for Genetic Resources
SLU	Sveriges Lantbruksuniversitet (Swedish University of Agricultural Sciences)
SP-IPM	Systemwide Program on Integrated Pest Management (*of the* CGIAR)
SP-PRGA	The CGIAR Systemwide Programme on Participatory Research and Gender Analysis for Technology Development and Institutional Innovation
SRI	Soil Research Institute, Ghana
SWNM	The CGIAR Systemwide Program on Soil, Water & Nutrient Management
TAC	Technical Advisory Committee (*of the* CGIAR)
TCA	Tratado de Cooperación Amazónica
TIP	Traditional Irrigation Programme, Tanzania
TSBF	Tropical Soil Biology and Fertility Programme, Kenya (*now* TSBFI)
TSBFI	Tropical Soil Biology and Fertility Institute (*of* CIAT, *formerly* TSBF)
UBC	University of British Columbia, Canada
UCor	Universidad Católica de Córdoba, Argentina
UCR	Universidad de Costa Rica
UNA	Universidad Nacional Agraria, Nicaragua

UNAH	Universidad Nacional Autónoma de Honduras
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNIVALLE	Universidad del Valle, Colombia
UPWARD	Users' Perspectives With Agricultural Research and Development, *based in* the Philippines
USDA	United States Department of Agriculture
WARDA	West Africa Rice Development Association, Cote d'Ivoire
WFCP	Water for Food Challenge Program, Sri Lanka
WRI	World Resources Institute, USA
WV	World Vision, USA
WWF	World Wildlife Federation, USA
WWW	World Wide Web

Abbreviations

Ac/Ds	The first pair of transposons discovered (biotechnology)
ACMV	African cassava mosaic virus
AES	Agroecosystem
AFS	Agroforestry systems
Al	Aluminum
ARIs	Advanced research institutes
AROs	Advanced research organizations
AYT	Advanced yield trials
BCMV	Bean Common Mosaic Virus
BGBD	Below-ground biodiversity
BMP	Best management practices
C	Carbon
CA	Central America
CBB	Cassava bacterial blight; *also* Common bacterial blight of beans
CBWM	Community-based watershed management
CC	Climate change
CD-ROM	Compact disk—read-only memory
CFSD	Cassava frogskin disease
CH_4	Methane (a pollutant)
CIALs	Comités de Investigación Agrícola Local (Colombia)
CLOs	Comités locales (local committees)
CO_2	Carbon dioxide (a pollutant)
DCs	Developed countries
DNA	Deoxyribonucleic acid
DS	Decision support
ERI	Enabling Rural Innovation
ESTs	Expressed sequence tags (biotechnology)
FM	Forest margins
FPR	Farmer participatory research
FTE	Full-time equivalent
GA	Gender analysis
GCC	Global climate change
GHG	Greenhouse gases
GIS	Geographic information systems
GKP	Global Knowledge Partnership
GM	Genetically modified
GOs	Governmental organizations
GWP	Global warming potential

HS	Hillsides
IA	Impact Assessment
IAEM	Integrated agroecosystem management and conservation
IARCs	International agricultural research centers (the CGIAR system)
ICTs	Information and communication technologies
INIAs	Instituciones Nacionales de Investigación Agropecuaria (national institutions for agricultural and livestock research)
IPDM	Integrated Pest and Disease Management
IPM	Integrated pest management
IPR	Intellectual property rights
ISFM	Integrated soil-fertility management
KS	Knowledge-Sharing
LA	Latin America; Latin American
LAC	Latin America and the Caribbean
LDCs	Lesser developed countries
LIMS	Laboratory information management systems
LoRSDIs	Local rural sustainable development initiatives
M&E	Monitoring and evaluation
MAS	Marker-assisted selection
MTA	Material transfer agreement (used in germplasm exchange)
MTP	Medium-Term Plan (CIAT)
N	Nitrogen
N_2O	Nitrous oxide (a pollutant)
NARES	National agricultural research and extension systems
NARIs	National agricultural research institutes
NARS	National agricultural research systems
NGOs	Nongovernmental organizations
NRM	Natural resource management
NZ	New Zealand
OD	Organizational Development
P	Phosphorus
PB	Plant breeding
PM&E	Participatory monitoring and evaluation
PNRM	Participatory natural resources management
PPB	Participatory plant breeding
PR	Participatory research
PRR	Phytophthora Root Rot
PYT	Preliminary yield trials
QTLs	Quantitative trait loci
R&D	Research and development
RAeD	Rural Agro-enterprise Development
RHBV	Rice “hoja blanca” virus (rice white leaf virus)
RIIs	Research intensive institutions
R-to-C	Resource-to-consumption *framework*
SLM	Sustainable Land Management
SP	Systemwide program (*of the* CGIAR)
SROs	Specialized research organizations
SRT	Single row trials
SS	Senior staff (*of* CIAT)
TLA	Tropical Latin America