CIAT
Medium-Term Plan
2010-2012

Eco-Efficient Agriculture for the Poor

CIAT
Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture
Consultative Group on International Agricultural Research

Abridged Version
June 2009

CIAT
Medium-Term Plan
2010-2012

Eco-Efficient Agriculture for the Poor

Abridged Version
June 2009

CIAT
Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture
Consultative Group on International Agricultural Research

Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture
Apartado Aéreo 6713
Cali, Colombia

June 2009

Centro Internacional de Agricultura Tropical. 2009. CIAT Medium-Term Plan 2010-2012.
Abridged version. Cali, Colombia. 75 p.

This abridged version of the MTP does not include reference to: Alignment to CGIAR Priorities, Elaboration of Partners Roles, Center Financial Indicators and Financial Plan. See the full version in CIAT's website (www.ciat.cgiar.org).

CONTENTS

1. OVERVIEW

Introduction

Eco-efficient agriculture for the poor
CIAT aims to reduce hunger and poverty in the tropics through research that increases the eco-efficiency of agriculture. Eco-efficient agriculture increases productivity while reducing negative environmental impacts. Eco-efficient agriculture meets economic, social and environmental needs of the rural poor by being profitable, competitive, sustainable and resilient. Too often, productivity gains - increased production per resources used- have come at the expense of the environment or have not provided benefits to the poor. CIAT has, therefore, adopted the concept of 'Eco-efficient agriculture for the poor' as harmonizes the economic, environmental and social elements of development. It strives towards solutions that are competitive and profitable, sustainable and resilient, and generate benefits for the poor.

Eco-efficient agriculture for the poor enables family farms to take advantage of technologies that use resources more effectively, deliver sustainable increases in productivity and yield more abundant food supplies. Science for impact is CIAT's contribution to achieving an eco-efficient agriculture for the poor. The core of CIAT's work is strategic research focused on producing outputs of new knowledge that yields improved technologies, resource management practices and institutions and policies. CIAT places high priority on insuring that there are clear pathways from its research outputs, to their use by partners and their ultimate impact on reducing hunger, poverty and natural resource degradation.

CIAT sees co-development of research products with its national partners as key, and emphasizes of user participation in technology development and evaluation at the earliest possible stage. All CIAT research outputs are developed with partners. This both contributes critically to producing these outputs by complementing CIAT's comparative advantage and also contributes to the strengthening of capacity in national agricultural research systems. Helping to nurture a new generation of tropical agricultural scientists is an important goal for CIAT.

CIAT is concerned not only that its research outputs are taken up by public research systems scientists, but that through partnerships involving farmers, the private sector and civil society, that research outputs result in adoption of improved technologies, practices, and decisions. CIAT judges its own performance primarily by the impact on the poor of its research outputs. Participation of end users in the evaluation and development of new technologies is a mainstream practice.

Of particular concern is that eco-efficient agriculture yields benefits for rural women. Due to unequal access to resources, women typically comprise the majority of the rural poor. Thus eco-efficient agriculture can not effectively address the needs of the poor without taking into account the particular needs of women.

CIAT's research outputs are integrated into production systems and taken up by users at a regional basis, with priority first on its home region of Latin America and the Caribbean, then on eastern and southern Africa and on south-east Asia. CIAT scientists conduct research in Latin America, Africa and Asia to meet diverse needs and to develop globally significant international public goods by promoting south-south linkages among the regions.

CIAT is increasing the accessibility and availability of its outputs, making 'open' as the default setting to share as many of its research outputs as possible. CIAT seeks to extend this approach with our partners across Latin America to help create a Latin American "Agricultural Commons" that transforms the way knowledge is generated and applied in the region.

New Strategic Directions

During 2008, CIAT developed revised strategic directions to enable it to better achieve this vision of eco-efficient agriculture. These strategic directions were drawn up while the CGIAR was going through profound change, a process still underway. CIAT's strategic directions are intended to provide a compelling framework for program development on the basis of CIAT's strengths and experience, while allowing sufficient flexibility to shape the Center's future in accordance with the evolution of the CGIAR.

The development of these directions involved consultations with many partners and stakeholders, particularly in Latin America and the Caribbean (LAC); participation in the CGIAR change process and careful consideration of the recommendations of the 2007 External Program. CIAT envisages playing a unique role in the CGIAR system, both in terms of the commodities on which it works and in terms of the special partnerships it nurtures in LAC. Most of CIAT's research is global in scope. CIAT aims to help create conditions both in LAC and elsewhere in the tropics that are essential for eco-efficient agriculture through a tri-part strategy:

1. **Agrobiodiversity** – Providing affordable and nutritious food as well as pathways out of poverty by increasing the productivity of crops.
2. **Tropical soils fertility management** – Overcoming one of small farmers' greatest obstacles to sustained increases in agricultural production.
3. **Latin America and the Caribbean** – Working with partners to solve problems of high priority for the region, while also generating global public goods.

Improved crop and forage production is vital for improving food security, enhancing human nutrition and raising agricultural incomes. CIAT conducts research in LAC and through partnerships around the world on four globally important crops:

1. **Common bean** – The world's most important food grain legume, which in Africa is grown mainly by women.
2. **Cassava** – The third most important food crop in the tropics, after rice and maize, and second only to maize in its suitability for multiple uses. IITA plays a lead role in cassava research in Africa.
3. **Tropical forages** – A key input for production of meat and milk (LAC's most important high-value agricultural products), with much potential for enhancing natural resource management (NRM). CIAT works in close collaboration with ILRI in Africa and Asia.
4. **Rice** – The most important staple food in South America and the world. CIAT research focuses on the unique characteristics of rice in LAC, while IRRI and the African Rice Center (WARDA) concentrate on Asia and Africa.

Crop improvement and soil fertility management are closely related. Improved varieties can be adapted to low soil fertility through more efficient use of soil nutrients, while legumes, such as beans and many tropical forages, can improve soil fertility through biological nitrogen fixation. Crop yields vary greatly according to management, so there is much scope for improving productivity through better agronomic practices. Better management of crop residues and integration of forages into cropping systems can increase soil organic matter, boosting productivity while helping mitigate climate change through carbon sequestration and reduced greenhouse gas emissions. CIAT research on tropical soil biology and fertility focuses on integrated soil fertility management and sustainable land management.

To address the expressed needs and demands of the LAC region CIAT pursues an ecoregional strategy. An ecoregional approach integrates the aims of increased agricultural productivity and improved NRM, taking into account both the biophysical and socio-economic perspectives, through inter-institutional partnerships. The agenda of CIAT's ecoregional research will focus on four main topics:

1. Improvement of crops that are important in LAC but also globally.
2. Improvement of other crops that receive high priority in LAC.

3. NRM and policy research on issues that receive high priority in LAC.
4. Strengthening research capacity in the region through institutional innovation, knowledge management and skills enhancement.

This Medium Term Plan 2010-12 is the first step in implementing these strategic directions.

Highlights of Project Portfolio

Consistent with the tri-part strategy explained above of increasing crop productivity, managing the soil resource to enhance and sustain this productivity, and giving particular attention to the priorities of LAC, CIAT is now organizing its research through three research areas: Agrobiodiversity, Tropical Soils, and Latin America and the Caribbean.

A presentation of the rationale and outputs for all of the programs in these three areas follows below and constitutes the bulk of this Medium Term Plan. Some of the major changes embodied in this new MTP are reviewed next, while greater details are presented in the Program Descriptions.

Biotechnology Consortium for LAC
New tools and methods of molecular biology have opened revolutionary prospects for crop improvement. Latin America is a treasure house of plant genetic resources that can make a major contribution to eco-efficient agriculture for the poor not only in LAC but also in Africa and Asia. However, outside of a few countries with particularly strong research systems, (e.g. Brazil & Mexico), many tropical countries have unstructured collections of genetic resources with a weak knowledge base; uneven technical capacity and poorly developed links between conventional breeding and biotechnology; and infra-structure that is not up to date. With better knowledge of their genetic resources, where they are, and what their potential is, LAC could take much better advantage of genetic resources to achieve eco-efficient agriculture for the poor.

For example, in Central America and the Andes a number of actions can be taken to better utilize their crop genetic resources: strengthen crop breeding capacity including phenotypic characterization; improve access to genomics facilities and bioinformatics capacities; develop low cost rapid propagation systems and transgenic crops, including access to biosafety fields and knowledge of how to manage the entire process of transgenic design and deployment.

CIAT, like some LAC partners, is well placed to take advantage of these new scientific tools. However, there is risk of a growing technological gap between the commercial crops in well resourced countries and many tropical crops in smaller countries with fewer resources to invest in public agricultural research. If they remain technologically laggard, farmers in developing countries, especially poor farmers, will face the prospect of a competitive disadvantage and depressed incomes while poor consumers face higher food prices. Consequently it is critical to breech the emerging technology gap in agriculture.

Consultations with partners have begun for the visioning of a regional consortium to integrate innovative approaches to empower breeding for neglected crops. Such a consortium could catalyze regional efforts to train the next generation of LAC researchers to meet the new challenges of the 21st century. This consortium would enhance LAC agriculture competitiveness through strategic partnerships with leading institutions in the region (EMBRAPA, CINVESTAV, CATIE, Zamorano, BIOTEC, INIAs), universities, and private sector. The consortium would accelerate the integration of genomics and plant cellular technologies with breeding and germplasm conservation while targeting specific traits for non CGIAR crops.

The consortium would operate both in the policy and the technical realms. Policy issues would include the economic assessment of research priorities; intellectual property considerations; and biosafety policy. Technical progress would depend on regional leadership in important research areas including proteomics, metabolomics, and genome sequencing. CIAT would work closely with partners on phenotyping and

genotyping platforms; tissue culture; transgenics; bioinformatics; and gene expression. Ultimately the consortium would catalyze strong breeding capacity with knowledge of genomics tools that are linked to efficient phenotypic characterization (quality, pest and disease, abiotic stress, etc.). Access to genomics tools would be either national, regional or outsource facilities tied to local bioinformatics capacities and the national ability to access and manage transgenic products.

After years of inadequate support for crop improvement, it is now time for bold, innovative measures to regain momentum in this research, thus enabling it to respond decisively to agriculture's huge challenges and opportunities. A biotechnology research consortium which responds to regional demands, could take advantage of this opportunity. Its aim will be to exploit the potential of molecular biology and genetic transformation, not just in research on crops for which the center is responsible, but for the improvement of other species that rank high in the priorities of our regional partners.

During recent years, CIAT has piloted the concept of a biotech partnership with researchers in Colombia, and the outcomes have been quite positive. Now, it is time for full-scale implementation of that approach. The outcome will not be more science for its own sake but problem-solving research at the genomic level that yields clear payoffs in the field and marketplace. With that practical orientation, CIAT-supported uses of biotechnology will focus on valuable plant traits, such as efficiency in water use and uptake and use of nitrogen, acid soil tolerance, disease and pest resistance and micronutrient content.

During 2009 CIAT will be consulting widely with partners and stakeholders about the development of this consortium. It is anticipated that this will lead in 2010 to the development of a full program that would become part of the 2011-2013 MTP.

A regional platform for integrated soil fertility management in Africa

Improved soil fertility is crucial to raising crop productivity and ending hunger in Africa. Given both the severity and widespread variability of this challenge, overcoming it will require a research partnership of significant scope and strength. In sub-Saharan Africa, efforts to build such a partnership can begin with FARA's extensive and highly productive African Network for Soil Biology and Fertility (AfNet), which is coordinated by CIAT's TSBF Institute and consists of dozens of members working at more than a hundred sites in 22 countries. AfNet will seek to catalyze the creation of a soils research platform that unites national organizations with all of the CGIAR centers that conduct research on soils in rainfed farming systems: CIMMYT, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), IITA and the World Agroforestry Centre (ICRAF). The aim of the platform will be to bring research on soil management more forcefully to bear on the challenges of reducing hunger and poverty, while enhancing NRM, especially in sub-Saharan Africa.

Such a partnership represents an important opportunity for the CGIAR centers and their partners to forge important but disparate soils research efforts into a combined initiative that confronts the whole range of problems related to Africa's declining soil fertility and land degradation. A consolidated soils research platform in Africa, linked to similar research in LAC and Asia, can make integrated soil fertility management a reality many poor farmers in Africa and beyond.

During 2009 CIAT will be consulting widely with partners and stakeholders about the development of this platform. It is anticipated that this will lead in 2010 to the development of a full program that would become part of the 2011-2013 MTP.

The Amazon Ecoregional Program

CIAT's research agenda in the Amazon derives not so much from its agriculture production or the large absolute number of poor there, as it does from its globally significant natural resources. The Amazon is a major watershed, carbon sink and source of biodiversity, so continued misuse of its land resources – through unsustainable agricultural practices, degrading pastures, illicit crop production and exploitative timber

extraction – has catastrophic consequences for the entire world. Finding attractive but less environmentally damaging livelihoods for Amazonian inhabitants is a matter of high global priority.

The center will contribute to that effort through research aimed at halting land degradation, improving farmers' access to markets and enhancing ecosystem services, with particular emphasis on adaptation to climate change. Outputs from the center's research on cassava, tropical forages and rice are also highly relevant. CIAT's current work in this sub-region takes place through the CGIAR Amazon Ecoregional Systemwide Program which operates under the umbrella of the Amazon Initiative, which is currently hosted by EMBRAPA. The Ecoregional Program is an important research resource for the wider development objectives of the Amazon Initiative. The Ecoregional research program is coordinated by CIAT, and along with numerous national partners, includes from the CGIAR the Center for International Forestry Research (CIFOR), World Agroforestry Centre (ICRAF), and Bioversity International.

Tropical Fruits

Growing domestic markets and economic globalization have created many opportunities for the rural poor to take up the production and/or processing of higher value agricultural products, with the aim of boosting and diversifying their incomes. The potential of this avenue out of poverty is reflected in rising consumption of fruits. CIAT initiated research with a Tropical Fruits Program in 2001. For the last two years this work has continued, but it was embedded in a broader Linking Farmers to Markets Program. However, to give greater focus and higher effectiveness to this research, with this MTP it is restored to full program status.

CIAT's Tropical Fruits Program will develop new production technology for selected neo-tropical fruits species; develop tools to improve the capacity of small farmers to compete in fruit markets; and generate new technologies of disease and pest control both to enhance product quality and market acceptability and also to reduce the environmental and human health consequences of excessive pesticide use.

Decision Support and Policy Analysis

CIAT proposes to intensify its research in decision support and policy analysis, with the aim of determining the kinds of institutional arrangements and policies needed in order for small farmers and entrepreneurs as well as rural laborers to participate successfully in growth markets. This research will complement IFPRI's policy research. This research will have four foci: climate change, ecosystem services, linking farmers to markets, and impact assessment. While CIAT expects to give a higher overall priority to this body of research, major elements of this research were presented in the previous MTP as outputs in the Resilience and Linking Farmers to Markets Programs. CIAT is convinced that taking advantage of new market opportunities is crucial to improving the income of the rural poor. Enhancing knowledge on fostering these market linkages is an important research output not only for the Decision & Policy program but also for Tropical Fruits and the Amazon Ecoregional Program.

Focusing CIAT's Agenda

CIAT's research on natural resource management will be sharply focused on integrated soil fertility management and ecosystem services, while work on land use dynamics and decision support tools for landscape management will be discontinued. Research on remote sensing to monitor land-use changes has already been phased out, along with research on community-level watershed management.

In addition to Soil Fertility Management research and its ecoregional program in LAC, CIAT will sharpen the focus of its research on the genetic improvement of crops. As partners assume greater responsibility for plant breeding, the center will concentrate more on developing source materials with desirable traits, from which partners can assemble final products. This shift is well advanced with rice in LAC, where the public-private partnership FLAR carries out an increasing share of breeding formerly done by CIAT. Similarly, in cassava improvement, IITA in Africa, EMBRAPA in Brazil and national institutions in China and Thailand will play a major role in developing varieties for release to farmers. Breeding of *Brachiaria* grass will depend on partnerships with the private sector in several countries and with public institutions such as EMBRAPA in Brazil.

Another shift made necessary by CIAT's pursuit of new research directions consists of a reduction in work on farmer participatory research. In recent years, rural innovation has been a pillar of the center's research strategy, resulting in the development of new participatory research methods and a territorial approach to agro-enterprise development. Those products are now commonly used in CIAT's own research and are being widely applied by partners. While the center will continue to use participatory approaches where appropriate in all its research programs, it will no longer seek to develop new participatory methods.

Over the last decade, crop and agro-ecosystem health has figured importantly in CIAT's research, but in the future efforts in this area will be reduced. The development of biopesticides and research on endophytic fungi and bacteria, for example, will be discontinued, while work on whitefly will be scaled down. Any further research in those areas will take place only in collaboration with the CGIAR System-wide Program on Integrated Pest Management or the entity that succeeds it as a result of the CGIAR change process. In genetic improvement, center researchers may devote less attention to disease and pest resistance, as they increase emphasis on efficient use of resources, tolerance to abiotic constraints and enhanced nutritional quality. For the most important pests and diseases, however, work on genetic resistance will be maintained.

Alignment with CGIAR Priorities

CIAT's research agenda continues to be highly aligned with CGIAR System Priorities (SPs). Some 89% of CIAT's work is fully directed to SPs. Much of the 11% in new research, training and development related activities are also in fact oriented towards the achievement of SPs. Among SPs, CIAT's largest investment, 29% remains in priority 2, genetic improvement of staple crops. This is an increase over recent years. Linked with this research is a major investment in priority 1A, conservation of staple crops, amounting to 18% of total investment. Taken together, CIAT investment in genetic improvement and conservation constitutes one half of its agenda research.

Due to the expansion of the work of the tropical soils fertility research area, investment in priority 4A, integrated land and soils research, continues to surge, rising some $2 million in 2009. It now comprises 20% of CIAT investment compared to 15% two years ago.

Non-System Priority Activities

Accelerating the flow of new varieties through seed multiplication and distribution is a common non-system priority activity. Significant quantities of forage seed have been distributed by partners and CIAT in LAC and SE Asia, and thus led to concrete outcomes at farm level. Seed will be supplied to FENALCE, the National Federation of Cereal Producers that is responsible for diffusion of legume production technology in Colombia, to re-establish a national system of bean yield trials. In addition, farmers groups are being given the opportunity in Colombia to work with biofortified beans, with higher levels of iron and zinc. Likewise CIAT is working with a wide diversity of farmers and civil society organizations in Africa for the multiplication and distribution of bean seed. While outside the strict definition of SPs, in reality this work is closely tied to CIAT's agenda research.

Capacity building is an important component of the agenda to strengthen/benefit from the research capacity of partners and to enhance our capacity to deliver research products. Capacity building includes knowledge sharing workshops, group and individual training, and informal training. This effort is closely linked to dissemination of knowledge through internet based tool, website and extension materials and learning alliance. The audience include farmers, technicians, researchers, the private sector and educational institutions, the latter reached through individual and group training as well as internet based tool (i.e. the forage knowledge toolwww.tropicalforages.info). Likewise degree training is a frequent activity. For example, three African scientists are completing their PhDs while doing thesis research with CIAT on topics related to drought resistance in beans. Again, while this is outside the strict definition of SPs, in fact it makes a significant contribution to achieving CGIAR objectives.

The CIAT Science Park, Agronatura is a critical part of CIAT's non-research agenda activities. Agronatura provides a platform for partners whose principal interest is either in development related activities or for research on crops that are not CIAT mandates. This framework enables partners to co-invest through CIAT to realize complementary activities that CIAT itself would not undertake alone but that contribute to the overall objective of eco-efficient agriculture for the poor.

2. AGROBIODIVERSITY RESEARCH AREA

Increased in productivity of crop plants under shifting and stressed environment will continue to be the key for food security, and will requires a greater emphasis on developing adequate research tools and deploying highly Eco-efficient varieties. The added increased in productivity will have to come from a better implementation of agronomical practices to close an existing yield gap, the development of better-adapted productive and nutritious varieties using the power of breeding and molecular biology tools and implementing adequate reaching end users strategies.

To achieve these goals, CIAT maintains the world's most complete collections of the genetic resources of cassava, common beans, and tropical forages and four Agrobiodiversity programs are engaged in a global effort for the development and delivery of Eco Efficient germplasm of cassava, common bean, tropical forages, and rice (rice research is presented in detail as part of CIAT's LAC Research Area).

The programs focus on:

- Conservation of cassava, common beans, and tropical forages Genetic Resources.
- Improved Beans for the Developing World.
- Improved Cassava for the Developing World.
- Improved Forages for the Developing World.
- Improved Rice for LAC.

The research strategy focuses on the exploitation of the vast genetic resources for sources of genes for disease and insect resistance, abiotic stress tolerance, nutritional quality and yield potential. The programs research activities are strongly integrated with technological and scientific competences in biotechnologies, human nutrition and reaching end users that allow CIAT to carry out cutting edge major projects and to implement delivery system. The programs develop basic tools and technologies that delineate the molecular genetic basis of cassava, beans, rice and tropical forages, to accelerate crop improvement and the development of innovative agricultural practices. The programs integrate plant breeding with a large array of biotechnological techniques including molecular markers, genomics, tissue culture and genetic transformation.

Research is carried out in collaboration within the CGIAR Challenge Programs. Collaboration with a wide range of partners in developed and developing countries is a key characteristic of CIAT Agrobiodiversity Research Area.

AGBIO1: Genetic Resources Conservation Program

CIAT has assembled the world's largest collections of beans, cassava and tropical forages. CIAT's role as custodian for over 65,000 accessions of more than 850 plant species meets the expectation of the international community under the International Treaty on Plant Genetic Resources for Food and Agriculture, signed in October 2006. CIAT has insured conservation of its materials by sending a safety back-up to the Global Seed Vault of Svalbard, Norway, in February 2008. In addition to conservation, CIAT has actively distributed samples of genetic resources, over 500,000 samples in 31 years of work. The challenge to promoting the eco-efficiency of agriculture by increasing productivity with a minimal environment footprint has three implications for its Genetic Resources Conservation Program (GRCP): (i) efficient conservation of a

larger set of designated germplasm, (ii) improved distribution service of germplasm and data, and (iii) a research agenda targeted at improving the later two.

CIAT plays a critical role for *Phaseolus* beans and *Manihot* cassava in the Global Crop Conservation Strategies financed by the Trust Global Germplasm. Since the global community expects more diversity from the CIAT genebank, management of this greater number of accessions requires increased efficiencies in conservation and multiplication. The CIAT-GRCP will systematically acquire germplasm of beans and cassava currently absent from the in-trust collections, mostly by explorations, in line with future crop improvement efforts (e.g. tolerance to heat, drought, and salinity). The GRCP will resume germplasm evaluation for abiotic and biotic stresses, as well as some technological traits (e.g. starch characteristics in cassava). Such evaluation was stopped after 1985, and thus significant sets of the in-trust collections have never been evaluated. Moreover, the stresses associated with climate change (drought, temperature extremes, water logging) require the identification of new sources of tolerance.

The GRCP research agenda aims at improving technologies for better conservation at lower cost. Examples include: new methods for slow growth of cassava clones *in vitro*, ultra-drying of seeds of beans and forages for delaying regeneration, conserving botanic seeds of cassava, identification of internal genetic copies to avoid expensive redundancy. The development of a DNA bank is a cost effective response to users who want samples for genomic studies, without re-accessing the plant germplasm every time. Another drive is in the understanding of the structure of genetic diversity for beans and cassava to help identify which sets of germplasm should be collected in priority. Once collected, increased and maintained, molecular marker testing guarantees the genetic integrity of the accessions, so that users can find any genetic information they need. Functional genomics studies will find variants with complementary alleles for the best expression of genes responsible of an important trait (e.g. photosynthesis).

International Public Goods. The designation of more than 65,000 accessions of beans, cassava and tropical forages into the Multilateral System of the International Treaty, and the annual reporting to the Governing Body about distribution of samples worldwide, formalize the role of CIAT genebank as generator of international public goods. South East Asia depends on CIAT for variability in the offer of cassava germplasm. Similarly, eastern and south Africa depends on CIAT for variability of beans. Conversely, most South American countries rely on CIAT for the offer in tropical forage germplasm. Although rich in bean genetic resources, both Central America and the Andes expect from CIAT bean germplasm from the other region, namely for disease resistance genes. Availability of germplasm with all characteristics documented helps advance research in biology or genetics labs all around the world.

Different research works, although carried out by the genebank to address a conservation need on any of the CIAT mandate crops, are however generic and susceptible of broader applicability. Research on slow growth *in vitro* that aims to extend the time lag between each subculturing opens the possibility to reduce costs for many *in vitro* conservation facilities keeping clonal crops. The technology of molecular markers developed at CIAT to understand better patterns of genetic diversity or to spot internal genetic copies within collections, helps to solve problems of sampling during germplasm collecting efforts or to reduce redundancy in *ex situ* collections. Again that technology is not crop specific, but has broader applicability. These technologies as IPGs have been and will continue to be the purpose of several training activities.

Outputs

The period (2010-2012) of this MTP will be a transition for CIAT genebank, while it will continue to participate in many training activities, as a new generation of professionals initiate work in LAC countries. Continuity in training is further justified by the different backstopping activities for NARS, given the support by the Trust to NARS for the regeneration of national collections. On the one hand, there will be the consolidation of the Upgrading process launched with the GPG1 and GPG2 projects supported by the World Bank and part of a collective effort with the other CGIAR genebanks. The genebank will continue with the shipping of safety back-ups to Svalbard, CIMMYT and CIP. The upgrading of the facilities for increased energy efficiency and

physical security will be completed. The effort of recovering of 'institutional memory', namely documenting 2-3 decades of germplasm evaluation and linking with germplasm requests on the internet, shall be continued, as integral part of the delivery of international public goods.

On the other hand, in view of new stresses (e.g. heat, drought, water logging) induced by climate change, and demands by traditional/new markets (e.g. popping beans for low energy cooking requirement, cassava with root protein content), CIAT genebank will resume germplasm explorations for beans and cassava, specially in the primary centers of genetic diversity. This seems possible given the good number of ratifications of the International Treaty by LAC countries. CIAT genebank will participate in the evaluation of germplasm for traits little or not considered so far (e.g. the abiotic stresses above). This evaluation is likely to involve new technologies, the design of which will require in-depth knowledge of plant genetic resources.

***Output 1*: Keeping collections up to international standards.** Users of the in-trust collections expect high quality germplasm in terms of viability, health, and genetic quality (i.e. without genetic contamination, drift or erosion). Research will improve the protocols for the detection of diseases of quarantine importance, for example, PCR based detection of Frog Skin Disease in cassava. Another research area is the spotting of internal genetic copies in the in-vitro cassava collection, where maintenance costs are high. To make safety back-ups that can be run at low costs, research will be conducted on ultra drying, slow-growth *in vitro* and cryoconservation. This research will not only increase internal efficiencies in collection management, but also these advances can be shared by many genebanks in LAC countries. Consultations with partners in the regional PGRFA networks, with Bioversity International and the Trust are also critical for the shaping of the research agenda.

Impact Pathway: Collections that are kept non viable, disease infected, or genetically different as compared to the original materials, are likely to make no impact at all, while at equal costs of management as compared to collections up to international standards. First, distribution is likely to be stopped by any plant quarantine authority, starting in Colombia. Second, poor seed drying will force to a frequent regeneration of collections, increasing thus the conservation costs. Published research results and training carried out towards the reaching higher international standards have an outcome far beyond the in-trust collections kept by CIAT, but also on the germplasm collections maintained by the NARS, leading to efficiency gains in the conservation of a much broader range of collections.

***Output 2*: Making in-trust germplasm available to user communities.** The output is the timely delivery of the germplasm and its information (passport and evaluation data). CIAT will increase the amount and quality of information available on its website (e.g. exploration reports, 'Cahiers de Phaséologie' on the distribution of wild bean species). The germplasm ordering system is being improved and linked automatically with a report system of Standard Material Transfer Agreements, allowing CIAT to report quickly to the Governing Body about distribution of materials registered in the Multilateral System of the Treaty. Cases of non-delivery due to non-availability, poor viability or poor health will be reduced. 'Customer' satisfaction feedback will be continued. The CIAT genebank website will increase linkages with SINGER (the information system of the CGIAR genebanks); USDA Pullman for beans; and EMBRAPA/CENARGEN of Brazil for cassava. Common registries for beans and cassava and for forages with ILRI, will be further developed. The DNA bank will be expanded to encompass progressively the three genetic collections.

Impact Pathway: Germplasm distribution rates have been of 5-7,000 samples yearly over the past ten years, indicating a relatively high level of distribution, an interest by CIAT programs, partners and users worldwide into genebank materials, and a capacity by CIAT genebank to deliver. From the germplasm distribution statistics over 30 years, CIAT genebank has had most of its recipients in the Western Hemisphere; yet, as cassava becomes more a crop for industry, distribution of germplasm and final impact will increase into Africa, India, South East Asia and China. The Asiatic countries will also request more germplasm of (Neotropical) forages for a variety of domestic animals, and of beans as vegetables. The providing of germplasm with well documented characteristics including mutants and genetic stocks is also key for the

advance of genetic mapping work currently under way for beans and cassava, itself linked to marker assisted selection. The end users and beneficiaries are almost anywhere in the world, as recipients of in-trust germplasm are located in more than 110 countries.

AGBIO2: Bean Program

Beans are the most important food grain legume in the tropics, and are widespread in Africa and Latina America and the Caribbean. Because of their importance both to small holder producers and in the diets of the poor, more eco-efficient production of beans is necessary. This involves greater resource productivity, less environmental damage, and better nutritional quality.

The Bean Program's 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, in ways that are eco-efficient; 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 augmenting the supply of beans, and by improvement of their nutritional value.

Our products are designed to respond in particular to the needs of small, resource-poor bean farmers in Latin America and Africa. Our research strategy focuses on the exploitation of the vast genetic resources of bean that are stored in CIAT's gene bank with 41,000 accessions of common bean and related species, and that are our most unique resource. Most traits are still selected by conventional means in field sites or in greenhouse evaluations where most important diseases, soil 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 products are seed based, others involve agronomic practices or are knowledge based. Our research is strategic combined with both basic and applied elements, as called for by the particular challenge.

Strengthened institutions that enhance bean product quality and delivery is a central concern of the program. The Bean Program 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, and people living with HIV/AIDS all participate and benefit. We aim to 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 communication mechanisms to adapt knowledge and results relevant to them. Scaling up regionally and internationally will be done through international NGOs, advocacy, and communication.

Several research issues are of particular importance for eco-efficiency in beans: pests and diseases; drought; plant nutrition; and the growth of urban markets in the developing world.

Host plant resistance and IPM: Pest and disease control through plant resistance and cultural control has long been a mainstay of the CGIAR centers and of the CIAT Bean Program. It is thus not an innovation of eco-efficient agriculture, but it is a necessary component. Pesticide abuse in Latin America and Africa is not widespread in dry bean production (except for control of the white fly vector of Gemini viruses in Latin America) but it is rampant in snap bean production and must be reduced with resistant cultivars and IPM. Climate change will have big impacts on the distribution and intensity of biotic constraints. Heat and reduced rainfall may increase insect pests in some regions; excess rainfall in the Andes and in East Africa may intensify root rots and other diseases.

Drought tolerance and yield potential: Drought is one of the biggest risks of agriculture, and climate change may increase rainfall irregularity. Among important bean production areas, Central America and Mexico have always experienced occasional droughts and are expected to become even drier, as is southern Africa. Research on drought resistance of bush bean has led to unexpected gains in yield potential under favorable conditions, leading us to reflect on physiological yield limitations of the crop, especially with regard to remobilization efficiency of biomass to grain. Improved remobilization, we think, can make the crop more efficient in many respects and contribute directly to yield.

Fertilizer use and Symbiotic Nitrogen Fixation: Soil related constraints are probably the most important yield limiting factors and although some use of fertilizer inputs seems inescapable, there is great opportunity for improving fertilizer use efficiency. Root architecture of beans can be readily modified to make nutrient recovery more effective and efficient, employing known traits (such as increased basal root number and longer root hairs) and others that are under study, including aluminum resistance.

Symbiotic nitrogen fixation (SNF) is another technology that needs to be revived in light of eco-efficient agriculture. Climbing beans have long been known to fix much more N, and can return enough N to the soil to increase yields of the subsequent maize crop. Climbing beans have excellent yield potential, and have gained wide acceptance in Africa since the 1980's when CIAT introduced germplasm adapted to mid-altitudes (1500 to 2000 masl). Breeding efforts at present are directed toward improving heat tolerance of climbing beans, to broaden their adaptability and to make their benefits available to farmers in warmer production regions. Semi-climbing beans that require less staking material may also represent an opportunity for SNF. This work in Africa is especially connected to CIAT's Integrated Soil Fertility Management Program.

Urbanization implies moving large amounts of foodstuffs from farmgate to plate. Agriculturalists can contribute to eco-efficiency by targeting at least some research effort to production areas with more efficient access to urban centers. Possible target regions for bean research could be eastern Kenya in relation to Nairobi; the highlands of Mexico in relation to Mexico City; the western lowlands of D.R. Congo in relation to Kinshasa. Economic analysis will be needed to compare relative competitiveness of different production regions in relation to different markets. Reducing cooking time would be another important contribution toward conserving energy.

International Public Goods. Include the following:

- 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 pathogen populations with 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. Screening methods to identify biotic and abiotic stress resistant genotypes. 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.

Outputs

Output 1: **Beans with improved micronutrient concentration that have a positive impact on human health.** Nutrient-dense foods are more efficient in delivery of nutrition to a population, kilo per kilo and dollar for dollar. Biofortified beans can improve human health, and economic analysis has shown repeatedly that this approach is resource efficient compared to other public health options. Bean nutritional improvement has

focused on doubling the concentration of iron in the grain, and raising zinc by 40%. In a broader public health context, diet-related chronic diseases disable thousands and drain public resources. Diabetes alone costs Latin America an estimated $65 billion every year! Long known to be beneficial due to slow digestibility of complex carbohydrates, beans also have therapeutic effects for diabetes patients with circulatory disorders. Bean consumption also reduces the risk of myocardial infarction and at least two types of cancer. Thus, rescuing a traditional diet, including beans, should be a public health goal. Maintaining bean consumption in urban environments may demand more attention to specific traits such as flavor and texture, or canning quality where processed beans are preferred.

This research is targeted to small farmers and poor rural and urban consumers in Africa and Latin America. Targeting is developed in collaboration with nutritionists and with experts in GIS, to address human populations with nutritional deficiencies in iron and zinc. 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. Improved germplasm is shared or developed jointly with NARS partners, who supply basic seed to a range of organizations active in seed production (local seed companies, NGO's, CBO's, women's groups) who in turn distribute to farmers. NGOs and health workers play a special role in delivery. Benefits accrue to farmers/consumers through stable food supply of more nutritious beans for home consumption, and potentially to poor urban consumers. Assumptions for the successful delivery of these products 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 catalyzer (to promote downstream alliances in the uptake chain). This product is complementary to those of CIMMYT and CIP.

Impact Pathway: Output 1 is targeted to small farmers and poor rural and urban consumers in Africa and Latin America. Targeting is developed in collaboration with nutritionists and with experts in GIS, to address human populations with nutritional deficiencies in iron and zinc. This Output involves both small seeded germplasm that 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. NGOs and health workers play a special role in delivery. Benefits accrue to farmers/consumers through stable food supply of more nutritious beans for home consumption, and potentially to poor urban consumers. 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 catalyzer (to promote downstream alliances in the uptake chain). This Output is complementary to those of CIMMYT and CIP.

Output 2: **Beans that are more productive under low input agriculture of poor farmers**. This output includes both technologies aimed at improving food security among the rural poor and also to develop beans and strategies that respond to market opportunities. Genetically improved varieties that address the biotic and abiotic constraints of bean production are a primary product of this output. Improved germplasm is diffused through many of the same channels as beans with improved nutritional value, with the exception that partners may have less specific interests, and may be more production oriented. The role of CIAT is that of primary source of research for development. Better research methodologies such as molecular markers for resistance genes 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. On the other hand, crop management practices are of direct benefit to farmers as users, potentially across all bean ecosystems. Uptake chains 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. A sub-product of this line of work are beans that respond to market opportunities, and that benefit small farmers in both Latin America and Africa. Farmers in Ethiopia have already benefited from tapping into export markets for canning beans, and other countries are positioning themselves to follow suite. In Central America exporters are seeking to fill a niche created by the Latin population in the USA. This is a demand-driven activity, and in large part has generated its own impact pathway. Exporters and international grain buyers have established market chains that give them access to export quality beans. CIAT's role has been that of supplying germplasm in some cases, and in others to facilitate communication, and to give support in seed systems to avail quality seed to farmers of very specific varieties.

Impact Pathway: Beneficiaries of Output 2 are in some cases researchers (both inside and outside of CIAT), and in some cases are bean producers. For example, molecular markers for resistance genes 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. Improved germplasm is diffused through many of the same channels as beans with improved nutritional value, with the exception that partners may have less specific interests, and may be more production oriented. The role of CIAT is that of primary source of research for development.

AGBIO3: Cassava Program

Globally Cassava is the world's third most important food staple in the tropics, particularly important in the African and Latin American lowlands. It has huge potential for processing into multiple food, feed and other products, and this market led development is important in Asia and Brazil.

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 or tolerant to several of 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 lands. In addition to its important role in subsistence farming and food security, cassava is acquiring an increased role in rural development as source of raw material for many processing pathways. The most important 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.

Cassava research at CIAT seeks to improve the eco-efficiency of agriculture traditionally by focusing on high and stable productivity through breeding and adequate cultural practices. However, there is an increasing interest in cassava as a cash crop and processing it, from small, household operations up to large industrial ones, which not only require high and stable productivity, but also would benefit from roots with specific properties. The globalization of economies and new technological breakthroughs offer a unique opportunity not previously available to the crop. In addition, advances in molecular biology, genetic engineering, plant-tissue culture protocols and processing technologies provide important tools that will allow bridging the main technological gaps between cassava and the cereals. Finally there is an increasing interest from governments, private sector and research institutions to reduce the environmental footprint left by cassava production and processing.

Our primary mission is to contribute to household and global food security in societies where cassava products are an important and traditional staple; to improve farmers' income as well as those from rural communities and processing facilities; and to develop and promote sustainable production and processing systems. Our outputs are designed to adapt to the rapidly changing economic environment for cassava, its farmers and the communities that produce and/or process it. Cassava research at CIAT is aware of the cultural and ecological differences, challenges and opportunities that cassava offer in Latin America and the Caribbean (LAC), Asian and African regions. 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. CIAT is aware that competition between cassava as raw material for different processing end-uses and its important food security role should be avoided. Processing cassava for large industrial facilities is occurring mostly in southern Brazil, Thailand, Vietnam or China where cassava is not an important food security crop. Nonetheless CIAT looks for a careful balance by the research team so the use new opportunities for cassava do not result in undesirable side effects compromising food security in rural or urban communities. We openly accept that the ultimate objective of the project is to turn cassava from a low-technology, subsistence crop into a cash crop that promotes technology adoption and offers better perspectives of improving farmers' livelihood and reduction of poverty, but with an increasing emphasis in achieving this through technologies that minimize the impact on the environment. This strategy is in full agreement with the conclusions of the Global Cassava Strategy initiative (FAO) and aligned with the strategies and priorities set by IITA as well.

Outputs

The new opportunities opened to cassava along with budgetary constraints have led the cassava product line at CIAT to reduce emphasis in worldwide breeding and emphasize more strategic pre-breeding activities to develop high-value genetic stocks that can be efficiently developed in spite of limited resources, or else would generate new resources to develop germplasm with enhanced nutritional quality. Other activities conducted at CIAT relate to more "upstream" research such as marker assisted selection, genetic transformation, identification of agents of biological control and ways to exploit them commercially, or development of new breeding methods such as the introduction of inbreeding through a protocol for the production of doubled-haploids (anther culture) also under development at CIAT. Validation and testing of new agronomic practices and the routine sharing of germplasm can be done by partners in Asia (basing our activities in Thailand and in close collaboration with the Department of Agriculture and Kasetsart University), Africa (where IITA plays an important role) and LAC (where CLAYUCA has proven to be key partner, in spite of its relatively recent creation). Therefore, the work related more to "development", is conducted by these partners. The research conducted at CIAT is gradually changing as the strategies to identify high-value traits have open the opportunity of investments from the private sector to exploit them. This unprecedented situation results in new funding opportunities but also in needs to address issues related to intellectual property rights. The emerging pest problems of cassava in Asia (particularly in relation to mealy bug and whiteflies) require the urgent action of CIAT to identify biological control agents that will be useful to the particular conditions in Thailand and surrounding areas where these problems are emerging. It is not unthinkable that this development is a consequence of climate change and can be the first steps of our project to start dealing with the consequences of this global trend.

Output 1: **Creation and maintenance of genetic stocks to overcome production constraints.** This Output builds on the work conducted by the Conserving Genetic Resources Program through conventional breeding and pre-breeding. CIAT takes advantage of hosting the cassava genetic resources collection with about 6500 accessions including about 200 accessions from wild relatives. to screen it for useful traits. This "pre-breeding" activity resulted important discoveries of valuable traits. Landraces of *Manihot esculenta* and other *Manihot* species proved to be important sources of high-value traits (such as high-protein in the roots), tolerance to abiotic (such as post-harvest physiological deterioration and drought) and biotic stresses (whiteflies, African Cassava Mosaic Disease, etc.) Methodologies for the successful screening of landraces in germplasm collections have also been developed and shared with the scientific community.

There are four categories of cassava genetic resources that CIAT develops and shares: (a) relatively "unimproved" accessions from the germplasm collection which frequently are just old landraces; (b) genetic stocks used as sources for specific traits that are the result of specific crosses or careful screenings; (c) elite germplasm developed and evaluated for their adaptation to specific environmental conditions; and (d) genes, gene sequences and molecular markers. Landraces, genetic stocks and elite germplasm are routinely shared with NARs in Africa, Asia and LAC. IITA is an important bridge to introduce genetic variability for cassava research in Africa. While EMBRAPA is a key partner in Brazil, 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, eco-efficient productivity. CIAT is also developing technologies for properly identifying drought-tolerant cassava germplasm and from there to develop molecular markers that will facilitate its introgression and selection by NARs.

CIAT has shifted the objectives of cassava breeding to produce sources of high-value traits and emphasize the creation of genetic stocks (homozygous for the relevant trait). The HarvestPlus program will produce clones with enhanced nutritional value particularly in relation to carotenoids for vitamin A. For the animal feed industry and human nutrition, increased protein content is the main objective. For the starch industry novel starch types are of huge economic relevance. Different strategies have been implemented to develop these novel types and recently yielded its first fruits with the discovery of the long sought after mutation for a waxy starch in cassava. Recently different sources of tolerance to post-harvest physiological deterioration (PPD) have been identified (induced mutations, high-carotenoids content, wild relatives, and pre-breeding work).These approaches are gradually allowing the first steps towards the creation of genetic stocks that breeding projects worldwide can benefit from.

The major change that affects the execution of output 1 is the implementation of the new SMTA agreement for the exchange of germplasm that affects all CGIAR System centers. In addition the deployment of high-value traits require thorough analysis of issues related to intellectual property rights in agreement with the CGIAR policies.

Impact Pathway: Germplasm is shared through direct shipment of *in vitro* plants from elite germplasm identified in CIAT's breeding activities in the sub-humid, acid soils, or mid-altitude valleys environments. CLAYUCA has greatly facilitated the distribution of elite cassava germplasm through its stakeholders in Latin American and the Caribbean region. PPD-tolerant germplasm will be introduced in Africa and has already been shared with John Beeching's Lab (University of Bath, U.K.). For the starch and bio-ethanol industries the successful negotiation with a consortium of Thai institutions for the development and deployment of a waxy-starch cassava variety adapted to Thailand (TTDI) illustrate not only a very direct pathway for impact, but also a novel one. The agreement implies a detailed scheme for deploying the germplasm on one hand, revenues for the cassava product line at CIAT on the other and the first example of large financial investment of the private sector in cassava germplasm development and enhancement. For the high-carotene germplasm they are currently used as source for the development of commercial varieties to be deployed (tentatively in year 2011) in Nigeria and D.R. Congo, the two target countries for HarvestPlus. High carotenoids cassava cultivars are also appealing to be deployed within Agrosalud in LAC and offer commercial advantages for the feed industry. 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 Cassava Mosaic Disease is not present in the Americas. The role of CIAT is that of a primary research provider of the improved germplasm or genetic stocks. 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*: More efficient genetic enhancement approaches.** For cassava to remain competitive, a more efficient breeding scheme, particularly for low heritability traits such as yield, is needed. New breeding tools are required to develop the improved genetic stocks of output 1. Molecular markers are already fully integrated into the breeding scheme, CIAT has assumed a leading role in the areas of genetic transformation, development of protocols for the production of doubled-haploids homozygous lines and efficient methodologies for *in vitro* propagation of clean planting materials.

The intended users of this output are mostly NARs involved in cassava research. Eventually processing companies may start using some of the technologies developed at CIAT. This is the case, for example, of starch companies in Colombia, Nigeria and South Africa, implementing rapid multiplication methods (including tissue culture protocols) for the production of clean planting material of elite germplasm. The product of this output is knowledge, which is shared with the intended beneficiaries through scientific publications, the internet, training courses, conferences and presentations at scientific meetings. The outcomes of this output will be more efficient breeding system that will allow cassava to 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.

Throughout the many different activities the cassava research at CIAT and CLAYUCA are also paying special attention to the development of human capacity of its personnel and that of our collaborators. Training is achieved through individual visits, field days, demonstration plots, workshops, formal courses and scientific publications. These two institutions are committed to help cassava researchers, producers and processors world-wide gain access to all products and technologies developed.

There is no major change from the previous MTP in output 2 except for the growing concern on climate change that further highlights the relevance of our work regarding drought tolerance. At the end of August 2008, the molecular geneticists left CIAT (and several pending tasks) which have created considerable problems for the team to continue delivering as expected from different research projects.

Impact Pathway: Most of the products related to this output will have indirect impact through facilitated breeding approaches either in work directly conducted at CIAT or by NARs and IITA. Of a huge relevance is the breakthrough success in overcoming a bottleneck in the process of developing doubled-haploids from microspore culture. The exine in the developing cassava microspore is very thick and did not let scientists to see through. This proved very difficult because it was not possible to identify treatments that promoted cell division and probably prevented any further development of multi-cellular structures by pure physical strength of the exine. By the end of 2007 CIAT cassava and biotechnology teams succeeded in digesting the exine. Now up to 30% success in the production of multi-cellular structures can be attained. Next step will be the regeneration of plants from these structures. When this happens, a true revolution in cassava breeding will take place. Drastic changes in the genetic enhancement of the crop will be possible and the “design” of outstanding hybrids and predictable exploitation of heterosis finally a reality. There are good possibilities that the Bill and Melinda Gates Foundation will continue supporting this work that has already benefited from two consecutive 3-years projects with the Rockefeller Foundation.

***Output 3*: Eco-efficiency of production & processing of cassava.** Management of pests and diseases, likely to cause acute problems in large areas planted with cassava, has been an integral part of the cassava research at CIAT since its inception. There are three main type of products delivered through this output: sources of resistance to pests and diseases, agents for the biological control of pests and diseases; and diagnostic kits. The ultimate end-users of the results of this output 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, EMBRAPA and other 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 and human

health, 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. This output reflects one of the main strengths that cassava research at CIAT has had since its creation: its integral approach. As more cassava is demanded by different processing facilities, larger areas and continuous growth for a constant supply of raw materials will be required. This in turn will certainly result in better conditions for pests and diseases to become more prevalent. An integral approach for cassava production will then become more relevant than ever. The emergence of insect pests in areas of Asia that were relatively from them (particularly Thailand) offer a unique challenge for CIAT to support eco-efficiency through the powerful tools of biological control which was so successful in the similar problem of the mealybug in Africa.

This output also develops cultural practices and processing approaches for a competitive and sustainable cassava production and/or processing. The expected impacts include reduction of the negative impact on the environment of growing and/or processing cassava for example by promoting hedgerows for the prevention of soil erosion or developing systems for processing industrial byproducts of agro-enterprises. 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 eco-efficient agricultural practices. Assumptions for the successful delivery of these outputs include institutional and financial stability of partners, political stability, infrastructure, and institutional support. This output also relates to the activities conducted by CLAYUCA, which result in a productive and close collaboration between the two research groups. CLAYUCA also serves as a bridge between CIAT and NARs associated with CLAYUCA making available technologies and products to NARs. In this regard, therefore, CLAYUCA has been a key partner in the pathway to impact.

An increasing concern related to output 3 is the retirement of the two senior entomologists at CIAT and the departure of two pathologists (from the rice and forages program) that occurred during the last 12 month. Only one pathologist is left at CIAT (Elizabeth Alvarez from the cassava team) to attend to the four traditional commodities and tropical fruits in which she works actively. An additional change in the already mentioned emergence of insect problems in areas in Asia that had been relatively free from them. The senior agronomist that had been working in Asia for about 20 years will retire in May 2009. The scientist that will continue coordinating the work supported by the Nippon Foundation has already moved to CIAT's office in Bangkok.

Impact Pathway: One interesting example of pathway to impact related to this output is the commercialization by a private company of different agents for the biological control identified at CIAT for major pests. However, the most typical pathway is through the sharing of germplasm with high degree of resistance to insects and pests. Recently, marker-assisted-selection for resistance to CMD for the deployment of germplasm in Africa with adequate levels and high frequency of resistance to the disease has been successfully implemented. In the case of LAC, CLAYUCA has been very successful positioning itself as an innovator particularly in the area of cassava post-harvest processing and interacting with other industrial processes in handling by-products.

AGBIO4: Forages Program

The goal of the work on tropical forages, targeted at the crop-livestock interface, is to improve livelihoods of poor rural crop-livestock producers while contributing to eco-efficiency of production systems. Thus the purpose of our work is to explore the benefits of multipurpose forages on improving agricultural productivity, enhancing soil fertility, restoring degraded lands, improving water quality, reducing deforestation and mitigating the effects of climate change, though the conservation and exploitation of the genetic diversity of either the natural variation or breeding of tropical grasses and legumes. This results in positive effects on poverty alleviation through enhanced smallholder competitiveness and improved food security, while reducing the ecological footprint.

Livestock development is recognized as a key element for increasing the income of poor smallholders given the increased demand for animal products in developing countries. Recent analysis indicates evolving market opportunities for forages as prices for conventional feed resources, mostly grain-based feeds, are increasing while consumers want higher quality products. However, a high proportion of smallholder crop-livestock systems in the tropics are located in areas with prolonged dry seasons, exposed to waterlogging and/or with land in different stages of degradation. This leads to an inadequate supply of quality feed particularly in the dry season. In addition, in many cases smallholders with livestock and limited land (i.e., in Southeast Asia) have to walk long distances to harvest forages. On the other hand, tropical forages are amongst the few opportunities available to many smallholder farmers to produce high or added value products, due to the fact that forages can be grown not only in favorable but also marginal environments.

To accomplish the goal and purpose of the Tropical Forages Program, the research is being organized around three outputs: (1) Forage germplasm developed through collection, selection and breeding, (2) Forages as high value products developed to capture differentiated traditional and emerging markets for smallholders, and (3) Forages integrated into smallholder crop-livestock systems to realize the benefits of improved forages through adaptation, innovation and adoption, aiming at higher livelihood security through higher resource use efficiency and reduction of the ecological footprint.

Partnerships are formed with private seed industry, ARIs, NARS, and development partners to carry out strategic research to: select and breed forages; enhance adaptation of forage species to biotic and abiotic stresses; develop methods and tools for targeting, processing and evaluation of forages; employ operational research principles to develop forages for specific production and market niches; develop more sustainable crop-livestock systems using an innovation systems approach; explore the potential of improved forages for adaptation to and mitigation of climate change and reduction of the negative impacts of agriculture on the environment; and quantify the impact of forages on improving livelihoods and protecting the environment. Capacity building including group/individual training and knowledge management remains integral to our agenda to: (a) strengthen/benefit from the research capacity of partners, and (b) enhance our capacity to deliver research products in different environments.

International Public Goods. The research products of CIAT's Tropical Forages Program are in line with CIAT`s approach to eco-efficient agriculture for the poor and the mandate of CGIAR of producing international public goods (IPGs). They can be grouped into the following categories:

1. Defining mechanisms/processes (to assist in the development of screening methods) to understand how
    - improved forages affect animal productivity and product quality,
    - grasses resist pests and diseases,
    - forages adapt to acid soils,
    - forages adapt to drought and waterlogging,
    - and to what extent forages, mainly legumes, contribute to soil fertility,
    - grasses inhibit biological nitrification in soil.

2. Developing screening and evaluation methods to determine
    - forage quality for ruminants and monogastrics,
    - resistance to major biotic stress factors (i.e., spittlebug and *Rhizoctonia*),
    - adaptation to abiotic stress factors (i.e., adaptation to low soil nutrient status and high Al, to drought and poor drainage).

3. Developing superior forage genotypes/cultivars to increase livestock productivity and protect the environment
    - Integrate grasses and legumes selected from germplasm collections and through breeding that have broad adaptation and multiple functions into crop-livestock production systems using an innovation systems approach.

- Quantify trade-offs between use of forages for soil enhancement and as animal feed.
- Quantify the benefits of improved forages in reducing global warming potential through carbon sequestration and reduced emissions of methane and nitrous oxide.

4. Targeting and delivery of research results through dissemination of forage germplasm and decision support tools
   - Document conservation and distribution of germplasm.
   - Develop Decision Support Tools with information on adaptation, uses and management of different forage species.

Outputs

In line with CIAT`s focus on eco-efficient agriculture for the poor (i.e., balancing between economic, ecological and social impacts), outputs have been further sharpened. The research agenda builds on our achievements in increasing productivity of market-oriented smallholder crop-livestock production systems, while enhancing efforts to realize the environmental benefits of tropical forages. However, to respond to increased climate variability and extreme conditions, as a contribution to adaption to climate change more emphasis is placed on developing forages with high tolerance to both drought and waterlogging (Output 1). The efforts on developing forages will be complemented with research to realize income generation opportunities (Output 2) and enhance systems performance (Output 3). Forage-based systems not only contribute to livestock and crop production but can also reduce soil erosion, improve soil and water quality, and reduce global warming potential. Thus we will also increase our research on quantifying the benefits of improved forages with deep and abundant root systems in reducing global warming potential through improved carbon sequestration and reduced emissions of methane and nitrous oxide. The results are anticipated to have a positive impact on mitigation of climate change. However, information on the trade-offs between these multiple functions of tropical forages for crop-livestock production and environmental protection is still scarce. The assessment and quantification of the environmental effects of forage-based livestock production in relation to economic output will therefore integrate the three research outputs in the specific contexts of the three worlds of agriculture as proposed by the World Bank.

***Output 1*: Forage germplasm developed through collection, selection and breeding**. Forage grasses (e.g., *Brachiaria*) and multipurpose herbaceous and shrub legumes of high quality that are adapted to major biotic (e.g., spittlebug, *Rhizoctonia*) and abiotic constraints (e.g., low soil fertility, aluminum toxicity, drought, waterlogging) will be developed. Adaptation to the effects of climate change as a dynamic response is an integral part of the work on improving stress tolerance. Addressing forage conservation technologies suitable to smallholder systems and attention to emerging diseases and pests and climate change will further enhance the sustainability of smallholder systems. Results from this output will be inputs to Outputs 2 and 3 below.

Impact Pathway: To contribute to the improvement of livelihoods of poor, rural, crop-livestock producers through high quality forages adapted to major biotic and abiotic constraints, forage researchers rely on natural genetic diversity from core germplasm collections housed in the Genetic Resources Unit of CIAT and other international and national centers. Artificial hybridization to create novel genetic variation is used when major limitations in successful commercial cultivars have been identified and when evaluation of large germplasm collections has failed to identify the required character combinations (e.g., spittlebug and *Rhizoctonia* resistance with adaptation to acid soils and drought in *Brachiaria*). Screening methods and selected genotypes with superior forage quality, resistant to major pests and diseases and adapted 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.

***Output 2*: Forages as high value products developed to capture differentiated traditional and emerging markets for smallholders.** Research will emphasize the high value opportunities of forages, leading to improved market competitiveness of forages (such as hay, silage and forage meal) and derived ruminant (e.g., cattle, goat, sheep) and monogastric (e.g., pigs, poultry, fish) livestock products. This includes the

development of forage conservation methods targeted at smallholder systems. We work in a market-oriented value chain approach, involving the private sector, NGOs and governmental institutions.

Impact Pathway: To improve the efficiency of partners to better target forages to diverse environments, production systems and market niches, the forage team collaborates with the RDC on People and Agroecosystems to develop methods of participatory evaluation of forages, decision support tools and more effective and equitable market interactions. Selected forage genotypes are evaluated and disseminated with and by partners in different environments and production systems. The superior grass and legume genotypes are released and promoted by NARS and private seed companies, and adapted and adopted by farmers to intensify and diversify their production systems.

***Output 3*: Forages integrated into smallholder crop-livestock systems: realizing livelihood and environmental benefits.** Research will be focused on improving the efficiency of labor and critical inputs such as fertilizer and water, thereby increasing system performance. Legumes as green manures in cropping systems provide part of the nitrogen needed to sustain productivity of crops. At the same time research aims to balance between economic and environmental – and implicitly social – sustainability of tropical agriculture. We will analyze the contribution of forages to the economic and ecological balance in resource (nutrients, water, land and labor) utilization, carbon sequestration and greenhouse gas emissions. The major challenge is combining higher agricultural output (through higher forage productivity and quality) with greater input use efficiency in integrated production systems while at the same time contributing to mitigate the effects of climate change (e.g., exploring the potential of forages for carbon sequestration, reduction of methane emissions, inhibition of biological nitrification).

Impact Pathway: The benefits of improved grasses and legumes are realized through adaptation, innovation and adoption, aiming at higher livelihood security through higher resource use efficiency. For its work in Sub-Saharan Africa, Southeast Asia and Latin America and the Caribbean, CIATs Tropical Forages Program is collaborating with ILRI and CIAT-TSBF, with complementary research priorities and expertise to integrate forages in diverse crop-livestock systems. Adoption of new forage varieties results in more income to livestock farmers through more efficient use of land and labor, and more animal products for urban consumers, with impacts demonstrated in Latin America and the Caribbean and Southeast Asia. To reduce the ecological footprint and mitigate the effects of climate change, we integrate the decision support, biophysical and socio-economic expertise of CIAT, ARIs, NARS and development partners. The utilization of forages to enhance system performance and reduce the ecological footprint is expected to have direct impact at the household level while at the same time providing avenues in ecosystem services and providing tools for decision makers. This partnership and the interaction with the private sector have allowed us to amplify networks for delivery of research outcomes. Information sharing through knowledge tools such as SoFT (www.tropicalforages.info) reaches a wide audience ranging from researchers and development practitioners to educational institutions, and complements our continued efforts of individual and group training.

3. TROPICAL SOILS RESEARCH AREA

Vast areas of agricultural land in the tropics are succumbing to the threat of soil fertility loss. The problem is especially severe in Central America and is a major concern in sub-Saharan Africa, where fertilizer use is extremely low and about 500 million hectares are already moderately or severely degraded. Declining soil fertility means particularly severe limitations for women farmers, given the prevalence of gender inequality in access to more fertile land and to capital for purchasing inputs.

Unless effective and equitable means of overcoming this problem are applied on a massive scale, small farmers will be hard pressed to realize the benefits of improved crops. Recent rises in fertilizer prices have made the need for better soil fertility management techniques more urgent than ever, and their importance will likely increase, as the impacts of global climate change unfolds in tropical agriculture. Together with

better water management, prudent handling of soil fertility is central for making agriculture more eco-efficient.

Scientists have reached a broad consensus on the basic principles underlying a holistic approach referred to as "integrated soil fertility management" (ISFM). The approach recognizes that, while mineral fertilizers are necessary for sustainable management of tropical soils, they are not sufficient for this purpose. Long-term experiments have shown that, when such fertilizers are applied without organic inputs, the ability of crops to use nutrients efficiently declines over time. Thus ISFM combines appropriate use of fertilizers with various organic inputs, including livestock manures and locally available multipurpose legumes.

Another distinctive feature of ISFM is the recognition that interactions between the components of agricultural production – from water, soil, crops and pests on farm to input supplies, markets, rural institutions and health conditions in the surrounding landscape – are just as important as the individual components themselves. Thus, CIAT research on tropical soil biology and fertility focuses both on integrated soil fertility management and also on sustainable land management.

TSBF1: Integrated Soil Fertility Management Program

Soil fertility depletion has been described as one of the major constraints to food security and income generation in the tropics, particularly in sub-Saharan Africa (SSA) and Central America (CA). Despite proposals for a diversity of solutions and the investment of time and resources by a wide range of institutions soil fertility depletion continues to be a major problem. The rural poor are often trapped in a vicious cycle between land degradation, fuelled by a lack of relevant knowledge and/or appropriate technologies to generate adequate income and opportunities to overcome land degradation. Intensification and diversification of agricultural production is required to meet the food, feed, and income needs of the poor and this cannot be achieved without sustainable investment in soil fertility management.

To achieve sustainable investments in soil fertility management the Program has adopted the Integrated Soil Fertility Management (ISFM) paradigm. We define ISFM as '*A set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs, and improved germplasm combined with the knowledge on how to adapt these practices to local conditions, aiming to maximize agronomic use efficiency of the applied nutrients and thus crop productivity. All inputs need to be managed following sound agronomic principles.*' 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. This definition is in line with the goals of the African Fertilizer Summit, recently held in Nigeria, which aims at increasing fertilizer use from an average of 8 to 50 kg nutrients ha^{-1} by 2015.

Improving the natural resource base without addressing issues of health and nutrition and income generation is often the reason for lack of adoption of ISFM practices. Maximum benefits from ISFM practices can only be obtained within an enabling context, where profitable farm input and produce markets, improved health and nutrition, functional institutions, and good policy are in place. eco-efficiency is embedded in the ISFM Program through the definition of ISFM that focuses on maximizing agronomic input use efficiency (environmental dimension) and through the recognition that profitable access to markets (economic dimension) and food security and good nutrition for all (social dimension) are major drivers for adoption of ISFM.

The Program will be implemented in major impact zones with target cropping systems where soil fertility decline is a major issue and where a large number of people depend on these systems for food and nutrition security and income. In SSA, these include: (i) millet and sorghum-based systems in the West-Africa dry-lands, (ii) cereal-legume intercropping and rotations in moist-savannas of West, East and Southern Africa, (iii) cassava-based systems in humid lowland areas of West and Central Africa and (iv) banana-based systems in East and Central African highlands. Each of those zones has specific soil-related constraints to crop

production, including low nutrient reserves (e.g. low available N and P), poor chemical quality (e.g., low buffering capacity), and physical constraints (e.g., low soil depth), resulting in sub-optimal nutrient and water use efficiencies. In Central America, one agricultural impact zone with crop-livestock systems is targeted with actions in two important countries (Nicaragua, Honduras) in the region.

Some ISFM-based technologies have shown a high potential for large-scale adoption in some of the above Impact Zones and a relatively high increase in input use efficiency while further research for development investments are needed to fully assess the adoption potential of other technologies and their impact on resource use efficiencies.

The GOAL of the ISFM Program is to improve the livelihoods of rural families in the target Impact Zones by developing ISFM-based profitable, socially just, nutrient-dense, and resilient crop production systems and creating an environment enabling their adoption.

International Public Goods. International and regional public goods (IPG) generated by the ISFM Program include:

- Improved knowledge on soil processes, including the role of improved germplasm in regulating input use efficiency.
- Tools to take into account farm heterogeneity and farmer typologies in devising ISFM practices.
- Best-fit ISFM practices for the target cropping systems and Impact Zones.
- Decision support tools and models to analyze trade-offs among various livelihood realms.
- Innovative approaches for sustainable crop utilization and enterprise promotion, including linking farmers to market, and rural poverty reduction.
- Effective approaches to engage various stakeholders in ISFM technology evaluation and dissemination.
- Technological, institutional, market, utilization, and policy options for increasing delivery of benefits and broader impact.

TSBF-CIAT's comparative advantage is in conducting IPG research on ISFM in farming systems where declining soil fertility and soil degradation undermine rural livelihoods and market opportunities. However, while the institute will focus primarily on strategic, applied, and adaptive research, it will also support technology dissemination and development activities, working with partners via community-based organizations and NGOs, national and regional networks and global projects. Much of the research as well as NARES capacity building will be done via the Institute's main implementing network, the African Network for Soil Biology and Fertility (AfNet). Dissemination of findings will occur through effective partnerships with relevant development partners.

Outputs

The focus of the ISFM Program is closely related to that of the '*TSBF-CIAT's Strategy and Work Plan, 2005-2010*'. The 2008-2010 MTP, which was the first MTP drafted after setting up 2 Outcome Lines within TSBF-CIAT (Integrated Soil Fertility Management and Sustainable Land Management Outcome Lines) included most of the substantial changes in focus and orientation of the current Program. Important changes for the 2009-2011 MTP include:

- **Logframe and Output Targets:** The Logframe was refocused around the major Impact Zones as Outputs. The earlier Outputs included processes and principles, management practices, enabling environment, effective partnerships, and stakeholder capacity and are now embedded within these Impact Zones.
- **Inclusion of a Latin-American Impact Zone:** In view of the new Strategic Directions 2010-2020 document of CIAT 'Eco-Efficient Agriculture for the Poor, the geographical focus of the ISFM Program has been broadened to include activities in Central America.
- **Platform for soils research in SSA:** In line with above Strategic Directions, activities will be organized around a Soils Platform for SSA, in first instance focusing on the mid-altitude areas in Central Africa, coordinated from the CIALCA ('Consortium for Improving Agriculture-based Livelihoods in Central Africa') office in Bukavu, East DR Congo.

***Output 1*: ISFM for legume-cereal-based systems in sub-Saharan Africa promoted.** During the last two decades, sustainable maize-grain legume rotations and intercropping systems have been developed for the savanna Impact Zones. Accompanying ISFM practices relies upon retention of legume residues, judicious and targeted application of mineral fertilizer, resilient legume and maize germplasm and adaptation to local variation in soil fertility. Farmers in the Sahelian Impact Zone are adopting the 'micro-dosing' technology, which refers to the utilization of relatively low quantities of fertilizer (<20 kg ha^{-1}), either through point placement in millet or sorghum-based systems or through appropriate fertilizer management in maize-based systems. Micro-dosing is practiced in conjunction with water harvesting, or application of manure, crop residues, or household waste. In this Output activities will focus on creating an enabling environment, such as the "warrantage" or inventory credit system, to promote best ISFM practices in the Sahelian and savanna Impact Zones, based on a clear understanding of which enabling factors are required for widespread ISFM uptake by farmers. Decision support tools will assist in deciding trade-offs associated with these practices. Efforts will be made to institutionalize knowledge and approaches for evaluating and disseminating ISFM practices within relevant extension systems.

***Output 2*: ISFM for cassava-, and banana-based systems in humid sub-Saharan Africa assembled.** Cassava has often been coined 'poor people's food' and assumed to be a crop that could produce some yield where others failed. Consequently, efforts to integrate fertilizer and organic inputs into cassava-based farming systems have been limited. Currently, cassava is enjoying a new popularity and attracting renewed attention as a major resilient staple crop in the humid and sub-humid areas of SSA and as a cash crop for growing export markets in chips for livestock feed, starch, and other processed products. Bananas are among the most important food and cash crops in East and Central Africa and comprise principal components of food security and income generation within the region. Bananas require fertile soil, adequate moisture and pest management to achieve high yields and traditional banana production systems included the recycling of organic nutrients. Exportation of bananas to urban markets without the replenishment of the nutrients exported has resulted in unsustainable mining of nutrients in banana farming systems, leading to a decline in banana productivity. Both above systems are amenable to ISFM and Output 2 is aimed at developing such practices through proper understanding of the mechanistic principles underlying ISFM and ex-ante studies of the adoption potential of the emerging ISFM practices. Decision support tools and capacity building will trigger the initial uptake of ISFM within these systems within the timeframe of this MTP.

***Output 3*: ISFM for conservation agriculture systems in Central America assembled.** In the Central-American hillsides, land degradation is a major problem affecting approximately 75% of the area. Smallholders have no other choice than continuous crop production on lands prone to erosion. Soil nutrients are depleted, resulting in an overall soil fertility decline, contributing to low productivity and poverty. Results from earlier research activities indicated that the Quesungual Slash and Mulch Agroforestry System (QSMAS), a form of conservation agriculture, has beneficial effects on improving food security and reducing ecological footprints. QSMAS is based on (i) no slash and burn and management of natural vegetation, (ii) permanent soil cover, through continual deposition of biomass from trees, shrubs, weeds, and crops, and (iii) minimal disturbance of soil, through no tillage, direct seedling, and reduced soil disturbance. The integration of ISFM principles within the QSMAS systems has shown great potential. A specific challenge is to diversify the QSMAS through integration with livestock production in the region. Pastures are often highly degraded and dairy production drops dramatically during the dry season when milk prices increase 2-fold compared with the rainy season. The use of ISFM including improved crop and forage germplasm, adapted to low soil fertility and drought will contribute to sustainable livelihoods in the region. This Output is aimed at developing ISFM practices through a proper understanding of the mechanistic principles underlying ISFM. Decision support tools and capacity building will trigger the initial uptake of ISFM within the QSMAS within the timeframe of this MTP.

Impact Pathway: The impact of ISFM within the Impact Zones will be visible through improved production, income, human health and nutrition, and soil fertility, and reduced nutrient mining and conversion of natural fallow to agriculture. Each of the Outputs Targets aims at reaching specific users who are then geared towards common outcomes and impact through effective partnerships. strategic research outputs will be used mainly

by CGIAR, Advanced Research Institutes (ARIs), National Agricultural Research System (NARS), and Regional Consortia researchers who are envisaged to derive processes and principles based on applied research activities. NARS will then apply these principles, concepts and methods and adapt and improve ISFM practices to the prevailing production environments of their mandate areas. An enabling environment for adoption of ISFM, focusing on improved market access, knowledge on health and nutrition of farming communities, effective partnerships along targeted value chains, and stakeholder capacity building will not only create motivation for adoption of ISFM technologies but contribute directly to improved income and health and nutrition after adoption of such technologies. The intended users of these are development partners and farming communities with specific attention given to enlightening the ISFM research community on these issues. The building of human and social capital of all TSBF-CIAT stakeholders for effective research and sustainable management of tropical soils is necessary since managing soil fertility for improved livelihoods requires the integration of technical, social, economic and policy issues at multiple scales.

Since most operations in this Program are supported by specific projects, the operationalization of specific impact pathways will be dependent on the goals and objectives of these projects and will not necessarily cover the entire value chain within a specific project. The overall importance of this Program is then to oversee that the necessary links are created between various initiatives operating in similar Impact Zones to ensure a continuity of partner networks and necessary coordination to deliver the required Outputs to achieve impact.

The key assumptions for the Outputs are: (i) security and political stability does not restrict access to target sites and continuation of on-going activities; (ii) Poverty reduction strategies remain central to human development support and funding; (iii) TSBF-CIAT stakeholders remain engaged and show limited staff turnover, (iv) TSBF-CIAT management continues to adapt and innovate in response to changing priorities, and (v) linkages remain maintained among research and development organizations. Other important assumptions are: (i) investments in various aspects of the Program are linked in time and space, (ii) large-scale capacity building initiatives are implemented sufficiently fast and in close relationship with development-related investments, and (iii) rural service providers are operational and rural infrastructure is sufficiently developed.

TSBF2: Sustainable Land Management Program

Land degradation is one of the major constraints to food security and income generation in developing countries. It has direct effects on short term crop productivity as well as on the longer term sustainability of natural resources.

Moreover, there is the added challenge to maintain or improve the resilience of the productive capacity of the soil in view of climate and environmental change.

In order to address land degradation we need to look at the larger agricultural production landscape (that comprises the bio-physical, socio-economic and the cultural and political landscape). The production landscape needs to be understood in terms of the provision of environmental (or ecosystem) goods and services. Soils play a key role in the provision of the services; soils store and cycle water from rainfall and irrigation and filter toxic substances through clay sorption and precipitation processes that determine surface and ground water quality, soil organisms decompose organic materials, cycle nutrients, regulate gas fluxes to and from the atmosphere, regulate soil borne pest and diseases and maintain soil structure through bioturbation. The affect of agriculture on these processes is the focus of this program along with the reciprocal affect of these processes on future agricultural productivity.

The main objectives of the SLM program are

- To enhance knowledge and understanding of soil ecological functions that sustain a productive agriculture and maintains or improves biodiversity and ecosystem services.

- To utilize targeting of land use and soil management interventions to better reverse erosion of the soil resource base.
- To enhance the production of ecosystem services through sustainable agricultural production and payments for ecosystem services.

The SLM program has defined 2 outputs to satisfy the objectives and goals defined.

Output 1: Eco-efficient land and soil management practices evaluated for landscape levels.
Output 2: Options for enhanced and sustained agricultural production and ecosystem services, regeneration of ecosystem function and adaptation to climate change developed.

International Public Goods. The IPG of the SLM program include the following:
- Improved understanding on soil (biological) processes;
- (Standard) methods for the assessment of soil quality and soil health, including soil biological, chemical and physical components;
- Indicators of soil quality and soil health;
- Assessment of soil quality and soil health for agro-ecosystems of major importance and understanding of processes that lead to poor soil quality and health;
- Improved knowledge on how different stakeholders use and manage landscapes;
- Improved systems and practices for managing soil, water and land resources at a landscape level;
- Improved knowledge on global warming potential of different production systems;
- Innovative diversification options of land use within agricultural production landscapes;
- Decision support tools and models to analyze trade-offs among food productivity, ecosystem services and land conservation;
- Institutional innovations and policy options to reduce land degradation and to restore degraded lands.
- Three-tier-approach for sustainable crop and livestock enterprise promotion, linking farmers to market, and rural poverty reduction.

The TSBF Institute has a comparative advantage in conducting and coordinating IPG research on soil quality and soil health in a farming system and land use system context, where land degradation undermines rural livelihoods. However, while CIAT-TSBF will focus primarily on strategic research, it will support technology dissemination and development activities with partners via innovation platforms, regional networks and international projects. CIAT-TSBF SLM program will continue research on below-ground biodiversity as a means of beneficially managing soil biology. Much of the applied research and dissemination of findings, as well as NARSs capacity building, will be done via the Institute's regional partner network – the African Network for Soil Biology and Fertility (AfNet) and through national partners. Efforts will be undertaken to expand the MIS consortium in Central America to build a similar network for soil biology and fertility research in Latin America. CIAT-TSBF also collaborates with the South Asian Regional Network (SARNet) on soil fertility research in that region.

Outputs

Several changes have been made compared to the 2009-2011 MTP. They related to:

Outputs redefined and reduction in number of outputs and output targets. The number of outputs has been reduced to two, rather than the original five. Capacity building has been dropped as a separate output because these efforts are considered to be an integral part of the process to generate the outputs and impacts. The formation and capacity building remain an important objective of the program. Further, understanding the biophysical processes and principles that underlie soil health, soil and land degradation and principal and proximate causes that drive soil and land degradation as well as decision support tools for the targeting of interventions for sustainable land management is all integrated in one output. Biodiversity, being the basis for production of all ecosystem services, is naturally included as one of the components of the

diagnostic phase. The 'economically viable and environmentally sound soil management practices' has been retained as separate output.

Improved distinction between ISFM and SLM programs. The development of production technologies including soil management practices is very much the domain of the ISFM program. Ecosystem functioning is an important focus for the SLM program and the evaluation of (alternative) production systems in term of impact on ecosystem functioning at the landscape scale remains an important focus, and as such do also include technologies that target improved ecosystem services, like conservation measures and water harvesting technique. For this purpose we do want to evaluate production systems (like conservation agriculture, organic agriculture, crop-livestock systems, etc.) based on their global warming potential and ecological footprint index.

Program more clearly structured according to impact zones. Output targets are defined according to impact zones rather then based on thematic distinction and allows for a more integrated and specific program of activities and allows for better integration with other programs to realize benefits to the region. The SLM program aims to maintain its presence in the Amazon and Central American Mid-Altitude hillsides zone, even though the CSM-BGBD project will come to an end in 2009. It will try to do so by including existing projects and formulating new proposals for these areas. Activities in India and Indonesia will have ceased, but we will look for opportunities to continue our work in South and South-East Asia and to maintain our global outlook.

***Output 1*: Eco-efficient land and soil management practices evaluated.** This output aims to insure the eco-efficiency of soil management practices including ISFM technologies, soil conservation measures, and water harvesting technique, etc. Eco-efficiency must deliver both high productivity and minimum negative ecological footprint. The research of this program is closely integrated with that of the ISFM program. While the ISFM program concentrates on identifying practices that enhance farm productivity, the Sustainable Land Management (SLM) program focuses on the environmental and natural resource implications of new ISFM practices. The ISFM program works principally at the level of the field, the SLM program complements this with a landscape approach. From this perspective the SLM program looks at the landscape impacts of new ISFM technologies on outcomes such as ecosystem services like carbon sequestration, water retention, soil biodiversity, or organic matter cycling. Production systems will also be evaluated on their potential contribution to global warming and energy use efficiency. The SLM program looks at trade-offs between farm productivity and food production with ecosystem services.

For this output we will partly rely on IFSM trials that are conducted under the auspices of the SLM Program as well as the IFSM program and in close cooperation with AFNET, making use of their network long term trials. This includes studies on the effect of soil and land management on soil biodiversity. Ex-ante and ex-post adoption studies that look into the requirements of various systems for resources like land, labor, capital and manure will inform the definition of application domains. Information will be captured in fact sheets from which decision aids will be developed, constituting the knowledge base which will be the major element of this output. The decision aids will help select among various alternatives, for example, selection tropical forages for different types and qualities of organic matter. The knowledge base including the decision aids will be made available to third parties through the internet.

Impact Pathway: Output 1 will be documentation of a set of proven technologies and systems for SLM together with information on their application domains. This knowledge base will be made accessible through the internet and we hope the website will serve as a vade-mecum for a wide range of target audiences. However, the innovation and development platforms (to be established for each intervention domain) will be the main target audience and mechanism for the dissemination of the research outputs. The use of this information will allow stakeholders (farmers, development NGO, extension services, research community, etc.) to make better selection of the technologies they want to invest in and moreover to agree on a joint agenda and programme for intervention. It will reduce risks and enhance returns on investment and herewith

enhance changes for adoption of appropriate technology. It will allow for better trade-off analyses and herewith enhance negotiation power of the farmer communities.

This output target aims to improve the availability, accessibility and the applicability of research findings, from the various disciplines within and outside CIAT, that are relevant to SLM and sustainable agricultural production. It will aid planning of research within the organization and with partners. Constraints in the availability of information and lack of rigorous analyses and synthesis of results from these various experiments and studies have resulted in duplication of research efforts as far as ISFM and soil conservation technologies are concerned. So we hope this output will make a contribution to improve efficiency of the limited research funds that are available for agricultural research in the tropics and improved targeting of the technologies.

***Output 2*: Options for enhanced and sustained agricultural production and ecosystem services, regeneration of ecosystem function and adaptation to climate change developed**. The SLM program aims to identify domains for intervention in sustainable land management. These domains are concrete geographical spaces with specific bio-physical and socio-economic characteristics, but that also allows identification of the relevant stakeholder group that need to be involved in planning of concrete interventions Particular attention will be paid to appraising the Quesungual slash and mulch agroforestry system based on principles of conservation agriculture that could be an alternative to replace the non-sustainable, environmentally unfriendly slash-and-burn system that is traditionally used by resource-poor farmers in hillside agro-ecosystems of the sub-humid tropics in Central America.

The decision support tools for improved targeting of recommendation for sustainable land management will consist of a set of decision rules to define soil health problem domains, to define application domains of the various alternative technologies and production systems and to define the intervention domains. The possible interventions are evaluated basically by matching the requirements for the intervention with the conditions in each of the three types of domains specified. The tools developed for targeting interventions will assist in better targeting of investments by the rural development and communities.

The AfSIS project will provide detailed information on soil functional properties for the whole of Sub-Saharan Africa. It will rely on diagnostic field trials to infer information on soil health status (i.e. the ability of the soil to provide soil ecosystem related services). The response to fertilizer is an important characteristic. From the analyses of field trials decision rules will be derived for the management of the health of soils of different properties. These data will provide a comprehensive overview of land degradation and soil quality status for different impact zones.

This output will also embrace socio-economic data and address strategic alliances and organization of the stakeholders (e.g. farmer organization). For example, part of this work will be implemented through the formation of innovation platforms, but at the same time we will evaluate innovation platform as a proper mechanism in our intervention strategy. This will be done through an action research approach and will require use of participatory monitoring and evaluation techniques. Communities and stakeholders are involved with all the SLM project activities in the various impact zones to link research to development, but different strategies are applied. The SLM program will draw lessons learned from these different approaches to improve our intervention strategies and to enhance impact of our research within the various impact zones.

The SLM Program will work closely with the Decision and Policy Analysis Program on methodological issues related to studies of ecosystem services, and some of this work should overlap with the Amazon Ecoregional Program.

Impact Pathway: The impact pathway for Output 2 is similar though more focused on raising awareness and action preparedness. For the implementation of programs on the ground detailed information is needed and

possible interventions (introductions of technologies) need to be considered within the wider context of the production systems and in production of alternative systems within the context of the production landscape. An area-wide approach is often required and interventions have often failed because technologies have been viewed in isolation or particular farming systems have been targeted without looking at opportunities for efficiency gains using an area-wide approach. This output aims to address this constraint by providing a systematic way for characterizing and diagnosing the production environment and for identifying and evaluating interventions options considering various technologies and alternative systems at a landscape level.

Detailed data and information on status of land degradation on a continental scale (that AfSIS will provide) will be of enormous value to better predict the impact of climate change, to assess environmental impacts of land use change, to study potential for agricultural development, etc. This information will enhance the awareness of the magnitude and urgency of the problem of land degradation and will increase the willingness to take action. The accurate diagnosis and understanding of causes of land degradation and declining yields, the constraints and opportunities for SLM will contribute to better targeting of investments and finally the evaluation of alternative intervention strategies and options, the improved assessment of risks and changes of success will help to organize stakeholders and define a common cause. In the end, the decision making process is improved and the planning and targeting of interventions is improved. Again platforms will be the main vehicle through which the interventions are planned and through which we aim to enhance the cohesion and integration of the intervention form the various actors and stakeholders. This will greatly help the cause of the rural poor, to enhance their livelihoods and improve their environment. The creation of the right platforms to address these issues at local, national and international level will be critical though for its success.

4. LATIN AMERICA & THE CARIBBEAN RESEARCH AREA

Following the recommendations of the recent EPMR, responding to the interests of partners, for example, as expressed in FORAGRO, and refocusing on its roots and particular comparative advantages within the CGIAR, CIAT will pursue eco-efficient agriculture on an ecoregional basis, working in high-priority sub-regions of LAC, many of which have strong similarities with regions in Africa and Asia. LAC's extraordinary biological, climatic and socioeconomic diversity especially favor a focused effort to enhance agriculture's eco-efficiency.

An ecoregional approach in international agricultural research is consistent with expressed needs and demands within LAC. During recent months, CIAT has consulted with a large and diverse group of actors from both public and private sector organizations across the region. This involved formal discussions with many partner institutions in our host country, Colombia; with other major national partners, such as the Brazilian Agricultural Research Corporation (EMBRAPA); and with key regional entities, including the Center for Tropical Agronomic Research and Higher Learning (CATIE), the Forum for Agricultural Research and Development in the Americas (FORAGRO), the Inter-American Development Bank (IDB) and Inter-American Institute for Collaboration in Agriculture (IICA).

The information CIAT gleaned was highly diverse, but it conveyed a number of clear messages about the role and strategic directions of international research. To begin with, partners called on CIAT to operate more closely with existing research capacities in the region. In 2006 there were 19,000 full time agricultural researchers in LAC. Partners see a potential for CIAT to become a regional technological platform, working with the strong national programs for common regional objectives that are widely shared.

They called on the CGIAR to extend its crop research to include support for efforts on a wider array of crops (such as tropical fruits and biofuel feedstocks) that are important throughout the region. At the same time, they asked CIAT to continue with the conservation and improvement of beans, cassava, rice and tropical forages. In crop improvement, partners especially want to see CIAT concentrate on making biotechnology tools more accessible and more relevant to the needs of LAC. In addition, they urge the center to continue its

efforts to strengthen small farmers' links to markets. Partners consider public-private partnerships to be necessary for the success of that work, and they look to international research for the technical backstopping needed to make such partnerships effective. Recognizing CIAT's past experience in NRM research, partners in LAC also requested a heightened emphasis on environmental services, including carbon sequestration, biological nitrogen fixation and provision of clean water.

In general, partners expect the center's research agenda to respond flexibly to regional needs and to closely match regional priorities. They also recognize, however, that many of their own priorities fit well within the wider agenda of the CGIAR, including its major efforts in Africa. CIAT will need to respond to the region's diverse demands through an innovative approach that pursues research on a variety of crops, while also helping achieve a more competitive, market-oriented small-scale agriculture and more sustainable management of the region's biodiversity and other natural resources, drawing on global links and experience.

In pursuing a renewed ecoregional role, CIAT will have to come to terms with two important institutional developments in LAC's agricultural research systems. First, to reverse the erosion of research capacity that has taken place in some disciplines and countries over the last decade or more, the center needs to assist – and LAC partners welcome its assistance – in creating a whole new generation of agricultural scientists. Second, CIAT must address the striking duality in public sector research that has emerged during recent years, with a few countries (notably Brazil and Mexico) possessing strong research systems, while in a larger number research capacity has deteriorated as resources for this work have dried up. To implement a full agenda of research for LAC, it will be important to explore new roles for large national systems and to strengthen networks that meld large and small into a coherent ecoregional framework. There is recognition that regional funding sources, for example, FONTAGRO and IDB, will have to be tapped in order to fully resource these important initiatives.

An important step in developing an eco-regional research strategy would be to hold a regional meeting to identify priorities and partnerships between national innovation systems and not just CIAT, but the broader CGIAR. This meeting would aim to reach agreements to formulate projects and jointly identify investment resources. FORAGRO has expressed interest in convening such a meeting.

LAC1: Rice Program

Rice is the leading food staple in South America and the Caribbean. While most of the world's rice is produced in Asia, which is home to IRRI, in LAC there are unique pests and diseases, as well as distinct grain types and cropping systems that require regional development of germplasm. The demand for rice in LAC is growing, and the region's abundant land and water resources give it the potential to be a growing supplier of rice to the world. During 1990-2004 rice production in LAC expanded annually at 3%, much higher than in any other region. Rice is grown under diverse agro climatic/soil conditions and production systems and the crop is subjected to diverse biotic and abiotic stresses, different from Asia and Africa. Mainly medium to small resource-poor farmers predominate in Central America and the Caribbean, and in the northern part of South America; some medium to large mechanized farms are found, especially in the Southern Cone. Therefore, there is a need to develop germplasm and technology appropriate for diverse type of rice production systems and different breeding strategies and rice materials are needed.

Eco-efficient rice production systems, with high productivity and low impact on the environment are critical for the future. There are opportunities for growth in the rice sector in LAC. Recent data collected by FLAR in several countries indicate that by using better agronomic practices and improved varieties farmers are getting 1-2 ton/ha more of rice lowering production cost/ton of rice. Global temperatures, particularly night-time temperatures, have risen steadily in recent decades, whilst climate models for LAC are predicting 2-3 C increases in mean temperature and greater variability in rainfall distribution. Rice lines with improved water-

use efficiency and more resilience to temperature changes will be the Rice Program contribution to adapting to climate change.

Through different breeding strategies, and use of biotechnology tools that allow the incorporation of traits more efficiently, CIAT is generating both segregating populations and advanced lines. These are transferred to partners through CIAT's nurseries, FLAR, GRUMEGA, AgroSalud, and INGER. 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.

The Rice Program conducts research that is complementary to research carried out by both IRRI and WARDA especially in the development of breeding populations via the utilization of wild rice species through the Generation Challenge Program. We are focused on the utilization of *O. rufipogon*, *O. glaberrima*, *O. barthii*, *O. meridionalis* and *O. latifolia* as sources of yield potential, grain quality, resistance to RHBV and its vector *Tagosodes*, blast, *Rhizoctonia*, rice necrotic virus, and the nutritional quality of milled rice. Interspecific breeding lines and populations are shared with IRRI and WARDA. CIAT also played a complementary role in the interspecific hybridization project led by WARDA that resulted in the development and release of NERICA lines. Complementarities, collaboration and linkages are further analyzed, discussed and fine tuned via the WARDA/IRRI/CIAT programmatic alignment.

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, and rice lines that are developed at CIAT enter into the public domain as international public goods. One of the most relevant and important products of the CIAT Rice Program 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 are 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. Additionally, the adaptation and use of biotechnology tools in rice breeding programs by our partners will add another strategic dimension to products coming out of the CIAT Rice Program.

Outputs

The main significant changes affecting the Rice Project are related to the new CIAT organization where some research activities were eliminated or consolidated. The previous IP-4 Rice project is the new Rice Program "Improved Rice Germplasm for Latin America and the Caribbean". This Rice Program has three main Products: 1- Rice Germplasm for Improving Human Health and Nutrition in LAC; 2- Enhanced Gene Pools for Irrigated and Upland Rice in LAC; 3- Genotypic and Phenotypic Platforms for Rice Enhancement. The previous output 1, "enhanced gene pools", include pre-breeding activities for both irrigated and upland rice as well as collaborative activities with FLAR; many activities of the previous output 2, "integrated crop, pest and disease management", were eliminated while others consolidated into Product 2. The previous output 3, "intensification and diversification of rice cropping systems for small farmers", was eliminated. Two new Products, "Rice germplasm for improving human health and nutrition in Latin America", and "Genotypic and Phenotypic Platforms for Rice Enhancement" were added.

From 2008 onward, core resources for the rice research activities have been significantly reduced. The strategy is to complement and strengthen the CIAT-FLAR platform with other institution(s) to attract more attention and funding via special projects. These changes are reflected in the consolidation or elimination of several of the Output Targets.

***Output 1*: Rice germplasm for improving human health and nutrition in Latin America and the Caribbean**. People living in areas where rice consumption is high (Haiti, Nicaragua, Bolivia, Panama, Dominican Republic, Colombia, and rural Brazil) are suffering from a number of major nutritional problems. Women and children are especially susceptible to deficiencies in micronutrients, particularly vitamin A, iron and zinc. As a result, they are at risk of disease, premature death, lower cognitive capacity, and poor quality of life. The costs of these deficiencies are high and economic and health indicators in LAC are deteriorating. Biofortified rice lines will be Rice Program's contribution to combat malnutrition in LAC through the development of and deployment of high iron and zinc rice lines. Research carried out at IRRI suggests that there is genetic variability in the rice genome to increase iron and zinc in the rice grain. It has been reported that consumption of biofortified rice, without any other changes in diet, is efficacious in improving iron stores in women with iron-poor diets in the developing world. We plan to develop rice lines having 6-8ppm of iron and 22-25ppm of zinc in milled rice using different breeding strategies. Progress made is good and some varieties with improved nutrient content, high yield potential, tolerance to main diseases and pests, and good grain quality will be released soon.

Impact Pathway: This product is concerned with the development of high iron (6-8 ppm) and zinc (22-25 ppm) rice lines to combat malnutrition in LAC. Final intended users are urban and rural consumers, especially poor sectors. Improved rice germplasm as an instrument for improving human health and nutrition as well as for increasing productivity will benefit the poor people in Latin America (40% of LAC's population). Nutritionally improved staple food will provide an inexpensive, cost-effective, sustainable, long-term means of delivering micronutrients to the rural small resource poor farmers and the urban resources poor consumers. This project is carried out in close partnership with research institutions in Colombia (FEDEARROZ), Bolivia (CIAT-Bolivia, and ASPAR), Cuba (IIA), Brazil (EMBRAPA), Dominican Republic (IDIAF), Nicaragua (INTA and farmer's associations), and more recently Panama (IDIAP). Breeding material is evaluated for iron and zinc and selected ones are sent to AgroSalud's partners for local testing. Our partners, whom operate based on a network of germplasm exchange and participatory breeding activities in the region are in charge of testing, evaluating, multiplying and distributing seed of biofortified rice lines, and in collaboration with local nutritionists and socio-economists will estimate the benefits of the technology on the improvement of human health and nutrition as well as on increasing the productivity of rice and farmers well-being. Finally, lines with increased iron and zinc content will be named and release locally by our partners in AgroSalud.

***Output 2*: Enhanced Gene Pools for Irrigated and Upland Rice in Latin America and the Caribbean**. The genetic base of both irrigated and upland rice in LAC is very narrow. To increase the genetic diversity of rice, we use different breeding strategies, including interspecific crosses, composite populations, introgression and recombinant inbred lines, and we are developing biotechnology tools that allow the incorporation of traits more efficiently. Wild species are valued as a unique source of genetic variation; however, they have rarely being used for the genetic improvement of quantitative traits. Since 1994 the CIAT Rice Program has been characterizing and utilizing wild rice species. The strategy in place makes use of molecular maps in combination with backcrossing to elite breeding lines or commercial varieties to develop populations that are used to identify and transfer quantitative trait loci (QTLs) associated with traits of agronomic importance to cultivated rice. Results to date indicate that several traits of agronomic importance, including yield and yield components, and tolerance to biotic and abiotic stresses, have been transferred from *Oryza rufipogon*, *O. glaberrima*, and *O. barthii* to improved rice cultivars. More recently, *O.glumaepatula*, *O.meridionalis* and *O. latifolia*, a tetraploid wild species from Latin America carrying the CCDD genome, are being used. A crossing program to recombine desirable agronomic traits identified in elite lines derived from diverse interspecific crosses (introgressions and recombinant lines) is now underway.

Broadening the genetic base of rice is also conducted through the development of synthetic rice populations using recurrent selection. Recurrent selection methods contribute to meeting the goals for continuous genetic improvement by assessing genotype x environment interactions to identify specific potential parents and pooling then to create site-specific synthetic rice populations with a broader genetic base. Through short cycles of selection and recombination, linkage barriers are broken down and favorable genes are

accumulated. This is a smooth process of continuous improvement. These activities for rice improvement are carried out in close collaboration with partners in LAC via the REDMEGA network. The CIRAD-CIAT team started developing basic populations targeting the various rice ecosystems present in LAC, in partnership with scientists in Colombia, Venezuela and Cuba for the tropical ecosystem; Argentina for the subtropics; and Chile and France for the temperate zone. These populations are shipped to regional partners and evaluated locally. A marker-assisted selection program for recurrent selection will further improve the efficiency of the method.

Impact Pathway: The objective is this product is to develop enhanced gene pools for both irrigated and upland rice, which are made available to our partners by different means. In the late 80s CIAT made the decision not to name and release rice varieties but left this decision to NARS. So the impact pathway depends entirely on the local evaluation, testing and selection of the breeding nurseries (CIAT-ION) that are prepared and sent to our collaborators every year, based on local demand. Our breeding lines are used as progenitors in further crossing by national rice breeding programs. In some cases these lines are released as commercial varieties after further selection, purification and seed multiplication. Typically this process takes 10-12 years after receiving the CIAT-ION nursery. The CIRAD-CIAT team set out to develop collaboration with rice breeders throughout LAC and took the lead in creating and sharing synthetic populations and providing training through the Working Group on Advanced Rice breeding (GRUMEGA). Improved populations are shared with regional partners and evaluated locally. Most of the cooperators use this material to develop site-specific populations by introgressing additional variability to meet their specific breeding objectives. They then use these populations in their rice-improvement programs by recurrent selection. Recurrent selection is an activity that has been promoted through the GRUMEGA network. During the last 10 years, it has held many Rice Breeder Workshops and many local partners get populations and advanced rice lines from these activities. We are 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 also a valuable source for germplasm exchange and enhancement as well as other forms of collaboration. Again, our regional rice partners are responsible for the release of varieties, which is the main impact of this Product 2. A very high percentage of the new rice varieties contain CIAT germplasm. The request for germplasm is highly variable (early segregating or advanced/fixed lines, parental lines) and depends on the production constraints affecting rice, and rice production systems used in a given country. In general, the smaller rice producing countries need advanced materials. The larger rice programs use germplasm and segregating populations to make their own selections. At the end, our impact will be measured by an expected increase and more eco-efficient rice production in LAC, with improved rice competitiveness through lower production costs and higher yields.

Our pathway to impact is a framework for collaborative research built on five pillars: (i) capacity building, (ii) germplasm development and sharing; (iii) workshops for germplasm evaluation and selection, (iv) conferences to present results and advances, and (v) publications with and by collaborators.

***Output 3*: Genotypic and Phenotypic Platforms for Rice Enhancement**. Rice production faces the difficult challenge of obtaining reliable yields under variable conditions, notably due to the prevalence of biotic and abiotic stresses exacerbated by climate stresses. Numerous genes of economic importance are transferred from one varietal background to another through conventional breeding approaches, a time –consuming effort. Sometimes, screening procedures are cumbersome and expensive, and require large experimental area. Molecular biology is one of the key tools for generating more scientific advances that may not only reduce hunger and malnutrition in developing countries but also to contribute to an eco-efficient rice production. The entire genetic makeup of rice has been decoded, and more than 15,000 SRMs markers are available in rice, which allows us to tag genes of interest by tight linkage with molecular markers saving time and money, thereby increasing the efficiency of the breeding process. This approach, called marker-assisted breeding, has already been implemented in developed countries, but a large cadre of trained scientists and plant breeders working in developing countries will be required to reap the benefits of crop genomics. CIAT's scientists are using genetic engineering including transformation to transfer genes associated with desirable crop traits into elite lines or successful commercial varieties. A lot of molecular data have been generated at

CIAT in rice on different agronomic traits, including an anchor marker map, several mapping populations, a field phenotyping platform and transformed rice lines carrying DREB-gene associated with drought tolerance. CIAT has permission from the Colombian National Biosafety Committee and excellent biosafety and field facilities for the generation and testing of transformed rice. Lines with better water and nitrogen-use efficiency will allow savings in water and fertilizer costs.

Increasing the yield potential is one of the most challenging goals of current rice research. For many years conventionally-bred rice varieties could not make significant improvements in grain yield. Hybrid rice has done it in China and it is slowly expanding in other parts of the world. Some limited efforts in hybrid rice have been going on in LAC, but they lack the necessary dimension to success. CIAT could play a decisive role in creating a strong partnership with IRRI and regional partners, by developing an independent hybrid rice consortium for LAC.

Impact Pathway: This product relates to activities in biotechnology that were housed in the CIAT Biotechnology Unit but that were conducted in close collaboration between rice scientists in the IP-4 rice project and the SB-2 project. The main objective is to integrate biotechnology tools available at CIAT and advanced institutions collaborating with us into the rice breeding program, especially via marker assisted selection and genetic engineering. Our pathway to impact will be similar to those already describe in Product 2, mainly through: (i) capacity building, including sharing of methodologies, databases, and software, (ii) development and sharing of genetic and breeding tools; (iii) workshops for germplasm evaluation and selection, (iv) conferences to present results and advances, (v) publications with and by collaborators, and (vi) collaborative research projects with strategic partners on activities of common interest.

LAC2: Tropical Fruits Program

Cultivation of high value commodities with growing demand offers great economic opportunities for smallholder farmers. Rural employment and better profitability of farming systems have been associated with the production of High Value Agricultural Products (HVAP). HVAP, defined as '*crop, fish, livestock or non-timber forest products that return a higher gross margin per unit of available resources (land, labor, capital, human capacity) than other products within a given location and context'* describe very well the characteristics of Tropical Fruits. More than 1100 species produce edible fruits in the LAC region, many of them with established and growing markets. Therefore fruits, as well as other high value crops, offer an alternative for crop diversification and a real opportunity for income generation. The opportunities for income generation are challenged by diverse constraints that vary from one region to another depending on the species of fruits, the agro-ecological and market conditions, political will and infrastructure.

With rapid urbanization in the tropical countries providing powerfully growing internal demand, as well as the globalization of economies and growth of global food markets, the prospects for tropical fruits are excellent. This trend represents an opportunity for small scale smallholders who often have competitive advantages of an ability to more intensively manage small land holdings as well as access more productive lower cost labor.

However, this opportunity for family farmers is limited by multiple challenges that need to be addressed, both on the production and on the marketing side. Indiscriminate and excessive use of pesticides, with the subsequent build up of undesired residues, become a barrier for accessing markets, and jeopardize the nutritional benefits of Tropical Fruits as a vehicle to supply vitamins and minerals to the poor. Sustainable production practices with minimum ecological footprint are required and need to be developed jointly with grower communities and local regulatory institutions.

Another critical challenge is limited organizational skills, inappropriate market access and lack of capacity to respond to changing market demands. 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, market dynamics 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 farmers more competitive, productive, and sustainable. Public and private policies become strategic elements to develop inclusive business models that consider smallholder growers in the rural development scheme.

Within this context the mission of the tropical fruits program at CIAT is "*Improve the competitiveness of smallholder producers of tropical fruits and service providers through information and technologies that result in more sustainable production practices and systems, better access to markets and increased household income*"

The research agenda of the Program has taken into consideration the eight primary issues identified through a Global Assessment of the Horticultural Sector: (1) access to markets, (2) post-harvest deterioration and food safety, (3) genetic resources conservation and development, (4) sustainable production systems and natural resource management, (5) capacity building, (6) enabling environment, (7) gender equity and (8) nutrition and human health. Our research outputs will address some of the issues.

The Tropical Fruit Program can only be effective in reaching its goals of improving the welfare and increasing the incomes of rural communities by working with local partners: our success is dependent not only on our efforts but also on being able to find effective partners willing to work with us. CIAT will continue to build bridges among countries in the region to exchange information and knowledge related to biophysical and social aspects that result in the successful development of the fruit industries, and have had impact in the rural population. CIAT's role is critically important for a regional strategy in Tropical Fruits. Due to its effect on income generation and, in some cases restricted export market size, the willingness to exchange information among countries is not always present and needs to be constructed. The Tropical Fruits Program will continue to develop a strategic core research business built upon regional needs and aligned with the findings of the Global Assessment, as well as applied research as demanded by local partners and development organizations. Linkages to the CGIAR Ecoregional Program for the Amazon will be a central part of program efforts.

International Public Goods. Tropical fruits outputs are biophysical and knowledge-intensive innovations (methods, tools, good agricultural practices) which are derived from both lessons learned across regions, locations and crops, as well as from direct laboratory experimentation. Publications of research outputs will be our main IPGs. However, adaptation and application of research findings will be done on a case by case basis by partner organizations, including NARs, producer organizations and development bodies. CIAT aims to participate in such adaptations and use that opportunity as a co-learning strategy to refine our understanding of the products to maximize impact of our products. Intended users of our products will be donors, policy makers, rural development institutions, NARS, University researchers and the private sector. Alliances with the private sector will be critical for broadening product adoptability.

Outputs

The Tropical Fruits program was formed in 2001 to respond demands from stakeholders of the LAC region, and hosted by the Agrobiodiveristy Research for Development Challenge (RDC). In 2007, due to organizational changes it was moved to Agroecosystems Research for Development Challenge under the outcome line of Markets, Institutions and Livelihoods. In 2008 Tropical Fruits merged with the group of Rural Agroenterprise Development and with The Institute of Participatory Research in Agriculture to form the Outcome Line Linking Farmers to Markets. The new strategic directions for CIAT include a Tropical Fruits Program as part of the strategy for LAC, again, in response to multiple consultations with regional stakeholders.

Operationally, the Tropical Fruits Program will remain as a platform where the biophysical and the social sciences will naturally meet to create solutions that address identified problems of the fruit sector. Products to be generated by the Program emerge through a sequence of steps initiating with needs assessment for

product targeting and design, product development, production system analysis, pathways for reaching end users and impact assessment.

***Output 1*: Technologies for improving the competitiveness of smallholder tropical fruit producers.** The focus of this output will be on the development of technologies for propagation of planting material and characterization and optimization of production systems.

Little, if any, breeding has occurred in many of the tropical fruit species in the developing countries. Small farmers producers are planting material which is accessible to them, but which is either not suitable to their locations nor does not comply with market demands. Therefore, we will use participatory selection processes for identification of elite clones with consumer demanded characteristics. The methodology for participatory selection will built on existing CIAT's skills in this area, but in direct cooperation with local partners; through this interaction we are also strengthening their capacity to implement such approaches in Tropical Fruits. Examples using Naranjilla (*Solanum quitoense*) and Andean blackberry (*Rubus glaucus*) will be considered to draw lessons and learn from these processes. Introduction of elite clones that comply with market demands and, when possible, bearing disease resistance will have a very significant impact in human health of growers and consumers alike, and will result in implementation of good agricultural practices that will facilitate access to international markets.

Methodologies for clonal propagation of elite materials need to be developed, optimized, and transferred to either farmers groups or commercial nurseries. The clonal propagation will be done either through conventional horticultural methods (i.e. Avocado, plantain), or through tissue culture technologies when phytosanitary risks demand such approaches (i.e. coconut, naranjilla).

Smallholders Tropical Fruit production systems are seldom monocropping but typically cultivate multi- strata cropping systems, including agroforestry. Tools for rapid analysis of feasibility, and design of fruit production systems, combined with identification of ecosystem services (carbon sequestration, control of soil erosion, water quality, biodiversity) will be developed. Products emerging from such systems will bear non-tangible characteristics that will facilitate access to emerging niche markets. Modeling tools will be built using naranjilla, Andean blackberry and peach palm as examples of agroforestry like production systems. Development of these tools will facilitate bridging collaboration with other Programs, including the Ecoregional Program of the Amazon Initiative.

Impact Pathway: The nature of the products derived from this output will be useful to many stakeholders, including NARs, local nurseries, local and international development NGOs and farmer organizations, and research institutions.

In the case of elite clones selected through participatory methods, farmer organizations and NARs will be responsible for keeping the germplasm, with assistance from CIAT regarding effective propagation methods to secure the genotype. Methodology, either through tissue culture or vegetative propagation will de developed at CIAT and shared with relevant stakeholders. CIAT will prepare publicly available booklets that will be posted on CIAT's website for interested parties to downloaded. Also, CIAT will be prepared to receive visitors for hands on training when the methodology has been developed on site; however, it is envisioned that partner organizations will be co- sharing the development of the technologies. Farmers and farmer organizations will receive the benefits through facilitated access to elite germplasm, which could be accessed from local nurseries or directly from agro-business developed by the farmer organizations per se.

***Output 2*: Policy guidelines and innovations to ensure pro-poor and equitable supply chains in the face of a highly dynamic world.** Although smallholder farmers may have competitive advantages in production, and although there is a growing demand for tropical fruits both , from domestic urban populations and also from new or more accessible export and niche markets, smallholders often face competitive disadvantages in the marketing chain that need to be overcome for them to benefit from new market opportunities.

Market access, presents different challenges fro smallholders for domestic and export markets; for supermarket chains, and niche versus traditional export commodities. Many factors determine the bargaining power of smallholders, including the quantity, quality and competitiveness of their supply, and the confidence in their reliability held by those further along the value chain. Wholesalers, processors, transporters, retailers and consumers manage by their own quality criteria. A key research question is how to build and sustain customer support for products that promote development. To effectively answer this question, it is important to take a cue from simple businesses that work very well. Research can help answer the question of how best to leverage market linkages to achieve growth for diverse members of rural communities and make small farmers attractive partners to large buyers.

Discrete products will include protocols for diagnosis and selecting germplasm based on market signals, and tools for assessing benefits, costs and risks of targeted fruit species, improved knowledge management and an understanding of the mechanisms that govern effective supply chains. Mechanisms to link farm enterprises into the agri-food chain in a more equitable manner will be identified and validated with development partners, private sector buyers and public sector organizations in Latin America.

Sustainable supply chains linking smallholders and key corporate buyers will be catalyzed, evaluated for equity, gender and environmental effects, and appropriate lessons out scaled through links with business partners, development and donor agencies in Africa, Asia and Latin America. A guide to improved knowledge management and innovation in agri-chains for linking smallholder farmers into higher value markets will be developed and validated. This research will draw heavily on the work of the CIAT Program on Decision and Policy Analysis.

Impact Pathway: Working closely with development NGOs, local governments and large private enterprises strategies for streaming value chains, the strengthening of farmer organization to assure sustainable smallholder participation in value chains will be out scaled. When available, public documents will be posted in CIAT's and partner's websites for other to access, share and use it.

***Output 3*: Technologies for management of diseases and pests.** Disease and pest control amounts to almost 50 to 60% of the production cost in many tropical fruits. Due to biological pressures (pests and diseases) on their crops, farmers rely heavily on use of inorganic chemical control methods that induce resistance in pests and pathogens making damage from pests even greater and more difficult to control. Moreover, chemical residues reach an inacceptable level in fruits both for human health and the environment.

Disease management components and strategies will be developed for tropical fruits, particularly the model crops of naranjilla, Andean blackberry, plantain and avocado targeted by Output 1 above – and in close collaboration with work on that output. Testing disease resistance inducers, and development of biopesticides will be part of the strategy to reduce the indiscriminate use of inorganic chemicals

Access to new domestic and international markets will be seriously jeopardized unless production practices are improved, including reduced use of crop protection chemicals. Those limitations are the rule rather than the exception in developing countries, and therefore local governments, and the private sector are pressing national research organizations to develop phytosanitary strategies to overcome quarantine limitations imposed by importing countries. However, expertise and state of the art technologies for proper pests and disease agents identification are often lacking, or could be strengthened where they exist. CIAT aims to build a regional platform for diagnostics of major pests and diseases affecting tropical fruits. Services demand from the academia, NARS, local sanitary regulatory bodies and the private sector are becoming more prevalent and offer an opportunity for a more strategic development of a regional platform built through regional partners.

Impact Pathway: Products and information generated in this output have direct relevance to farmers and researchers alike. Delivery of the outputs will occur through different venues, according to the stakeholder. Participation in scientific venues and publication in peer review journals will target researchers. Booklets

containing more applied approach of the scientific information will be prepared and made available to NGOs, farmer organizations and phytosanitary authorities through web based technologies. When feasible, co-development with farmers participation will be encouraged and implemented, increasing the likelihood of technology adoption.

LAC3: Amazon Ecoregional Program

The Amazon Ecoregional Research Program (a CGIAR Systemwide Program posted by CIAT) faces the challenge of contributing to research and development interventions that concurrently meet the short- and long-term needs of environmental conservation and the well-being of local populations. This program will support the identification, development and dissemination of sustainable land use systems that avoid further deforestation and support governments and civil society in their goals related to human welfare, environmental services, and improved governance. While CIAT is the host institution of the CGIAR Ecoregional Program that operates under the overall umbrella of the Amazon Initiative, Bioversity, CIFOR and ICRAF are full participants in the Amazon Ecoregional Research Program along with national program partners.
The Amazon Ecoregional Research Program addresses several key problems including poverty, greenhouse gas emissions due to land use change that contribute to global warming, and biodiversity loss. Nearly 70 million ha of Amazon forest have been cleared over the last 30 years, mostly in Brazil. More than 30 million hectares of Amazonian pasture have been abandoned or are severely degraded. Soil erosion from slash-and-burn agriculture has led to leaching of naturally occurring mercury into rivers, eventually concentrating up the food chain in fish consumed by humans – bringing about significant human health problems.

To contribute in addressing these key problems the Amazon Ecoregional Research Program addresses four development challenges that were collectively defined by the Amazon Initiative

Capacity building for national and local organizations is an important component for effectively implementing the above research agenda with lasting positive impacts in mind. As part of the Amazon Initiative, the Eco-Regional Research Program will in particular carry out training and outreach activities in Amazon countries to develop new capacities for research into environmental services and livelihoods to apply this capacity in regional collaborative projects. Capacity-building will be based on research activities and, during the next two years, prioritize acute training needs, as for example, in the area of incentive-based ecosystem services management and agroforestry tools.

The Amazon Ecoregional Research Program promotes the participation of member institutions of the AI Consortium in collaborative research activities implemented through the Program. The AI Consortium is a platform for collaborative research and development by institutions working in the Amazon region. Scientists and development practitioners in seven countries of the Amazon participate in the AI. Formed and led by national and international research centers, the AI fosters broader collaboration between the member organizations and civil society organizations. By early 2009, 28 institutions are members of the AI Consortium, in addition to the four CGIAR centers. Apart from working closely with AI members, the Amazon Ecoregional Research Program will strengthen alliances that are strategically linked to the four main outputs. For example, GTZ and international NGO such as TNC, will become ever more important partners with regard to output 1.

Outputs

Output 1: **Mitigation and adaptation to climate change.** The Amazon is of global importance in regulating climate change, representing a significant storehouse of carbon reserves and source of greenhouse gas (GHG) emissions. At the same time, projections show that both peoples and the biodiversity of the Amazon will be at risk as climate changes. Output 1 will work on *available options, decision support tools and policy instruments for Amazon farmers and communities to mitigate and adapt to climate change and to enhance their provision of environmental services*. In this regard, it is linked to CIAT Decision and Policy Analysis program.

Adapting to and mitigating climate change requires research for development. Mitigation research has to contribute to the design of effective and equitable strategies to reduce emissions from deforestation and degradation (REDD), enhance sinks of atmospheric carbon. Adaptation research needs to develop strategies for dealing with increasing climate risk across all sectors of the rural economy. Designing resilient land use systems and rural safety-nets can ultimately address both adaptation and mitigation objectives.

Work related to output 1 has been initiated in 2008 by facilitating the formation of a "policy value chain" that spans from policy recommendations based on region-wide stakeholder consultations, to policy and program development, and to effective and equitable policy implementation. A specific target of this output for the next two years is the co-development and dissemination of recommendations for cost-effective and equitable reduced emissions from deforestation and degradation (REDD) strategies in at least four Amazon countries.

A related target is a tool for implementing organizations (such as local and national governments) wishing to apply for national and international carbon funding, this output will develop a framework including principles, criteria, indicators and verifiers for baseline assessments and monitoring of carbon stocks to be validated through pilot locations in Amazonian countries.

Adaptation research will target the development of policy recommendations to reduce the vulnerability of local rural economy segments and selected land use systems (e.g. agroforestry, silvopastoral systems) to climate risk in Brazil and through the prediction and evaluation of climate change impacts on agroforestry species in the Peruvian and Ecuadorian Amazon.

Impact Pathway: The overall expected outcomes of work on mitigation are the adoption of appropriate sustainable land use systems (SLUS) that provide positive impacts by increasing carbon (C) stocks through increases in biomass and, eventually, in soil C; and by decreasing GHG emissions through avoided deforestation.
(1.1) Analysis of the carbon footprint of land use systems: Outputs will be methods for and the measurement of C stocks associated with different land use systems, including sustainable systems tested and developed by the AI-EP; and of GHG emissions associated with the conversion of land use systems – e.g., the conversion of forest to slash-and-burn agriculture. The expected outcomes will include the adoption of appropriate SLUS by smallholder and colonist communities in the forest margins, and achieving this is expected to have positive impacts in terms of C and decreased GHG emissions. Measurement techniques will be needed to institute PES schemes and to measure impact of the SLUS themselves.
(1.2) Development of resilient land use systems to maintain and increase carbon stocks: This work will be conducted in collaboration with Outcome Line 2, sustainable production on deforested and degraded lands. Outcomes will be systems and adoption of systems that represent C stock increases and reduction of GHG emissions due to avoided deforestation. Policy instruments will be developed and promoted in collaboration with the Amazon Cooperation Treaty Organization so as to foster this adoption. Impacts are thus the maintenance and increase in C stocks, reduced GHG emissions, and positive welfare impacts from the more sustainable systems (including PES and product market chain development).
(1.3) Development and testing of payment schemes for the management of ecosystem services (PES), including the exploration of C market opportunities: This will be a central area of innovation for the AI-EP, involving as partners CIFOR, ICRAF, NARS and other national agencies, with outcomes including adoption of schemes to reward local communities for adoption of practices that diminish GHG emissions and systems that increase C stocks; and enhanced effectiveness of organizations working on rights and compensation for environmental services. Impacts are essentially the same as those for 1.2: maintenance and increases in C stocks; reduced GHG emissions; and welfare gains to local communities via PES.
(1.4) Identification and application of international instruments that can reduce deforestation and forest degradation: This innovation area is expected to produce analyses of policy options and the promotion of a "policy value chain" that favor adoption of SLUS and of AI advocacy in support of appropriate policy instruments. The overall expected outcome of work on adaptation is adoption of appropriate SLUS that provide positive impacts in terms of people's and communities' abilities to maintain and increase their

welfare in the face of climate change. Welfare gains are expected through PES generated by adoption of SLUS and through financial gains made from product and market chain development generated from the SLUS. Impacts stemming from adoption of appropriate SLUS will again be maintenance and increase in C stocks; and reduced GHG emissions.
(1.5) Examination of current mechanisms used to cope with risk: This innovation area will provide the outcome of understanding how communities have used their traditional knowledge to face risk related to production activities. Impact will be indirect: a building block to help in the development of local and national mitigation policies and programs.
(1.6) Testing of innovative community based fire management: Accidental and uncontrolled fire will be one of the more difficult problems people will face as the Amazon dries and heats up due to CC. The AI-EP will work with communities to develop fire prevention and management methods. While less fire will mean a decrease in GHG emissions, more important will be maintenance of the productive systems on which communities' livelihoods depend.
(1.7) Testing of adapted germplasm and land use systems (in collaboration with Outcome Line 2): The outcome of this innovation area will be critical to success: development, testing, and adoption of appropriate SLUS that are adapted to the future hotter and drier conditions of the Amazon. More drought and heat adapted crops, varieties, and products will be needed. Successful germplasm development and systems adoption will have the positive impact of sustaining the livelihoods of the peoples of the Amazon.
(1.8) Work with local and national governments on appropriate adaptation programs: The AI-EP will have to work closely with local and national governments as they develop programs and policies to help those negatively affected by CC. Outcomes will be that local and national governments formulate and then enforce programs and policies that lessen the negative effects of CC on Amazon communities. The impact would again be the maintenance of livelihood systems on which the peoples of the Amazon rely.

***Output 2*: Adoption of sustainable land use systems in deforested and degraded areas.** Systems and technologies for sustainable production (or sustainable land use systems, SLUS) in deforested areas of the tropics have been developed in recent decades, e.g. improved, legume-based pastures, multistory agroforestry systems, small-scale timber plantations, silvopastoral systems, secondary forest management, and improved fallows. These technologies offer the possibility of harnessing the Amazon's underutilized interspecific and intraspecific genetic diversity – a possibility favored by increasing awareness and concern for environmental issues among politicians, policy-makers, consumers and producers; new markets for previously untraded goods (environmental services); consumer interest in niche and novel products; and more accessible markets at national levels (due to infrastructure improvements) and international levels (due to removal of trade barriers). Currently, the adoption of SLUS is limited by a series of constraints: poor targeting; lack of germplasm insufficient quantity and/or quality or at accessible prices; market limitations, including but not limited to the lack of development of markets for environmental services; the combination of free access to forest frontiers and insecure land tenure; and lack of supporting systems (technical support, credit).

Output 2 will work on improved management and technical options, decision support tools and innovative institutional arrangements to allow Amazon farmers and communities to adopt Sustainable Land Use Systems (SLUS) for enhanced ecosystem services provision in deforested and degraded areas.

Research and development have produced the building blocks of sustainable land use systems. Technological innovations may well be a part of appropriate future sustainable systems. Such innovations, however, need to be adapted to particular conditions and geographical areas. For innovations to be successfully disseminated, local key constraints to adoption need to be identified through participatory natural resource management research. Such research must contribute to targeting related policies and institutional arrangements. Incentive-based policy approaches can contribute to the adoption of sustainable land use, but must be designed properly to integrate with existing policies and avoid adverse side effects.

Adoption of many SLUS depends on available seed or germplasm for multi-purpose trees, forages, legumes, and crops. As one of its priorities, the Program will develop improved germplasm for a selection of Amazon

agroforestry (fruit and timber tree) species through participatory domestication, and disseminate them to farmers through enhanced germplasm supply systems and improved agronomic techniques. This work will be led by ICRAF.

Targeted project and policy design requires knowledge about the temporal and spatial distribution of ecosystem services, the feasibility of project and policy implementation, as well as the benefits that local populations and the society can derive from them. The Amazon Ecoregional Research Program will contribute to harnessing the value of publicly available spatial information on management options for SLUS and for enhanced provision of ecosystem services by developing an online interface for the analysis of spatial data according to regional research priorities. This target will be jointly developed with the CIAT Decision and Policy Analysis program.

Impact Pathway: Outcome Line 2 will primarily operate at national and sub-national level, with impacts at all levels. At the local level, i.e. in priority intervention zones, we envisage the following outcomes:
(2.1) Selection and adoption of SLUS and implementation of appropriate adaptive research.
(2.2) Improved germplasm supply; initiation of programs based on improved national technical capacity.
(2.3) Local policies (e.g. at state and regional government levels) formulated or reformulated.
(2.4) Innovative reward for environmental services schemes instituted.
(2.5) New practices and approaches to dissemination and scaling-up adopted.

The outcomes listed will produce the following impacts at local and national levels:
- Land use systems that prevent and reverse environmental degradation and that sustain environmental services; and
- More resilient livelihoods, including more stable incomes and greater food security.

At regional and global levels, in addition to the aggregate of the local and regional impacts, the following emergent impacts will be produced:
- Enhanced biostability of Amazonian ecosystem;
- Reduction in global levels of greenhouse gas emissions.

The achievement of these outcomes and impacts would also rely on the broader AI Consortium (i.e. as distinct from AI-EP) adding an explicit policy advocacy and dialogue component to its remit.

***Output 3*: Enhanced benefits from forests for livelihoods and the environment.** Forests and forest resources provide livelihoods for current forest dwellers and a temptation for loggers, ranchers, and perhaps future biofuel crop producers. Much of the Amazon forest is populated by indigenous and traditional populations and agricultural settlers with different degrees of dependence on forest resources. Increasing the direct benefits derived from forests by the local population is an important step towards reducing its loss. The challenge faced by the Amazon Ecoregional Research Program will be to add value to standing forests by supporting forest dependent local livelihood strategies and related policy programs through targeted comparative research and regional knowledge exchange.

Output 3 will work on assessment methods and decision support tools to enhance benefits from forests for the livelihoods of Amazon smallholders and traditional communities and to the environment. This work will be led by CIFOR.

Multiple-Use Forest Management (MFM) has been envisioned as a promising and more balanced alternative to timber-dominated strategies of forest use. However, in practice, it is not a dominant strategy and is often a marginal activity in forest sectors. Under the right conditions MFM could diversify forest use, broaden forest productivity and provide incentives to maintain forests. The Amazon Ecoregional Program, in partnership with other national and international organizations, will conduct a basin wide assessment to identify how MFM has been promoted or hindered and describe the factors leading to the observed outcome. Among other

outcomes, this effort will provide recommendations and strategic future steps for policies and approaches to promote MFM.

Impact Pathway: The "forest" Outcome Line will provide outcomes at the sub-national, national, and regional levels; and impacts at all levels from local to global. Several outcomes and impacts of the three sub-components are expected.

The sub-component working on the potential of underutilized forest species and populations will have the outcomes, first, of the dissemination of appropriate forest seed and germplasm; and of associated needed knowledge for the management of such germplasm; and, second, of the marketing of a wider range of forest products. The expected impacts of use of underutilized forest species would be greater income stability resulting from greater marketed product diversity; and increased income of forest resource users.
The sub-component of multiple and diversified forest use and management seeks the outcome that stakeholders recognize and support such management. In this case, stakeholders are policy makers, NGOs, foresters/forest managers, and end users. Impacts would be the maintenance of environmental services in terms of biodiversity and carbon stocks; and improved, more stable livelihoods of end-users.

A third sub-component would examine the issue of resource access and use. Outputs would be innovative systems that build on the traditional use rights of forest communities in the establishment of more formal land tenure and resource access rights. The expected outcomes would be increased and improved stewardship of forest resources and lands by local communities; and such stewardship would be expected to maintain and enhance the provision of environmental services.

***Output 4*: Fair, financially attractive market value chains for Amazon products.** Research for development will focus on removing constraints and identify opportunities for the development of new and existing value chains of Amazon products. This will involve research on product development and diversification as well as on benefit distribution in Amazon value chains. Products from forests and from deforested or degraded lands have the potential to improve the welfare of Amazon communities if appropriate products can be identified and developed, if seed and germplasm systems can be established, and if market value chains can be developed. Integration of such products in sustainable land use systems (SLUS) can have positive impacts in terms of environmental services. Output 3 will work with this market innovation focus to develop products (e.g., tropical fruits and fruit products, non-timber forest products, agricultural outputs, sources of bio-fuels and seed and germplasm needed in SLUS and systems (e.g., forest, agroforestry, agro-silvo-pastoral) to produce those products. The central area of concern for this output will be establishing innovative, successful ways to facilitate market value chain development, with close links with Bioversity and CIAT's Tropical Fruits program.

Output targets over the next two years include the generation of a focused approach for value chain development for the realization of the economic potential of Amazonian fruit tree and non-timber forest products, specifically for peach palm (*Bactris gasipaes*), aguaje (*Mauritia flexuosa*), camu-camu (*Myrciaria dubia*), cupuazu (*Theobroma grandiflorium*) and ungurahui (*Oenocarpus bataua*). In 2011 it is expected to develop best practices for improved knowledge management and innovation systems for enhanced participation of Amazonian poor and vulnerable smallholder communities in agro-enterprises exploring new products developed from these selected Amazon fruit tree species.

Impact Pathway: (4.1) Identification, ex ante impact analysis and targeting of potential products, especially but not limited to high value crops: Outputs are to include identification and characterization of potential products, spatial and socio-economic targeting of geographical areas, communities, and expected markets, and ex ante impact analysis. Impacts will be positive in terms of welfare if successfully developed, targeted, and marketed; and if positive investments in failures are avoided.
(4.2) Product development and seed and germplasm management: Outcomes will include product development, including domestication and selection, and development of appropriate seed and germplasm

systems. Positive welfare impacts will be obtained as new, marketable products are developed and if people have access to affordable needed seed and germplasm (and if market value chains are successfully developed, below).
(4.3) Production in SLUS: As an important outcome, crops, trees or other planted products, and forest products will be integrated into SLUS. Positive welfare impacts will be derived from production in sustainable systems. Positive environmental impacts are expected from these more intensive, often tree- and perennial crop based diverse systems.
(4.4) Market value chain development: The crucial outputs are methods to facilitate equitable, sustainable market value chains; and the development of the chains themselves in target communities. Outcomes will depend on intended users overcoming the constraints and taking advantage of the opportunities listed in the rationale. The innovation area will have to deal with information management, negotiation along value chains, problems of infrastructure, developing continuous production and economies of scale, product standards and quality control, resources access and land tenure, and financial mechanisms. Positive welfare impacts will be derived in terms of income, income stability, employment creation, and value added. Social and human capital gains will accompany successful market chain development and participation.

LAC4: Decision and Policy Analysis Program

The Decision and Policy Analysis program focuses on providing policy relevant research outputs around 4 thematic areas where significant demand exists in Latin America. These are ecosystem services and benefits to the poor, climate change and building of resilience into agricultural systems, design of pro-poor and equitable supply chains in a dynamic world, and impact targeting, facilitation and assessment. While being thematically diverse, the underlying research processes within the research program are quite similar, namely spatial and economic analyses. The program strongly believes in the power of information for making better decisions about agricultural and natural resource investments, from the farm- to the global- level. Through partnerships with key stakeholders, the provision of information and policy recommendations on these key thematic areas can contribute to outcomes in both research and development which enhance livelihoods and improve the management of natural resources in agroecosystems.

This program is born out of the Agroecosystems Resilience Project from the 2009-2011 MTP. The MTP presented here is a modified version of the program which has been realigned based on the new Strategic Directions of CIAT, which acknowledges the importance of Latin America and promotes the concept of eco-efficient agriculture. The themes contained within this research program represent both research areas where there is significant demand from Latin American institutions (public and private), and where CIAT has some comparative advantage.

Although the focus is on Latin America, the program also aims to transfer experiences to other continents, as well as engage in global-scale research which suits the demands of Latin America as well as other tropical regions. An example of the types of knowledge and tools which we envisage being transferable include the design and implementation of payment schemes for environmental services, which are currently undergoing a revolution in Latin America, and from which model cases could serve as examples for establishing such schemes in Asia and Africa.

International Public Goods. IPGs generated from this program are generally knowledge-intensive innovations (methods, tools, good practice guides), and are derived from lessons learned systematically across environmental, socio-economic and geographical situations. Outputs are robust enough to be targeted subsequently at global and/or very broadly regional levels. Our IPGs constitute: internationally published good practice guides (and similar outputs) and peer-reviewed journal articles of research methodologies and policy relevant research results, software tools (e.g. Canasta, Homologue) made available permitting other users to adapt and apply them to their local conditions.

As a baseline to many of the quantitative analyses made under the different outputs is the generation of data, itself of value to a range of partners. The program has in the past generated a number of important IPGs in the form of economic, environmental and agricultural databases (spatial and tabular) which are made available online to stakeholders and partners. These include the SRTM topography database (http://srtm.csi.cgiar.org), the WorldClim climate database (www.worldclim.org) and the Latin American Population database (http://gisweb.ciat.cgiar.org/population/index.htm). The program continues to develop such databases, including improved agricultural land-use data for the globe, and socio-economic databases at sub-national scales for Latin America. All these IPGs are to be distributed through the web to our partners and other research organizations.

Beyond the basic data, the program develops a range of methodologies and tools. For example, under output 2 one envisaged IPG are good practice guidelines for the use of the SWAT model for the design of payment schemes for water-based ecosystem services, and economic models such as ECOSAUT which assess the expected socio-economic benefits of such a scheme. The models themselves are made available to research and development organizations engaged in the development of PES schemes, and the good practice guidelines are published in both peer-reviewed publications and through open-access booklets.

Outputs

Output 1 and 3 remain as a continuation of output 1 and 2 from the 2009-2011 MTP. Outputs 2 and 4 are new outputs for the 2010-2012 MTP, and have been selected as key issues for Latin America where CIAT can play an important role in the generation of new knowledge and guidance on policy issues. Output 4 was formally contained in the Linking Farmers to Markets program of the 2009-2011 MTP, and has been modified in focus to fit more closely with this program, taking a more policy-focused alignment towards addressing the issues surrounding international markets and the poor in Latin America.

***Output 1*: Impact assessment for targeting, documenting and increasing the effectiveness of research and development.** This output refers to both internal reflections on CIAT's impacts, through ex-ante and ex-post impact assessments, but also to the support of other research and development programs with impact targeting through spatial, economic and institutional analyses (impact mapping). This output takes advantage of CIAT's considerable collection of environmental, agricultural and socio-economic data to develop both new methods and apply existing methods to target R&D interventions, and to evaluate potential benefits and strategies for the deployment of new agricultural technologies. Some of the new methods developed under this output include the continued development of methods for the identification of environmental niches for crops, and extrapolation domain analyses for supporting technology transfer.

The Program is also developing methodologies for maximizing impact during and after the life of R&D projects. This includes the development and application of Participatory Impact Pathway Analyses (PIPA), and the use and promotion of novel ICT/KM tools for enabling broader inclusion of partners, and dissemination of research results beyond the standard research networks. This research support service generates IPGs in itself in terms of methodologies, but also maximizes the impact and generation of IPGs in other R&D projects within and outside of the CGIAR system.

Specific developments in this output for the next two years include the development of meta-databases of phenotyping trials, which together with extrapolation domain analyses will facilitate the targeted deployment of new drought-tolerant varieties developed by the GCP and other CGIAR Centre breeding programs. Work is also underway to improve knowledge of key pests and diseases of CIAT mandate crops, including cassava diseases. The work includes the development of predictive maps for pest distribution, permitting greater understanding of the environmental drivers of pest presence and pressure, and linking this with socio-economic analyses of affected communities can inform research programs on the best-bet research strategies for mitigating negative impacts.

Changes: Output 1 in essence remains the same as Output 1 from the Markets, Institutions and Livelihoods project from the 2008-2010 MTP. However, it has evolved since this time last year with greater clarity in the long-term strategy. Hence, the specific outputs for 2009 remain the same as in the 2008-2010 MTP for Markets, Institutions and Livelihoods, but there are a number of new specific outputs for 2010 onwards. Specifically, the output target on "An assessment of the potential of payment for environmental services generated from agriculture to both improves the environment and rural livelihoods" (previously a 2010 output) has moved to Output 2 of this project, where the work on ecosystem services is explicitly within the strategy. Three new specific outputs have been added, which develop methods for mapping extrapolation domains, and institutional analyses of water and poverty issues in the Andes included.

Impact Pathway: The impact pathway for this research is specific to each individual output target, and is hence difficult to present succinctly in this main text. However, the objective of this specific output is to maximize the impact of R&D interventions through the better targeting, prioritizing and documenting of impact. Through the application of ex ante impact assessment in existing and significant R&D projects, the results from this output will lead to better decisions about where and how to invest limited R&D investments. The users of CIAT's impact work are principally researchers themselves, but also development agencies, whose final objectives are to enhance rural livelihoods.

***Output 2*: Managing ecosystem services to the benefit of the rural poor.** Large and reliable harvests depend upon ecosystem services. Fertile soils, ample water, and healthy biodiversity are beneficial inputs to agricultural production. These inputs also reflect the potential of ecosystem services. Degradation of natural resources is common in Latin America and throughout the world. Pressures to earn money in the short-term prevent longer-term sustainable land management practices. Trees are cut; soils erode; water sources dry out.

Nevertheless, some people may be willing to help pay the costs of sustainable management practices. Carbon in vegetation and roots has value; avoiding soil erosion saves costs downstream; communities and cities want reliable water. Farmers may be willing to change their practices if the money is right. But who would be willing to pay? What investments are required? How effective are the changes in management?

The sustainable management of ecosystem services is a critical component of eco-efficiency in agriculture, and has direct implications for bringing direct and indirect benefits to the rural poor as both net users and providers of several ecosystem services. In Latin America there is considerable demand for research on the best means of managing ecosystem services, especially through the use of novel payment schemes (PES). This output therefore has two major areas of focus. Firstly, the output looks to analyze cases across the Andes and Amazon and extract lessons for what policies work for promoting the conservation and sustainable use of ecosystem services to the benefit of the poor, and secondly the output develops specific tools and methodologies for quantifying ecosystem service flows and valuing them to a variety of stakeholders across institutions and landscapes. Both these focus areas aim at increasing the success rate of payment schemes through learning what contributes to successful, long-term schemes, and ensuring that schemes are established with realistic goals, and that all stakeholders in the scheme have access to information about the costs and benefits of implementing it.

The output focuses primarily on water-related services and carbon-based services as these are both critical resources under the current environmental outlook, and services for which both demand and formal markets exist for the establishment of payment schemes. However, other ecosystem services (e.g. biodiversity) are also considered when relevant through the bundling of multiple services.

This output is currently exclusively based in Latin America, although significant potential for transfer of lessons from Latin America to other regions exists, starting with Asia and then moving on to Africa.

Impact Pathway: The research in this output aims to improve the design and effectiveness of payment schemes for environmental services. The primary users of the research results are the authorities setting up payment schemes for environmental services, which are typically local and international NGOs, local and national government environmental bodies, and rural- and urban- private enterprises including water authorities, industrial agriculture businesses and international carbon trading companies. Through the learning of lessons from meta-analyses, and through the development of methods and tools for valuing ecosystem services CIAT partners directly with many of these organizations. Policy guidelines are also produced, which provide practical recommendations for implement payment schemes for these primary users. Uptake of CIAT methods, tools and best practice guidelines result in greater efficacy of payment schemes, resulting in higher success rates and eventually leading to sustainable management of ecosystem services and direct and indirect benefits to the rural poor trough both payment and increased natural capital.

***Output 3*: Understanding impacts of climate change in order to identify adaptation pathways for the rural poor.** As in most areas of the tropics, climate change is expected to have profound impacts on the agricultural sector in Latin America. Research efforts need to be targeted, and adaptation mechanisms in the field and along supply chains need to be identified, developed and implemented. CIAT is uniquely positioned to combine strong modeling capacity with explicit knowledge of agricultural systems and livelihood strategies to identify the threats that climate change poses to tropical agriculture, and identify how research and development should respond.

This output aims at developing methods and tools for evaluating the impacts of climate change on crop productivity and livelihood strategies, and evaluating a range of adaptation options for confronting future changes in climate. The output focuses on the next 15 years, rather than providing long-term estimates of changes, and envisages the key users of the research products as researchers themselves, international and national level policy makers and development agencies looking to promote adaptation pathways for rural communities.

Some examples of specific outputs from this area of work include the development of breeding strategies for CIAT mandate crops and other key crops for the next 15-20 years. Breeding programs take time, and hence the products of research decisions made today are likely to be released under different climate conditions. Coupling of climate change scenarios with sound crop suitability and productivity modeling can identify the main challenges facing each crop, and when combined with socio-economic datasets on poverty, population and nutritional characteristics, concrete breeding strategies can be developed which will help adapt agricultural systems to a future climate. Other examples include the development of suitability models for a variety of crops, and national and continental level analyses of the changing geography of crop adaptation to inform policy and development interventions. Some specific adaptation options such as the development of sound scientific means of establishing weather insurance schemes are also envisaged under this output.

Much of the modeling in this output is applicable globally, although specific evaluation of adaptation options are primarily focused on Latin America, especially Central America and the Caribbean where significant increases in temperature and reduction in rainfall is predicted.

Impact Pathway: This output provides policy-relevant results on the implications of climate change on agriculture, and through relevant dissemination of these recommendations better international (COP15) and national policy decisions (e.g. national adaptation strategies) can be made. Researchers in the Decision and Policy Analysis program are actively engaged in national and international fora in order to influence such policy decisions. Other direct users of the research products from this output are researchers themselves, who can use the results to design climate-proofed breeding programs, leading to new varieties adapted to future climate conditions. The identification of specific adaptation options, such as work underway with GTZ and CRS in coffee systems in Central America, lead to the promotion of practices which will increase the resilience of production systems to future changes in climate, leading to sustainable livelihood strategies for rural communities.

***Output 4*: Pro-poor supply chains in highly dynamic markets.** We know that under the right conditions, better information and skills that lead to better net returns can drive scalability and technology adoption. We know each case is different and that markets are dynamic and that understanding these markets is difficult. We need to understand how to get the biggest, widest, most equitable impact from our interventions. We believe market access holds many of the keys to driving success and hence scalability.

Improved information and knowledge management in supply chains can contribute to increased and sustained participation of small farmers, rural laborers and small scale rural entrepreneurs in profitable markets. Increased income also becomes a driver for other innovations including farmers' adaptation and adoption of new technologies and their investment in their natural resource base. Research helps answer the question of how best to leverage market linkages to achieve growth for diverse members of rural communities and make small farmers attractive partners to large buyers. Market linkages vary across LAC and the tropics in terms of products (staple commodities and high value crops such as tropical fruits), markets (local, regional, national and international), trading relationships (supply chains and value chains), and public and private policies. IFPRI analysis predicts that staple food crops meeting growing urban markets are likely to benefit the largest number of the poor, while higher value crops represent a different strategy likely to reach smaller numbers of more specialized small holders.

Market linkages set the agenda for most commodity and social science research, and understanding them will be important to many institutions in LAC and elsewhere. In both staple commodities and high value crops, markets guide the existence of and need for technology development, spatial analysis, rural institutions and organizations, and innovative public and private policies. Knowledge of what crop or variety to grow where, for what market, with what production technology and when, is critical to all members of the supply chain. Business models that effectively and profitably link small holder families and their organizations to other private sector actors in a sustained fashion are crucial.

This output aims to develop business models and public- and private- policy guidelines for ensuring that the poor benefit from national and international markets. This work will be especially linked to that of the CIAT Tropical Fruits Program and to the CGIAR Ecoregional Program for the Amazon.

Impact Pathway: This output engages with key actors directly to enable shared learning and improved practice. In the case of private sector policies, the principle scenario for this work is the Sustainable Food Lab which includes direct links to major private sector firms and the opportunity to influence their practice through improved knowledge and ways of engaging the poor. In many cases, these actors themselves are anxious to link with smallholder producers but lack the knowledge and skills needed to do so. CIAT researchers help facilitate this process while documenting results and developing scalable principles that are shared widely. Public sector actors are engaged via a regional learning network including Central America (Honduras and Nicaragua) and the Andes. This engagement will focus on reviewing the impact of public policy on supply chains of importance to the poor, designing and testing improved policies and documenting and disseminating the outcomes.

5. SYSTEMWIDE PROGRAMS

CIAT participates in a wide array of CGIAR systemwide, ecoregional and Challenge Programs. Together with IFPRI, CIAT hosts the HarvestPlus Challenge Program on improving the micro-nutrient density of staple food crops. As a Challenge Program, HarvestPlus presents its own separate MTP.

CIAT participates in all the other ongoing Challenge Programs: the Generation Challenge Program on genetic resources for crop improvement where CIAT has implemented commissioned and competitive research on beans, cassava and rice; the Food and Water Challenge Program, where CIAT has led the upper watersheds management research theme; and the Sub-Saharan Africa Challenge Program will CIAT coordinates the pilot

learning site for east Africa together with ISAR of Rwanda. CIAT's research in these Challenge Programs forms an integral part of its Program MTPs.

CIAT has also participated in a wide range of CG Systemwide Programs including, for example, the Systemwide Program on Genetic Resources which has played an important role in upgrading the CIAT gene bank; the IPM program through which CIAT has led a major research project on white fly pests; the African Highlands Initiative with which it has had several shared research positions. CIAT also participates in the Systemwide Livestock Program, the CAPRI collective action and property rights program, and the Alternatives to Slash and Burn, just to name a few. Like the Challenge Programs, work in these SPs is all presented as part of the Program MTPs.

SW1: Participatory Research and Gender Analysis

Because of unequal access to resources, the majority of the world's rural poor are women and the majority of the hungry and malnourished are likewise women. Thus, to truly overcome the challenge of poverty, international agricultural research has to take a conscious gender perspective. This has been a main focus of the CIAT hosted Systemwide Program on Participatory Research and Gender Analysis (PRGA) with numerous documented achievements since its establishment in 1997. The need to better incorporate a gender perspective into the international agricultural research system is both a prominent recommendation of the recent external review of the CGIAR System and a major objective of the ongoing CGIAR Change process.

CIAT and the PRGA both wholeheartedly support these new developments in the CGIAR, and look forward to a serious strengthening of a gender perspective in CGIAR research. Major challenges remain:

- A majority of agricultural research systems still lack a critical mass of participatory research (PR) and gender analysis (GA) practitioners, including in the CGIAR System.
- There is still little recognition and practice of gender analysis.
- There is still an unmet demand for capacity development in GA and PR methods.
- Learning and change need to be institutionalized, so that PR and GA can be mainstreamed in agricultural R&D thinking and practice.

In a changing institutional environment which involves the winding up of many of the current CGIAR Systemwide Programs, the several assets of the PRGA can be redeployed to support the evolution of new institutional forms to address pressing gender related issues. The assets of the PRGA include skilled human resources and a web of partnerships based on the credibility of long term relationships. CIAT intends to utilize these assets to help construct new approaches to critical issues of gender analysis in agricultural research. CIAT sees the need for two crucial outputs:

1. Mainstreaming gender analysis in agricultural research.
2. Enabling poor rural women to adapt to climate change.

Besides the two outputs proposed by PRGA, CIAT will increase investment in gender at various levels across the whole spectrum of activities during the period 2010-2012. The steady trend of gender work at the Center was reinforced during 2007-2008 when CIAT conducted its first Gender Audit –the most comprehensive assessment done on gender issues in most Centers covering all CIAT regions. Today, the robust sensitization strategy, recommended by the Audit, is in place and capacity building efforts are currently part of CIAT's activities in a bilingual mode both in English and Spanish. The strategic inclusion of gender research in CIAT's regional and Headquarters based programs ensures a strong focus on analysis. The analysis represented by sound indicators is widely needed in order to ensure concrete outcomes reaching benchmarks in science for impact. Since the strength of CIAT's work is demonstrated by the integrated work of the regional offices, a revised strategy to cover all regions is in on going to support sensitive research and the autonomy of implementation through concrete activities in all CIAT's major programs. Gender will be explicitly supported and surveyed in the Center's proposal preparation line, since a gender specialist will work with the peer

review team supporting the Resource Mobilization unit. This will ensure that all CIAT's future initiatives will include a gender lens in its proposed work.

While the emphasis is to build a hub at CIAT to support the work in all regions, an initial explicit emphasis will be pursued in the Latin American Program. In that light, the Amazon Initiative will support the inclusion of a gender component in the work they are currently conducting in Belem and other surrounding communities in Brazil. Through an appreciative inquire, the Amazon Initiative will disaggregate information by gender to come to an understanding of the best avenues to work in areas of Climate Change, linking farmers to markets and the use of non-timber products. Another unique aspect of the work in Latin America, particularly in the Amazon, is portrayed by the vast diversity of ethnic groups and Indigenous peoples who inhabit this eco-region. They maintain relevant and intricate patterns of land ownership and exploitation which is intimately related with their ancestral beliefs and felt needs, oftentimes influenced by external factors such as proximity and access to markets. A gender sensitive approach will enhance work with local communities, allowing for the rescue of local knowledge, which combined with new alternatives for agricultural production and forest management will provide them with optional pathways out of poverty. The South Asia Region will also invest in gender work through a monitoring approach to the livelihoods strategies of resource-poor upland smallholder farmers, that includes relevant groups of ethnic minorities and women. This time the gender work will be focused on the livelihood improvement at the household level. Households are not homogeneous units; men are women play prevalent roles in directing income to various competing activities including the level of food purchased for the family consumption. Understanding patterns of investment by gender in the integration of crop/livestock system in Cambodia, the Lao PDR, and Viet Nam will facilitate strategic decision making for accessing markets by the smallholders in that region. The work in the Africa Region will strengthen gender analysis in Seed Systems and Participatory Plant Breeding (PPB), which so far has been the flagship of the Participatory Research and Gender Analysis (PRGA) Program.

International Public Goods. The Program is unique within the CGIAR with its focus on PR and GA; it complements the Gender and Diversity Program, which focuses on staffing issues and capacity development among female scientists of many agricultural disciplines. The PRGA Program works alongside partners to develop methodologies that will be applicable over a much wider area, including across sub-regions and continents.

Both the products of the research (e.g. crop varieties) and the methodologies developed to achieve those products are international public goods, freely available to all (in a non-commercial context).

Outputs

The three Outputs of the 2009-2011 MTP have been consolidated into two. The former Output 2 (New approaches to measure the effectiveness of research processes that contribute to poverty reduction) has to some extent been amalgamated into the revised output on participatory plant breeding (Output 1). Under the current funding scenario, however, it has been necessary to drop work related to seed systems, impact assessment (except for publication of past work in this area) and political economy. In addition, the Output Targets have been refined. In fact, the whole of the Program's portfolio is dependent on securing adequate funding.

***Output 1*: Mainstreaming gender analysis in agricultural research.** Unless gender analysis is mainstreamed in agricultural research and development institutions, gendered patterns of inequity will continue to prevail, and the benefits deriving from agricultural research risk continuing to bypass women thereby exacerbating problems of poverty and inequality. The capacity for gender analysis remains limited in a wide range of agricultural research and development institutions. Addressing this challenge is a long term task for the CGIAR, beyond the life span of the PRGA. Alternative models have been proposed to meet this need, either a stand alone Gender Program of some sort, or more broadly supported that gender analysis be embedded in all future CGIAR mega-programs.

In either case, the PRGA will work closely with other CGIAR partners, including but not limited to IFPRI and the CGIAR Gender and Diversity Program in a common effort to find appropriate institutional forms for future mainstreaming of gender analysis in the CGIAR. In this transition phase, the PRGA will continue its work in 2010 in assessing the status of gender research and building capacity in pilot CG Centers. Likewise information dissemination on gender mainstreaming will continue in 2010, including the results of an ongoing (2009) inventory of gender research resources in the CGIAR.

Gender mainstreaming is a globally accepted strategy for overcoming the problems of those disadvantaged by gender. Gender mainstreaming in agricultural research and specifically in the CGIAR and partner institutions is not an end in itself, but a strategy to achieve, through gender equality in research processes, better outcomes and ultimately impacts for both women and men. Mainstreaming involves ensuring that gender perspectives and attention to the goal of gender equality are central to all activities – policy development, research, advocacy/dialog, legislation, resource allocation, and planning, implementation and monitoring of programs and projects. As identified by the CGIAR reform process, gender research is not mainstreamed in most CGIAR Centers – and doing so will require not only systematic policies and activities within each Center, but also support to them in doing so. It is the latter gap that this research will fill. The Program holds the only Systemwide mandate for gender in research. Its physical location at CIAT and CIAT's desire to mainstream gender make CIAT an advantageous choice for pilot work in this area.

Impact Pathway: With a variety of PPB methods (including new ones) at their disposal, and the practice of PPB institutionalized, plant breeders will be able to better target their efforts in variety development for staple crops in diverse, risk-prone environments (typical of resource-poor farmers). Moreover, attention to farmers' rights over the varieties developed should enhance the availability of material in a wider context (cf. variety protection imposed by commercial companies). Giving farmers the opportunity to share their experiences through media accessible to their peers elsewhere should 'spread the word' so that the whole farming population can benefit from PPB outputs. Consequently, farmers should be in a position not only to optimize their yield in the short term, but also to maintain enough variation to meet future changes (many imposed by climate change). This in turn should result in improved livelihoods and food security.

***Output 2*: Enabling poor rural women to adapt to climate change.** It is well documented that the poor in the poorest countries are most vulnerable to climate stresses in terms of food security. This is particularly true for women. While greenhouse gas emissions are generally lower among the poor who thereby typically can not play a leading role in climate change mitigation, the poor can not escape the consequences of climate change. Thus it is critical for the CGIAR to bring to bear analyses that can facilitate adaptation to climate change in a gender context. This research would include new participatory plant breeding (PPB) approaches with a gendered basis to help sustain and even support the broadening of the genetic base of poor people's crops for maximizing their use of agro-biodiversity.

Such 'Evolutionary' PPB could produce variability to ensure food security in the face of climate change and weather variability and could also potentially serve as an implementation tool for farmers' rights. All this would require additional support to local seed systems, especially those feeding off PPB programs.

PPB has proved ideally suited for the staple crops of the developing world's poor, as these crops often receive little or no commercial attention. PPB identifies adapted varieties for heterogeneous environments. Globally, the price of staple food crops soared in 2008, driven (at least in part) by the cultivation of more cash and oilseed crops (at the expense of staples) and the rising cost of oil. Moreover, agro-ecologies are now changing under the influence of climate change. PPB methods should enable 'evolutionary' plant breeding to keep pace with these changes and promote food security among the very poor. The PPB program seeks to refine our understanding of the situations in which joint efforts of farmers, scientists and others provide the most cost-effective delivery. PPB work in many Centers is highly fragmented and not 'institutionalized. Hence, the PRGA Program continues to have a clear role in helping to improve the institutionalization of PPB through

appropriate PPB approaches, methods and associated skills to achieve food security in the face of climate change and at acceptable R&D cost.

Ensuring recognition of the collective innovation and breeding efforts of farmers, and keeping their materials freely available for use and further breeding form major challenges, as do issues related to seed multiplication and seed policy. PRGA Program has the advantage of being the only Systemwide body with a mandate for PR, and its primary partner in this work (ICARDA) has one of the longest histories of PPB in the System. An alliance will be forged with other interested Centers and their partners to learn wider and robust lessons that catalyze institutionalization.

Impact Pathway: In working with Centers to determine their current gender status, and mapping a path for gender mainstreaming, the methodologies for assessing gender status will be refined. By working with 3-4 Centers concurrently, alternative methods should themselves be assessed, adapted and published. This should provide other Centers (and eventually other partners) with a choice of methods for gender mainstreaming. In mainstreaming gender issues in their research, partners internalize what they learn, resulting in institutional change; more specifically, partners then routinely utilize appropriate elements of PR and GA. With gender at the forefront, research and development activities should better target resource-poor farmers in a gender-differentiated way, ultimately leading to livelihood and food-security benefits for those farmers.

ANNEX 1. Logical Framework of CIAT Programs 2010-2011

AGBIO1: Genetic Resources Conservation Program

	Outputs	Intended Users	Outcome	Impact
Output 1	**Keeping collections up to international standards**	All users of the three commodity germplasm worldwide, namely in Central and South America, Africa and South East Asia.	Adoption or use designated germplasm in breeding/agronomy programs.	Better varieties, requiring less expensive inputs towards eco-efficient agriculture.
Target 2010: Materials	50% of bean backlog on introduction cleared, increased and characterized.			
Target 2010: Practices	Protocols for conservation of botanic seeds of cassava and wild *Manihot* species tested.			
Target 2010: Practices	Protocol for cleaned production of *Brachiaria* seed germplasm.			
Target 2010: Practices	DNA bank: 25% of in-trust bean and cassava accessions included.			
Target 2011: Materials	75% of bean backlog on introduction cleared, increased and characterized.			
Target 2011: Practices	DNA bank: 50% of in-trust bean and cassava accessions included.			
Output 2	**Making in-trust germplasm available to user communities**	Users, including countries of origin, worldwide can obtain quality germplasm from CIAT GRU; that germplasm is systematically safely duplicated.	The "Global System" foreseen by the Trust is getting concrete for beans, cassava, and tropical forages, and the NARS can rely on the CGIAR for a full back-up of their national collections.	More benefits in the society (farmers, breeders, agronomists, but also university departments) because of access to genetic resources at anytime; stable and secure access because of the safety duplicates.

	Outputs	Intended Users	Outcome	Impact
Target 2010: Materials	Samples of the designated collections of beans, cassava and tropical forages are distributed to users as per request (estimate 4,000).			
Target 2010: Materials	5,000 accessions are prepared for shipping to the Svalbard Global Seed Vault for the safety back-up of bean and tropical forages collections.			
Target 2010: Materials	3000 safety backups each for cassava, beans and forages shipped to CIP and CIMMYT.			
Target 2011: Practices	Methods for the detection of diseases of quarantine importance using the Real-Time PCR implemented.			
Target 2011: Materials	Acquisition of 100 samples of new germplasm for the breeders.			

AGBIO2: Bean Program

	Outputs	Intended Users	Outcome	Impact
Output 1	**Beans with improved micronutrient concentration that have a positive impact on human health**	NARS, farmers and consumers in Central America, the Caribbean, Brazil, East, Southern and Western Africa.	Release of high mineral varieties by NARS; testing of high mineral varieties by farmers; promotion by health partners.	Reduced levels of iron and zinc deficiency in bean consumers.
Target 2010: Practices	Marker assisted selection for one nutritional trait (iron) tested.			
Target 2010: Materials	Two large seeded lines with 50% more iron enter formal varietal release process in eastern and southern Africa.			

	Outputs	Intended Users	Outcome	Impact
Target 2010: Materials	15 Andean advanced bush lines with high mineral trait (HarvestPlus and complementary projects).			
Target 2010: Capacity	Elements of Pro-poor, pro women seed production, delivery and information systems confirmed and such seed enterprises established in 2 PABRA network countries.			
Target 2011: Materials	Two micronutrient dense bean varieties disseminated and promoted in two countries in eastern and southern Africa.			
Target 2011: Materials	20 F3.5 small seeded families with 90% more iron.			
Target 2011: Materials	At least 5 diversified bean based food products addressing micronutrient deficiencies are developed, tested and evaluated with farmers (male and female) and consumers (male, female and children) including vulnerable groups and made available in DR Congo and Rwanda for market, supplementary feed and household consumption (HarvestPlus).			
Output 2	**Beans that are more productive under low input agriculture of poor farmers**	Breeders and pathologists in CIAT and NARS; farmers in E and S Africa, Andean zone, Caribbean.	Farmers test improved varieties; NARS test elite lines in formal release scheme. Best bet IDPM practices and genetic combinations for stable resistance deployed; partners adopt new diffusion and/or marketing strategies.	Reduced yield losses from ALS, root rots and drought.

	Outputs	Intended Users	Outcome	Impact
Target 2010: Materials	10 BCMNV resistant climbing beans available for regional breeders.			
Target 2010: Materials	At least 5 genotypes combining drought resistance with aluminum resistance available for testing in Africa.			
Target 2010: Materials	At least 5 Andean genotypes as parents of higher level of drought resistance identified.			
Target 2010: Practices	At least 2 new and 5 existing integrated pest, disease and soil management options (with at least 2 per country) are evaluated for farmer acceptability and their effectiveness (including technical efficacy) in PABRA.			
Target 2010: Practices	At least 2 decision support tools are availed to at least 3 research, development or relief agencies.			
Target 2011: Practices	Evaluation of N fixation capacity fully implemented in breeding program.			
Target 2011: Materials	Root traits for efficient recovery of nutrients determined.			
Target 2011: Materials	5 canning bean lines with acceptable quality characteristics in yield trials in two countries in eastern Africa.			
Target 2011: Materials	10 red mottled and 10 red kidney lines tolerant to drought available to partners in east and southern Africa.			

	Outputs	Intended Users	Outcome	Impact
Target 2011: Practices	At least 3 tools for targeting technologies for bean production under environmental stresses or for nutritional enhancement are developed for PABRA.			

AGBIO3: Cassava Program

	Outputs	Intended Users	Outcome	Impact
Output 1	**Creation and maintenance of genetic stocks to overcome production constraints**	• Cassava breeding project in IITA. • National research programs and cassava farmers and communities in Nigeria, Uganda, Tanzania, Ghana, and India. • Scientists from national programs and universities. • Farmers that use cassava on farm for animal feeding.	• Increased productivity of cassava production systems from the introduction of elite cassava varieties from South America with CMD resistance. • Most important mechanisms for drought tolerance in cassava established. • Availability of high nutritional status cassava germplasm for evaluation of its agronomic and nutritional value. • Training in Shift in breeding objectives and methods at NARs.	• Improved food security and processing opportunities for rural communities that depend on cassava. • Increased and stable income of cassava farmers and processing facilities. • Improved nutritional status of communities in target countries that rely on cassava as a staple. • Rural development in cassava growing communities and reduction of poverty.
Target 2010: Materials	Transfer of at least 300 CMD resistant, early dry matter yield, delayed PPD and/or high and stable productivity under drought, acid soils and/or highlands cassava genotypes to National programs in LAC, Africa and/or Asia.			
Target 2010: Materials	30 genotypes developed with crude protein 2 standard deviations above the mean.			

	Outputs	Intended Users	Outcome	Impact
Target 2010: Materials	Identification and characterization of at least three new mutants for starch and/or root quality traits from the different strategies implemented. At least 500 new crosses made and evaluated to produce high-amylose clones.			
Target 2010: Materials	Shipment to Africa of at least 50 genotypes combining high carotene or protein in the roots with CMD resistance.			
Target 2010: Materials	Shipment of botanical seed of high-protein genotypes to LAC and Asia. Production of new high-carotenoids clones.			
Target 2010: Materials	Shipment of *in vitro* germplasm to EMBRAPA.			
Target 2011: Materials	Deployment of the first bio-fortified cassava (high carotenoids content).			
Output 2	**More efficient genetic enhancement approaches**	Field and molecular breeders from national programs, IITA and universities in developing and developed countries.	• More dynamic exchange of germplasm between CIAT, IITA and NARs. • Faster and more consistent genetic gains.	Benefits reach farmers and consumers more rapidly.
Target 2010: Materials	Development of markers associated with protein content and delayed PPD, from wild *Manihot* sp.			
Target 2011: Materials	Protocol for the production of doubled-haploids applicable to many different cassava genotypes.			

	Outputs	Intended Users	Outcome	Impact
Output 3	**Eco-efficiency of production & processing of cassava**	• Curators of germplasm banks, breeders, pathologists and entomologists from national programs, and universities in developing and developed countries. • Farmers.	• Molecular tools for detection. • Bioassays for transmission developed and implemented • Enhanced exchange of germplasm.	Farm incomes increased and consumer nutritional status improved through greater availability of improved cassava germplasm.
Target 2010: Materials	Identification of the pathogen(s) and insect vector(s) responsible for the frog skin disease (FSD) and clones resistant to the disease.			
Target 2011: Materials	Identification of the species of mealybug and white flies emerging as problems in cassava fields in Asia and agents for their effective biological control.			

AGBIO4: Forages Program

	Outputs	Intended Users	Outcome	Impact
Output 1	**Forage germplasm developed through collection, selection and breeding**	CIAT and NARS researchers and seed companies.	New forage cultivars (*Brachiaria* and legumes) are released by partners and adopted by farmers in LAC, Asia and Africa.	Increased efficiency of livestock production through feeding high quality grasses and legumes.
Target 2010: Materials	A range of improved *Brachiaria* cultivars commercially available.			
Target 2010: Materials	Two new forage options for smallholder pig and poultry systems identified.			
Target 2011: Capacity	Diversity and agronomic value of a collection of *Tadehagi triquetrum* assessed.			

	Outputs	Intended Users	Outcome	Impact
Output 2	**Forages as high value products developed to capture differentiated traditional and emerging markets for smallholders**	CIAT and NARS researchers, and seed companies.	New stress adapted cultivars of *Brachiaria* and high quality legumes with resistance to prevalent pests and diseases to capture emerging markets are released by partners and adopted by farmers in LAC and Southeast Asia.	Improved livelihoods of smallholder farmers through increased efficiency of livestock production, return from labor and income through planting forage grasses and legumes that are adapted to major production constraints and market opportunities.
Target 2010: Capacity	Supplementation of village pigs with the legume *Stylosanthes guianensis* is practiced by at least 1,000 small farm households through effective partnership with government and donor-funded development projects in Laos.			
Target 2011: Capacity	Alternative feed options in smallholder livestock systems tested in 2 hillside regions in LAC.			
Output 3	**Forages integrated into smallholder crop-livestock systems: realizing livelihood and environmental benefits**	CIAT, ARIs and NARS researchers, and seed companies.	New cultivars of grasses and legumes with adaptation to major production constraints released by partners and adopted by farmers in LAC, Asia and Africa.	Increased profitability and sustainability of livestock/crop production and improved NRM through planting multipurpose forages adapted to production constraints, market opportunities and climate change.
Target 2010: Policy strategies	Production vs environmental trade-offs determined between use of 2 cover legumes as feed supplement and for soil fertility improvement in maize-based systems in one hillside region.			
Target 2011: Materials	Contribution of nitrogen from a cover legume (*Canavalia brasiliensis*) to maize-bean system quantified in one hillside region.			

TSBF1: Integrated Soil Fertility Management Program

	Outputs	Intended Users	Outcome	Impact
Output 1	**ISFM for legume-cereal-based systems in sub-Saharan Africa promoted**	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, extension services, policy makers.	Locally adapted ISFM practices for legume-cereal-based systems are integrated in development initiatives in West, East, and southern Africa.	Farmers are adopting ISFM practices within legume-cereal-based systems with measurable impact on their livelihoods in terms of enhanced productivity, higher income, better nutrition, and an improved environment.
Target 2010: Practices	A set of two holistically evaluated 'complete' ISFM practices, including biological inoculants, for cereal-legume systems in the West-African Sahel and the West, East, and southern African moist savanna Impact Zones.			
Target 2010: Practices	A decision support framework for eco-efficient ISFM practices for cereal-legume systems in the West-African Sahel and the West, East, and southern African moist savanna Impact Zones.			
Target 2011: Capacity	An enabling environment for the adoption of ISFM practices, including strategic alliances along the legume-cereal value chains, sufficient knowledge on health and nutrition, effective partnerships, and technical stakeholder capacity for cereal-legume systems in the West-African Sahel and the West, East, and southern African moist savanna Impact Zones.			

	Outputs	Intended Users	Outcome	Impact
Output 2	**ISFM for cassava-, and banana-based systems in humid sub-Saharan Africa assembled**	CGIAR centers, ARIs, researchers from NARES and local universities, and regional consortia.	Principles for ISFM for cassava-, and banana-based systems are integrated in the research for development programs of national partners.	Farmers are experimenting with ISFM practices within cassava, and banana-based systems and adapting these to maximize their benefits to rural livelihoods.
Target 2010: Practices	A set of mechanistic principles underlying ISFM practices, for cassava- based systems in the West and Central African humid forest and for banana-based systems in the Central and East African mid-altitude Impact Zones, in close cooperation with AfNet.			
Target 2010: Practices	A set of two holistically evaluated 'complete' ISFM practices for cassava-based systems in the West and Central African humid forest and for banana-based systems in the Central and East African mid-altitude Impact Zones.			
Target 2011: Capacity	A decision support framework for eco-efficient ISFM practices for cassava-based systems in the West and Central African humid forest and for banana-based systems in the Central and East African mid-altitude Impact Zones.			
Output 3	**ISFM for conservation agriculture systems in Central America assembled**	CGIAR centers, ARIs, researchers from NARES and local universities, and regional consortia.	Principles for ISFM for conservation agriculture systems are integrated in the research for development programs of national partners.	Farmers are experimenting with ISFM practices within conservation agriculture systems and adapting these to maximize their benefits to rural livelihoods.
Target 2010: Practices	A set of mechanistic principles underlying ISFM practices for Quesungual agro-forestry systems in the Central American hillside Impact Zone.			

	Outputs	Intended Users	Outcome	Impact
Target 2011: Practices	A set of holistically evaluated 'complete' ISFM practices for Quesungual agro-forestry systems in the Central American hillside Impact Zone.			

TSBF2: Sustainable Land Management Program

	Outputs	Intended Users	Outcome	Impact
Output 1	**Eco-efficient land and soil management practices evaluated**	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmer groups, private sector agents, extension services, and regional consortia, conservation agencies.	Technologies and soil management strategies available for range of agro-ecological and socio-economic conditions provides viable options for various stakeholder groups and increases adoption of improved technologies.	Increased sustainability of productions systems and improved security of farmers in target impact areas.
Target 2010: Practices	Characterization and diagnosis of two major production landscapes in Malawi completed (in reference to sustainability of agricultural production and ecosystem and environmental services.			
Target 2010: Capacity	Rural diagnosis of agricultural production and livelihoods for one major production landscape in Tanzania completed.			
Target 2011: Practices	Rural diagnoses of agricultural production and livelihoods for second major production landscape in Tanzania completed.			

	Outputs	Intended Users	Outcome	Impact
Target 2011: Practices	Characterization and diagnosis of two major production landscapes in Nigeria completed (in reference to sustainability of agricultural production and ecosystem and environmental services.			
Output 2	**Options for enhanced and sustained agricultural production and ecosystem services, regeneration of ecosystem function and adaptation to climate change developed**	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia.	Create awareness on the status of land degradation in major production landscapes within the target impact zones, to enhance willingness to invest in sustainable agricultural production landscapes and to assist in prioritizing and targeting of interventions; Improved diagnosis of soil health problems informs identification of entry points and targeting of soil and land management interventions.	Partners adopt tools and techniques to target interventions in agricultural production that sustain or restore ecological and environmental quality and investments targeted to areas where the problems are most acute and severe; 'returns' on investment highly increased leading to productive and healthy rural environments.
Target 2010: Practices	A modeling tool to predict effect of soil management interventions and technologies on soil health status developed and validated.			
Target 2010: Practices	The role of soil organic matter in regulating BGBD and soil health tested across a number of experimental sites in at least 5 countries in the tropics.			
Target 2011: Capacity	Improved production systems (including technologies) and having multiple benefits of food security, income, human health and environmental services documented in terms of application domains.			

LAC1: Rice Program

	Outputs	Intended Users	Outcome	Impact
Output 1	**Rice germplasm for improving human health and nutrition in Latin America and the Caribbean**	Rice scientists, breeding programs, nutrition and health sector throughout the region.	1. High yielding rice lines with enhanced nutritional quality. 2. Network of six collaborating partners. 3. GIS studies on testing sites.	Reduced micronutrient deficiency and increased food and nutrition security among vulnerable populations living in Colombia, Bolivia, Brazil, Nicaragua, Cuba, Panama and Dominican Republic.
Target 2010: Materials	At least two lines with increased iron and zinc identified and ready for release by NARS.			
Target 2011: Materials	At least two lines with increased iron and zinc grown in demo plots by collaborators in at least two countries.			
Output 2	**Enhanced Gene Pools for Irrigated and Upland Rice in Latin America and the Caribbean**	• For the benefit of farmers in general, urban and rural consumers, industry and seed producers, and the rice community at large. • FLAR, GRUMEGA, INGER-LAC, and rice breeding programs throughout the region. • Rice breeders, pathologists, and farmers. • Rice scientists, extension agents, rice farmers and regulatory agencies.	• Breeding lines, populations and progenitors with broaden genetic base, high yield potential, tolerance/resistance to major pests and good grain quality used by our collaborators in their breeding programs. • New alleles associated with agronomic traits of importance available to our partners for further breeding work. • Breeder's workshops and capacity building.	1. Increased and more eco-efficient rice production. 2. Improved rice competitiveness through lower production costs and higher yields. 3. A more friendly rice production to the environment and people through lower use of pesticides. 4. Trained personnel.
Target 2010: Capacity	A CIAT-ION nursery distributed to 10 partners made up of about 120-150 rice lines carrying genes for durable resistance to rice blast and other desirable traits derived from wild rice species or composite populations.			

	Outputs	Intended Users	Outcome	Impact
Target 2011: Materials	10 rice materials tolerant to *B. glumae* developed.			
Target 2011: Materials	5 rice materials showing resistance levels to the new *Pyricularia* population developed.			
Output 3	**Genotypic and Phenotypic Platforms for Rice Enhancement**	• FLAR, GRUMEGA, INGER-LAC, and rice breeding programs throughout the region. • Our research partners and rice community in general.	• Breeding lines, populations and progenitors with broaden genetic base, high yield potential, tolerance/resistance to major biotic and abiotic stresses and good grain quality used by our collaborators in their breeding programs. • NARS trained in the use of marker kits for MAS (RHBV).	1. Increased and more eco-efficient rice production. 2. Improved rice competitiveness through lower production costs and higher yields. 3. A more friendly rice production to the environment and people through lower use of pesticides. 4. Trained personnel. 5. A robust rice sector will generate employment and maintain low prices for the poor consumers. The expansion of the genetic base of rice is leading to yield stability and better adaptability for abiotic and biotic stresses. 6. These facts will make LAC self-sufficient in rice and able to contribute to solving the rice production crisis in other regions. 7. At least two NARS using marker assisted selection in their breeding program.
Target 2010: Materials	50 introgression lines with chromosome segments substitutions from wild species.			
Target 2011: Materials	20 BC lines resistant to RHBV via SRR markers ready for field testing			

LAC2: Tropical Fruits Program

	Outputs	Intended Users	Outcome	Impact
Output 1	**Technologies for improving the competitiveness of smallholder tropical fruit producers**	Scientists and research managers; development planners and practitioners; producer associations; policymakers; donors.	Decision-makers gain better understanding of high value crop systems and performance, and thereby take informed decisions on resource allocations.	R&D efforts more effectively and systematically targeted. Increased productivity of high value, readily-marketed products.
Target 2010: Materials	Assessment of elite clones of naranjilla, Andean blackberry and avocado for disease resistance completed. Rural nurseries of naranjilla and Andean Blackberry established by at least 10 farmer associations.			
Target 2010: Practices	One database for accessions and performance of at least 4 high market value, underutilized crops and/or tropical fruit species established.			
Target 2011: Materials	Protocols for *in vitro* propagation of three tropical fruit species adjusted and implemented at CIAT (i.e coconut, strawberry, Andean blackberry).			
Output 2	**Policy guidelines and innovations to ensure pro-poor and equitable supply chains in the face of a highly dynamic world**	Policy-makers (private, public & donor), NGOs, farmer associations, researchers in CIAT and partner organizations.	More sustainable trading relationships between buyers and small holder farmers adopted and supported by enabling public sector policies.	Increased and more stable income streams available to smallholder farmers, their families and their communities.
Target 2010: Practices	Use of spatial analysis to develop a protocol for screening and selecting germplasm developed, published and applied, 5 high value crops (globally).			

	Outputs	Intended Users	Outcome	Impact
Target 2010: Capacity	At least five sustainable supply chains linking smallholders and key corporate buyers developed, evaluated for equity and environmental effects and outscaled through links with business partners, development and donor agencies in Africa, LAC and Asia.			
Target 2011: Policy strategies	Inclusive business model principles tested and improved in at least four chains in four countries.			
Output 3	**Technologies for management of diseases and pests**	National research and development agencies; and farmer associations in Latin America and Africa.	Cost-effective and environmentally friendly practices and tools promoted by national R&D agencies and in use.	Increased rural income through increased yield, higher market values and reduced production costs.
Target 2010: Practices	Disease management strategies verified for the model fruit expanded for testing with farmers growing naranjilla, Andean blackberry and avocado under a range of conditions.			
Target 2010: Materials	Plantain clones screened for disease (black sigatoka and moko disease) resistance made available to users.			
Target 2011: Practices	Microsatellite markers for assessment of genetic variability of major disease (*Colletothrichum* spp. and *Ralstonia solanacearum*) developed, tested and used.			

LAC3: Amazon Ecoregional Program

	Outputs	Intended Users	Outcome	Impact
Output 1	**Mitigation and adaptation to climate change**	Policy makers from global to local levels; local government agencies; development planners. Regional organizations (ACTO); regional and global policy development agencies (IDB, IDRB). Natural resources, forestry and livelihood specialists. Research and development partners: non-governmental organizations active in forests & livelihoods. Community-based organizations. National Agricultural, Forestry and Agroforestry Research Institutes, forestry agencies.	(a) Adoption of appropriate sustainable land use systems (SLUS) that provide positive impacts by increasing carbon (C) stocks through increases in biomass and, in soil C; and by decreasing GHG emissions through avoided deforestation. (b) Adoption of appropriate.	(a) Maintenance and increase in C stocks, reduced GHG emissions, and positive welfare impacts from the use of more sustainable systems. (b) Development of local and national mitigation and adaptation policies and programs that contribute to sustaining the livelihoods of Amazon farmers and communities.
Target 2010: Capacity	Recommendation for cost-effective and equitable reduced emissions from deforestation and degradation (REDD) strategies developed and disseminated in at least one Amazon country.			
Target 2010: Practices	Research and policy recommendations to reduce the vulnerability of local rural economy segments and selected land use systems (e.g. agroforestry, silvopastoral systems) to climate risk, specifically through the prediction and evaluation of climate change impact on agroforestry species in the Peruvian and Ecuadorian Amazon.			

	Outputs	Intended Users	Outcome	Impact
Target 2011: Practices	Framework including principles, criteria, indicators and verifiers for baseline assessments and monitoring of carbon stocks is validated through pilot locations in Amazonian countries, addressing voluntary mechanisms and alternative C markets.			
Output 2	**Adoption of sustainable land use systems in deforested and degraded areas**	Policy makers from global to local levels; local government agencies; development planners. Regional organizations (ACTO); regional and global policy development agencies (IDB, IDRB). Sustainable land use systems' specialists; NGOs active in sustainable land use systems. Community-based organizations. Governmental extension systems and private service extension providers. National Agricultural, Forestry and Agroforestry Research Institutes. National land management and soil fertility programs and projects.	(a) Principles, methods and practices developed for improved land use systems in the Amazon. (b) Policy, research and development communities are aware of the quality and extent of information available, and on gaps in information and knowledge on the determinants of ES provision. (c) Local practitioners use approaches for practical measurement of changes in levels of ES at plot and landscape levels. (d) Innovative institutional arrangements in place to secure rewards for smallholders engaged in positively impacting SLUS.	(a) Land-use systems to prevent and reverse environmental degradation and sustain environmental services at local and national levels. (b) More resilient livelihoods, with more stable incomes and greater food security. (c) Enhanced biostability of the Amazonian ecosystem. (d) Reduction in global levels of greenhouse gas emissions.
Target 2010: Capacity	Improved networking, sharing of and access to information on management options for SLUS and for enhanced provision of ES among researchers, practitioners and farmer organizations in Amazon countries.			

	Outputs	Intended Users	Outcome	Impact
Target 2010: Materials	Improved germplasm for prioritized Amazon agroforestry species developed through participatory domestication and disseminated to farmers through enhanced germplasm supply systems.			
Target 2011: Practices	Rapid appraisal tools for agrobiodiversity, watershed functions, C stocks, and soil quality at landscape scale adjusted and validated to the Amazon context to support multi-stakeholder dialogue on SLUS.			
Output 3	**Enhanced benefits from forests for livelihoods and the environment**	Policy makers from global to local levels; local government agencies; development planners. Regional organizations (ACTO); regional and global policy development agencies (IDB, IDRB). Natural resources, forestry and livelihood specialists. Research and development partners: non-governmental organizations active in forests & livelihoods. Community-based organizations. National Agricultural, Forestry and Agroforestry Research Institutes, forestry agencies.	(a) Strengthened regional networks and institutions through joint, collaborative research. (b) Improved understanding of the extent to which Amazon natural resources contribute to poverty alleviation and livelihood enhancement. (c) Improved understanding of the opportunities and risks associated with integrating agroforestry and smallholder agriculture in the Amazon into landscape approaches to natural resource management and rural livelihood security.	(a) Data and reports are used by governments and development agencies to inform investment decisions at local, country, regional levels, and beyond. (b) Research findings linked into improved natural resource management at farm and landscape level in diverse Amazonian contexts. (c) Local communities empowered to sustain these efforts.

	Outputs	Intended Users	Outcome	Impact
Target 2010: Capacity	Solid regional network of research and development organizations having produced a reliable dataset on Amazon smallholders' dependency on forests/ agroforests, built through household and community surveys of a sample of 2,200 households in 14 research sites of Bolivia, Brazil, Colombia, Ecuador, Peru, Suriname and Venezuela.			
Target 2010: Practices	Livelihood strategies and dependency on forests, agroforests and agriculture in 14 Amazonian sites comprehensively assessed through qualitative and quantitative methods, and research framework developed to comparatively examine resource constraints and livelihood opportunities for smallholders and communities in Amazonian forested landscapes.			
Target 2010: Practices	Comparison and identification of workable forest tenure models for supporting sustainable livelihoods and resource management.			
Target 2010: Other kinds of knowledge	Impact of logging on livelihoods – long-term implications of logging on NTFP consumption.			
Target 2011: Materials	Assessment of the potential of three Amazonian palm species to enhance the benefits of local population.			

	Outputs	Intended Users	Outcome	Impact
Output 4	**Fair, financially attractive market value chains for Amazon products**	Development planners. Market specialists; university professors. Research and development partners: non-governmental organizations active in value chain development. Community-based organizations. Private sector, agro-enterprises. Governmental extension systems and private service extension providers. National Agricultural, Forestry and Agroforestry Research Institutes.	Enhanced and highly organized value chains of Amazon fruit tree species and non-timber forest products, supported by improved approaches, germplasm and management practices.	(a) Economic benefits to smallholders through higher yield and greater product demand for priority species. (b) Wider application to other Amazon species of the model generated. (c) Rehabilitation of deforested or degraded areas through the implementation of perennial production systems. (d) Agricultural stabilization and deforestation reduction.
Target 2010: Capacity	Value chain development approach generated for the realization of the economic potential of Amazonian fruit tree and NTF products: framework developed for five Amazonian fruit tree species (aguaje, camu-camu, peach palm, cupuazu, and Ungurahui).			
Target 2010: Practices	Clean production practices developed for peach palm production in humid forest.			

LAC4: Decision and Policy Analysis Program

	Outputs	Intended Users	Outcome	Impact
Output 1	**Impact assessment for targeting, documenting and increasing the effectiveness of research and development**	Agricultural and environmental research organizations, development and environmental organizations, civil society groups, policy makers at regional, national and local scales.	Greater incorporation of the interests of the poor in the design and implementation of R&D projects.	R&D investments have larger impacts, of which a larger share goes to the poorest beneficiaries.

	Outputs	Intended Users	Outcome	Impact
Target 2010: Practices	Assessment of 10 phenotyping trial sites to provide information for future field trial planning and dissemination of high-yielding and stress-tolerant genotypes.			
Target 2010: Practices	Assessment of the potential global distribution of 5 cassava pests and pathogens to support the development of measures for reducing yield loss due to these problems.			
Target 2011: Capacity	Updated and dynamic African Bean Atlas.			
Output 2	**Managing ecosystem services to the benefit of the rural poor**	Policy-makers (public, private & donor), farmer organizations, NGO's, researchers in CIAT and partner organizations.	Improved conceptual and empirical understanding of how policy enables more effective management of ecosystem services and poverty alleviation.	R&D efforts lead to sustainable and resilient agroecosystems.
Target 2010: Other kinds of knowledge	Water-poverty interactions assessed in the Andes through expert knowledge and Bayesian network analysis.			
Target 2010: Practices	Establishment of a protocol for quantifying hydrological and socio-economic benefits of water-based payment for environmental services schemes.			
Target 2010: Practices	Spatial policy targeting tool for the Amazon implemented in an on-line map server.			
Target 2011: Other kinds of knowledge	Institutional priorities and arrangements identified with respect to water, poverty and agricultural production in the Andes.			

	Outputs	Intended Users	Outcome	Impact
Output 3	**Understanding impacts of climate change in order to identify adaptation pathways for the rural poor**	Policy-makers (public, private & donor), researchers, development practitioners, NGOs.	Research and development projects take into account likely impacts of climate change in designing their interventions based on sound climate and agricultural science.	Resilient agroecosystems contributing to stable livelihoods for the rural poor.
Target 2010: Practices	Breeding strategy recommendations to confront global climate change made for at least 3 crops on a global scale.			
Target 2010: Practices	Impacts of climate change on five coffee growing communities in Central America quantified through spatial modeling and participatory workshops with communities.			
Target 2011: Other kinds of knowledge	Weather insurance schemes based on sound climatological and agronomic science in place in at least two sites in two different countries.			
Output 4	**Pro-poor supply chains in highly dynamic markets**	Policy-makers (private, public & donor), NGOs, farmer associations, researchers in CIAT and partner organizations.	More sustainable trading relationships between buyers and small holder farmers adopted and supported by enabling public sector policies.	Increased and more stable income streams available to smallholder farmers, their families and their communities.
Target 2010: Practices	Global survey of inclusive business models conducted and published.			
Target 2010: Capacity	Learning network of public sector policy makers established to assess the effects of public chain policies on the poor in LAC.			
Target 2011: Practices	Inclusive business model principals tested and improved in at least four chains in four countries.			

SW1: Participatory Research and Gender Analysis

	Outputs	Intended Users	Outcome	Impact
Output 1	**Mainstreaming gender analysis in agricultural research**	Researchers, including plant breeders (CGIAR, NARS); Farmers' associations.	• Plant breeders adopt and adapt good practices in PPB, and thereby identify (together with male and female farmers) adapted varieties for specific farming contexts. • Farmers' rights and gender equality increased.	• Improved livelihoods of poor farming communities. • Food security for poor farmers (male and female).
Target 2010: Practices	An effective method for maximizing the improvement potential of agro-biodiversity by means of PPB demonstrated, as targeted to the poor in dry areas in a specific, defined region (e.g. Africa and/or Middle East) (ICARDA, IFPRI).			
Target 2010: Capacity	A documented set of stories from women farmers' experience in managing climate variability through PPB and other means (ICARDA).			
Target 2011: Policy strategies	A method to sustain the diversity of the genetic base of poor people's crops through PPB demonstrated.			
Output 2	**Enabling poor rural women to adapt to climate change**	CG Centers, NARS, NGOs.	• The practice of gender analysis is mainstreamed in CG Centers and partners. • Research products relevant to the needs and priorities of the poor.	• Sustainable livelihoods and greater food security among marginalized groups.

	Outputs	Intended Users	Outcome	Impact
Target 2010: Capacity	Gender-status-assessment methodologies applied and critically reviewed in other CG Centers.			
Target 2011: Capacity	Gender-mainstreaming best practices extended to Latin American institutions in collaboration with at least 2 NARS.			
Target 2011: Capacity	One tool box compiled drawn from a survey of training tools.			