TSBF Institute

Project PE-2: Integrated Soil Fertility Management in the Tropics

ANNUAL REPORT 2005

CIAT
Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

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

Annual Report 2005

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1. TSBF-CIAT RESEARCH FOR DEVELOPMENT STRATEGY

A. Research for development strategy of TSBF-CIAT

The 2005-2010 TSBF-CIAT strategy is aligned with the **Millennium Development goal:** "to help create an expanded vision of development that vigorously promotes human development as the key to sustaining social and economic progress in all countries, and recognizes the importance of creating a global partnership for development." The strategy encompasses the **CGIAR's agriculture and environment mission:** "to contribute to food security and poverty alleviation in developing countries through research, partnerships, capacity building and policy support, promoting sustainable agricultural development based on environmental sound management of natural resources." The strategy is also aligned with the CIAT's three research for development challenges: 1) improving management of agroecosystems in the tropics; 2) rural innovation research; and 3) enhancing and sharing the benefits of agrobiodiversity.
TSBF-CIAT's Program has three main goals. These are: (1) to strengthen national and international capacity to manage tropical ecosystems sustainably for human well-being, with a particular focus on soil, biodiversity and primary production; (2) to reduce hunger and poverty in the tropical areas of Africa and Latin America through scientific research leading to new technology and knowledge; and (3) to ensure environmental sustainability through research on the biology and fertility of tropical soils, targeted interventions, building scientific capability and contributions to policy.

TSBF-CIAT utilizes a range of approaches to achieve program goals in collaboration with its partners, with particular emphasis on the following:

Catalysis: Ensuring that partners are kept at the forefront of conceptual and methodological advances by conducting and promoting review, synthesis and dissemination of knowledge. This is done through workshops, training courses and sabbatical and short exchange visits.

Collaboration**:** Developing appropriate alliances with institutions across the research, educational and developmental spectrum, including linkages between institutions in the North and South.

Facilitation**:** Coordinating actions among partners to achieve progress and success in research. This is done by providing backstopping support in the preparation, submission, implementation and publication of research projects.

Conviction: Demonstrating tangible results by taking policy makers to the fields.

Internal and external reviews of the program**:** The Institute's activities and outputs undergo periodic critical reviews to ensure high standards and the achievement of the Institute's mission.

Since its founding in 1984, TSBF has conducted research on the role of biological and organic resources in tropical soil biology and fertility, in order to provide farmers with improved soil management practices to sustainably increase agricultural productivity. In recent years, TSBF-CIAT's research for development approach has been based on an Integrated Soil Fertility Management (ISFM) paradigm. ISFM is a holistic approach to soil fertility research that embraces the full range of driving factors and consequences of soil degradation — biological, physical, chemical, social, economic and political.

However, successful resource management and sustainable agricultural productivity need to go still further, into the realms of markets, health and policies (Figure 1). The central hypothesis is that natural resource management research will have more leverage if the apparent gaps between investment in the natural resource base and income generation can be bridged. Therefore, TSBF-CIAT's strategy proposes to take ISFM an additional step forward, by addressing the full chain of interactions from resources to production systems to markets and polices. Under the new framework, investment in soil fertility management represents a key entry point to agricultural productivity growth, and a necessary condition for obtaining positive net returns to other types of farm investments.

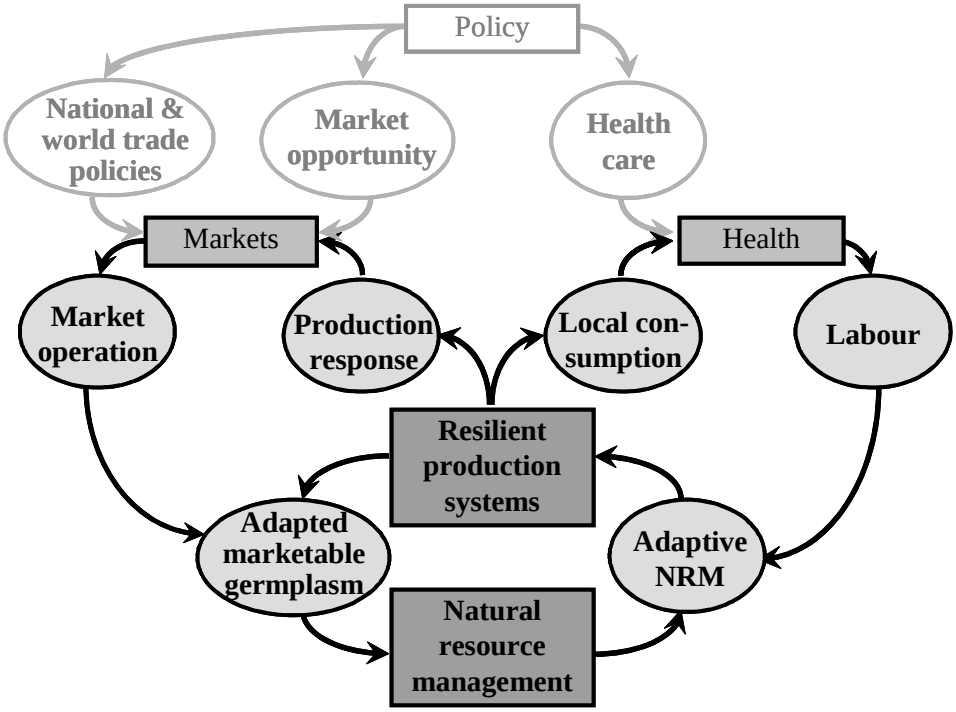

Figure 1. Conceptual framework of the TSBF-CIAT strategy. Topics in bold indicate the driving forces to be addressed by the proposed strategy; topics in shaded lighter gray are driving forces beyond the control of the Program.

TSBF-CIAT will pursue the following three major objectives under its strategy:

- to improve the livelihoods of people reliant on agriculture by developing profitable, socially-acceptable and resilient agricultural production systems based on ISFM;
- to develop sustainable land management (SLM) practices in tropical areas while reversing land degradation; and
- to build the human and social capital of all TSBF-CIAT stakeholders for research and management on the sustainable use of tropical soils.

To achieve these objectives, TSBF-CIAT's work is organized into five major outputs:

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

Each of these outputs has specific output targets for each year to contribute towards output level outcomes and output level impacts. The outcomes and impacts are accomplished through six major thrusts:

1. Intensification and diversification of cropping systems;
2. Managing the genetic resources of soil for enhanced productivity and plant health;
3. Moving from plot to landscape scale to address sustainable land management challenges;
4. Understanding farm level social dynamics;
5. Linking farmers to markets; and
6. Strengthening NARSs capacity.

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

As a relatively small research institute, it is important that TSBF-CIAT position itself appropriately on the research-development continuum. TSBF-CIAT's primary role and comparative advantage is in conducting international public goods research on ISFM in farming systems where soil degradation undermines local livelihoods and market opportunities. However, while TSBF-CIAT will focus primarily on strategic research, it is also ready to support technology dissemination and development activities with partners via regional networks and global projects. TSBF-CIAT will continue research on below-ground biodiversity as a means of beneficially managing soil biology, through the GEF-UNEP funded global project on below-ground biodiversity (BGBD) which has successfully completed its Phase I and is about to start its Phase II activities.

Much of the applied research and dissemination of findings, as well as NARSs capacity building, will be done via the Institute's two partner networks — the African Network for Soil Biology and Fertility (AfNet), and the Latin American Consortium on Integrated Soil Management (known by its Spanish acronym, MIS). TSBF-CIAT also collaborates with the South Asian Regional Network (SARNet) on soil fertility research in that region.

To carry out the work envisioned under the new strategy, the following staff positions will be called for:

Agrobiophysical scientists: These include specialists in integrated soil fertility management, soil biota management, soil and water conservation, ecosystem services, microbiology, and plant nutrition and physiology.

Social scientists (including agricultural economics): This staff category will be strengthened to permit greater emphasis on the socio-economic aspects of the new research paradigm.

Coordination: This includes the Institute Director, coordinators of the AfNet and MIS networks, and the coordinator of the GEF-UNEP Below Ground Biodiversity Project.

Funding: The estimated funding required for TSBF-CIAT's work is approximately US$5 million per year, for a total budget of about $25 million over the next 5 years.

B. Organization of the report

This annual report for 2005 is organized with the following sections. It starts with a brief summary of the strategy of the TSBF-CIAT followed by a brief description of the project and its logfrme that includes the 5 outputs, output targets for each output, outcomes and impacts at each output level as described in the CIAT Medium-Term Plan 2006-2008. This is followed with a section on research highlights organized according to the 5 outputs. The full report is organized by 5 major outputs of the project. Each output report contains its rationale, key research questions, milestones for the year 2005, highlights of research and specific output targets for the years 2006, 2007 and 2008. For each output target, the published work is reported as abstracts from refereed journal articles that were published in the year 2005. This is followed by the completed and on-going research activities that are related to each output target. Progress towards output level outcomes and output level impacts are summarized at the end of the report for each output. Information on list of staff, list of students, list of partners and list of publications is included in the Annexes section.

C. Project outputs and their link to strategy

The project has 5 major outputs. Output 1 (Biophysical and socioeconomic processes understood, priciples and concepts developed for protecting and improving the health and fertility of soils) involves research to develop principles and concepts that transcend the classical boundaries of the biophysical sciences and require integration with economics, sociology and anthropology. Integration of local and scientific knowledge to develop integrated “hybrid”knowledge and therefore could increase relevance to an overall strategy for sustainable soil management for improved food security and environmental protection.

Process and integrated knowledge generated from the research activities in output 1 needs to be translated into sustainable soil fertility and land management practices, adapted to the socio-cultural and economic environment in which these practices will be implemented. Research activities from Output 2 (Economically viable and environmentally sound soil, water, and nutrient management practices developed and tested by applying and integrating knowledge of biophysical and socioeconomic processes) are expected to enhance farmers’ capacity to translate best principles for soil, water and land management into practices that are appropriate to their environment and decision aids, condensing that knowledge for dissemination beyond the sites where this knowledge has been generated.

Managing soil fertility for improved livelihoods requires an approach that integrates technical, social, economic and policy issues at multiple scales. To overcome this complexity, research and extension staff need the capacity to generate and share information that will be relevant to other stakeholders working at different scales (i.e., policy makers, farmers). Thus the research activities in output 3 (Partnerships and tools developed and capacity enhanced of all stakeholders for improving the health and fertility of soils) are founded on building the human and social capital of all TSBF-CIAT stakeholders, research and management on the sustainable use of tropical soils.

Research activities of output 4 (Improved rural livelihoods through sustainable, profitable, diverse and intensive agricultural production systems) address the challenge of intensification and diversification of smallholder agricultural production that is needed to meet the food and income needs of the poor and cannot occur without investment in natural resource management, especially soil fertility. Investment in improving soil fertility is not constrained by a lack of technical solutions *per se* but is more linked to lack of access to information for improved decision making and analyzing trade-offs, inputs and profitable markets.

Soils play a central role for the provision of ecosystem services such as regulation of water quality and quantity, carbon storage and control of net fluxes of greenhouse gases to the atmosphere. Appropriate soil

management could result in enhanced provision of environmental services. The major objective of research activities of output 5 (Options for sustainable land management (SLM) practices for social profitability developed, with special emphasis on reversing land degradation**)** is to restore degraded agroecologies to economic and ecological productivity by generating technology, institutional and policy innovations that restore degraded agricultural lands, enhance ecosystem health and improve livelihoods.

2. PROJECT DESCRIPTION AND LOGFRAME

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

Project Description

Goal: To strengthen national and international **capacity** to manage tropical ecosystems sustainably for human well-being, with a particular focus on soil, biodiversity and primary production; to reduce **hunger and poverty** in the tropical areas of Africa and Latin America through scientific research leading to new technology and knowledge; and to ensure **environmental sustainability** through research on the biology and fertility of tropical soils, targeted interventions, building scientific capability and contributions to policy.

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

External Conditions: Security and political stability does not restrict access to target sites and continuation of on-going activities.

Important Assumptions: Poverty reduction strategies remain central to human development support and funding. TSBF stakeholders remain engaged with TSBF-CIAT strategic priorities and/or TSBF management continues to adapt and innovate in response to changing priorities.
Funding for research on globally-important issues continues.

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

Beneficiaries and End Users: Principally small-scale crop-livestock farmers and extension workers, NGO's and NARES in tropical agroecosystems of sub-Saharan Africa, Latin America and South-east Asia.

Collaborators: ***NARES:*** KARI (Kenya), DRSRS (Kenya), NMK (Kenya), KEFRI (Kenya), NARO (Uganda), NFA (Uganda), NEMA (Uganda), MOA (Uganda), ITRA (Togo), INRAB (Benin), SRI (Ghana), IER (Mali), IAR (Nigeria), INRAN (Niger), INERA (Burkina Faso); CORPOICA (Colombia), EMBRAPA (Brazil), Kerala Forest Research Institute (India), GBP Institute (India), SDREP (India), INTA (Nicaragua), DICTA (Honduras); IC-SEA BIOTROP (Indonesia), RIABGR (Indonesia), FNCRDC (Indonesia), FNCRDC (Indonesia), RRIEC (Indonesia), COSA (Indonesia), IOS (Cote d'Ivoire), ANADER (Cote d'Ivoire), NRMEE (Cote d'Ivoire), MOE (Cote d'Ivoire), INPDMDS (Cote d'Ivoire), ESDA (Cote d'Ivoire), UCA (Cote d'Ivoire), UAA (Cote d'Ivoire), BNETD/CCT (Cote d'Ivoire), CNRA (Cote d'Ivoire), (Instituto de Ecologia (Mexico), IEAC (Mexico), UNAM (Mexico), IFCP (Mexico), Centro Exp. Andres (Mexico), Reserve de la Biosfera de Los Tuxtlas (Mexico), ***ARIs:*** CIMMYT, ILRI, CIP, IFDC, ICRAF, IITA, ICRISAT, IRD (France), CIRAD (France), ETHZ (Switzerland), JIRCAS (Japan); ***Universities:*** Nacional (Colombia), UNA (Nicaragua), UNA and EAP Zamorano (Honduras),

Uberlandia (Brasil), University of Nairobi (Kenya), USIU (Kenya) Maseno University (Kenya), Methodist University (Kenya), Makerere University (Uganda), Kenyatta University (Kenya), Zimbabwe (Zimbabwe), Sokoine (Tanzania), Universidade Federal de Lavras (Brazil), Universidade Regionale de Lavras-FURB (Brasil), INPA (Brasil), UFAM (Brasil), Universidade De Brasilia (Brasil), Jawaharlal Nehru University (India), University of Agricultural Sciences (India), Kumaon University (India), Sambalpur University (India), Universitas Lampung (Indonesia), Brawijaya University (Indonesia), Gadjah Mada University (Indonesia), Bogor Agricultural University (Indonesia), Université de Cocody (Cote d'Ivoire), Universite D'Adobo-Adame (Cote d'Ivoire), Universidade Veracruziana (Mexico), Instituto Polytecnico (mexico), Leuven (Belgium), Paris (France), Bayreuth and Hohenheim (Germany), SLU (Sweden), NAU (Norway), Cornell (USA), Wisconsin-Madison (USA), Ohio State (USA), Colorado State University (USA), East Anglia (UK), Queen Mary University (USA), Michigan State University (USA), ITC (The Netherlands) University of Exeter (UK), and Wageningen University and Research Centre (Netherlands). ***Regional Consortia:*** AFNET, MIS, CONDESAN; ***NGOs:*** CARE, World Vision; CIPASLA, CIPAV.

Project Changes: TSBF-CIAT has developed and published a document on strategy and work plan for 2005-2010. CIAT activities of the Systemwide Program on SWNM are incorporated. Project logframe has been aligned to support goals of MDG, MEA and CGIAR Science Council priorities.

PE-2 Project Log Frame as in CIAT MTP 2005-2007

Project: **Integrated Soil Fertility management in the tropics**
Project Manager: **Nteranya Sanginga**

Narrative Summary	Measurable Indicators	Means Of Verification	Important Assumptions
Goal To strengthen national and international capacity to manage tropical ecosystems sustainably for human well-being, with a particular focus on soil, biodiversity and primary production; to reduce hunger and poverty in the tropics through scientific research leading to new technology and knowledge; and to ensure environmental sustainability through research on the biology and fertility of tropical soils, targeted interventions, building scientific capability and contributions to policy.	The principles of sustainable development integrated in country policies and programs. Reversal of the losses of environmental resources, especially loss of soil and below-ground biodiversity. Capacity built in tropical countries for sustainable management of natural resources. Developmental and environmental objectives taken inter-dependently.	National plans, human development and environment reports. Data from international organisations (UNEP, FAO, CG-institutes) that monitor the state of environmental resources. Impact studies, IARC and NARS reports, papers and publications.	Continued government and donor support. Sustained political and financial support for agricultural research and protecting the environment. Linkages maintained among research and development organizations.
Purpose To support the livelihoods of people reliant on agriculture by developing profitable, socially-acceptable and resilient agricultural production systems based on Integrated Soil Fertility Management (ISFM); to develop Sustainable Land Management (SLM) in tropical areas through reversing land degradation; and to build the human and social capital of all TSBF-CIAT stakeholders for research and management on the sustainable use of tropical soils.	By 2015, in at least two countries in each of the major tropical regions where TSBF-CIAT works, the number of rural people in extreme poverty reduced by 20%. By 2010, capacity built in at least three partner countries by at least three of the following: - a national level policy or legislative instrument developed by reference to a TSBF output. - all soil-related national institutions linked to TSBF networks with at least 50% of their scientists engaged in TSBF-inspired topics. - extension agencies and/or NGOs take up TSBF outputs to apply in their work programs. - farmers' organisations and/or civil society apply TSBF outputs in their plans and work. By 2008, TSBF-CIAT scientists are leading globally-funded research on at least three topics of key relevance to the international community (as identified in GEF, MDG, MEA, CGIAR mission and goal statements).	Reports of collaborating national and international institutions – in poverty reduction and sustainable development. National agencies surveys, development plans and reports. International agencies mission and goal statements related to TSBF-CIAT annual reports and accounts.	Poverty reduction strategies remain central to human development support and funding. TSBF stakeholders remain engaged with TSBF-CIAT strategic priorities and/or TSBF management continues to adapt and innovate in response to changing priorities. Funding for research on globally-important issues continues.
Output 1 Biophysical and socioeconomic processes understood, principles and concepts developed for protecting and improving the health and fertility of soils.	By 2006, indicators of soil health and fertility at plot, farm and landscape scales identified. By 2008, practical methods for rapid assessment and monitoring of soil resource base status developed. By 2010, decision tools for soil biota, nutrient and water management developed and disseminated to stakeholders.	Annual Reports/ publications. Reviews published. Documents of synthesized results. Detailed tables published in Annual Report. Decision guides for ISFM developed.	Sufficient operational funds for soil and plant analyses. Literature on constraints available. Farmers continue to participate. Projects SN-1, PE-3 and PE-4 actively participate. Active collaboration with participatory research project (SN-3), RII and NARS.

Narrative Summary	Measurable Indicators	Means Of Verification	Important Assumptions
Output 2 Economically viable and environmentally sound soil, water, and nutrient management practices developed and tested by applying and integrating knowledge of biophysical and socioeconomic processes.	By 2006, decision support framework for ISFM developed, tested with and made available to stakeholders in at least 2 benchmark countries. By 2008, communities in at least 3 countries demonstrate and test direct or indirect management options that enhance locally important ecosystem services using BGBD. By 2010, local baselines and interviews show that farmers' understanding of soil processes is demonstrably enhanced within community-based experimentation in at least 5 benchmark sites.	Annual Reports/ publications. Scientific publications. Soil and crop management guidelines published. Decision support systems developed. Annual reports.	Sufficient operational funds for soil and plant analyses. Literature on constraints available. Farmers continue to participate. Projects SN-1, PE-3 and PE-4 actively participate. Active collaboration with participatory research project (SN-3), RII and NARS.
Output 3 Partnerships developed and capacity enhanced for improving the health and fertility of soils of all stakeholders.	By 2005, AfNet, MIS, SARNET and BGBD Networks restructured and strengthened. Publications (i.e., journal papers, books, extension materials, policy briefs, etc.), workshops, documentaries, field days implemented by each project. By 2010, tools for dissemination of research knowledge developed by each project. By 2010, appropriate policies and innovative institutional mechanisms developed and promoted.	Annual Reports/ publications. Scientific information (theses, publications, workshop reports, project documents) disseminated to network members and all stakeholders. Network trials planned and implemented with partners. Degree-oriented and on-the-job personnel trained (Farmers, NARS, NGO's).	Continued interest/participation of NARS and ARO partners, and national and international universities. Continued support for collaborative activities e.g. Challenge programs.
Output 4 Improved rural livelihoods through profitable, diverse and intensive agricultural production systems.	By 2006, cereal-legumes and livestock systems, with nutrient use efficiency as an entry point, tested and adapted to farmer circumstances. By 2006, Quesungual and other related agroforestry systems, with water conservation as entry point, including crop diversification strategies, tested and adapted to farmer circumstances. By 2006 increase farm income and production in at least 20 pilot sites in at least 6 countries. By 2007, banana and cassava based systems, with the relation between pest, diseases and ISFM as entry point, including novel cropping sequences, tested and adapted to farmer circumstances. By 2008 improved production systems have triple benefits of food security, income and environmental services. By 2008, farmers are testing and adapting improved production systems in at least 15 sites in 5 countries. By 2010, validated intensive and profitable systems are being demonstrated, promoted by partners and adopted by farmers in 10 countries.	Annual Reports/ publications. Farmer's surveys. Regional/national production statistics. Land use surveys (satellite imagery, rapid rural appraisal).	Land survey data available. Farmers adopt new technologies. Socioeconomic conditions are favorable for achieving impact. Adequate resources available for soils research.
Output 5 Sustainable land management for social profitability developed, with special emphasis on reversing land degradation.	By 2007, identification, characterization and monitoring of degraded lands available for at least 2 regions. By 2008 methods for socioeconomic evaluation/valuation of ecosystem services for trade-off and policy analysis used, at least in 2 humid and 2 sub-humid Agro-ecological zones. By 2010, 30% of partner farmers in pilot sites used SLM options that arrest resource degradation and for increased productivity in comparison with non-treated farms.	Annual Reports/ publications. Farmers surveys. Regional/national production statistics. Land use surveys (satellite imagery, rapid rural appraisal).	Land survey data available. Farmers adopt new technologies. Socioeconomic conditions are favorable for achieving impact. Adequate resources available for land management research.

PROJECT PE-2: INTEGRATED SOIL FERTILITY MANAGEMENT IN THE TROPICS (CIAT-MTP 2006-2008)

	Outputs	Intended User	Outcome	Impact
OUTPUT 1	Biophysical and socioeconomic processes understood, principles, concepts and methods developed for protecting and improving the health and fertility of soils	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Principles, concepts and methods inform technology and system development	Improved soil health and fertility contribute to resilient production systems and sustainable agriculture
Output Targets 2006	Impact of three contrasting cropping systems on productivity and nutrient dynamics in hillsides and savannas quantified	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Partners testing the promising production systems	
	Standard methods for BGBD (belowground biodiversity) inventory published	CGIAR, ARIs, researchers from NARS and local universities, regional consortia	Partners and other global scientists using standard methods for BGBD inventory	
	At least three indicators of soil health and fertility at plot, farm and landscape scales in hillsides of Africa identified	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Partners begin validating indicators of soil health and fertility	
Output Targets 2007	At least three indicators of soil health and fertility at plot, farm and landscape scales in acid soil savannas identified	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Partners begin validating indicators of soil health and fertility	
	Land use intensity impact on BGBD evaluated in seven tropical countries participating in the BGBD project	Scientists participating in the BGBD project, ARIs, CGIAR, researchers from NARS and local universities, and farmers	Links between BGBD and land use management established and used as basis for developing sustainability in tropical farming systems	
	At least two indicators of soil quality used for farmer's decision making in hillsides agroecosystem;	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Partners incorporate farmer decision making in new proposals and on–going activities	
Output Targets 2008	Practical methods for rapid assessment and monitoring of soil resource base status developed	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Partners are using the methods with farmers	

	Outputs	Intended User	Outcome	Impact
	The social, gender, and livelihood constraints and priorities affecting the sustainable use of soils have been identified, characterized, and documented through case studies using innovative methods	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Partners are working to overcome the identified constraints with new proposals and on-going research	
OUTPUT 2	Economically viable and environmentally sound soil, water, and nutrient management practices developed and tested by applying and integrating knowledge of biophysical, socio-cultural and economic processes	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Technologies, systems and soil management strategies \adopted and adapted through partnerships	Adapted technologies contribute to food security, income generation and health of farmers
Output Targets 2006	Decision support framework for ISFM developed, tested with and made available to stakeholders in at least two benchmark countries in Africa	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Partners incorporating the DSS in new proposals and on-going research efforts	
	Cereal-legumes and livestock systems, with nutrient use efficiency as an entry point, tested and adapted to farmer circumstances in hillsides of Africa	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Cereal-legume systems and soil management strategies adopted and adapted through partnerships	
Output Targets 2007	Banana, bean and cassava-based systems, with the relation between pest, diseases and ISFM as entry point, including novel cropping sequences, tested and adapted to farmer circumstances in Africa	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Banana, bean and cassava-based systems and soil management strategies adopted and adapted through partnerships	
	Cereal-legumes and livestock systems, with nutrient use efficiency as an entry point, tested and adapted to farmer circumstances in acid soil savannas	CGIAR, ARI, researchers from NARS and local universities	Cereal-legume systems and soil management strategies adopted and adapted through partnerships	
Output Targets 2008	Communities in at least three countries demonstrate and test direct or indirect management options that enhance locally important ecosystem services using BGBD	BGBD network, CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, policy makers and global conservation organizations	Researchers, farmers, land users and policy makers and global conservation organizations increase their awareness of the benefits of conserving and managing BGBD	

	Outputs	Intended User	Outcome	Impact
	Quesungual and other related agroforestry systems, with soil and water conservation as entry point, including crop diversification strategies, tested and adapted to farmer circumstances in Central America	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	Quesungual system and soil management strategies adopted and adapted through partnerships	
OUTPUT 3	Partnerships and tools developed and capacity enhanced of all stakeholders for improving the health and fertility of soils	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	Strengthened and expanded partnerships for ISFM facilitate south-south exchange of knowledge and technologies	Improved institutional capacity in aspects related to ISFM and SLM in the tropics contribute to agricultural and environmental sustainability
Output Targets 2006	At least two capacity building courses on ISFM held	AfNet, MIS	Partners incorporating new knowledge and skills in new proposals and on-going research efforts	
	At least five capacity building courses on BGBD held at the global level and more at participating country level	BGBD partners, researchers, local universities and NGOs	Partners incorporating new knowledge on BGBD and skills in new proposals and on-going research efforts	
Output Targets 2007	Strategy for building capacity for SLM is developed with partners	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	TSBF-CIAT scientists and partners lead globally-funded research on at least three topics of key relevance to the international community (as identified in GEF, MDG, MEA, CGIAR mission and goal statements)	
	At least three capacity building courses on ISFM held by AfNet and MIS	AfNet, MIS	Partners incorporating new knowledge and skills in new proposals and on-going research efforts	
	Books, web content and papers produced by partners in BGBD project both north and south in seven tropical countries	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	Partners incorporating new knowledge and skills in new proposals and on-going research efforts	

	Outputs	Intended User	Outcome	Impact
Output Targets 2008	Farmer-to farmer knowledge sharing and extension through organized field trips and research activities result practices in at least two sites	Researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	Farmers realize benefits of knowledge sharing	
	Web content in the BGBD website enhanced to contain data and information on BGBD taxonomy and species identification	Researchers, CGIAR, ARI, local universities	Increased number of biodiversity scientists use the website for proper identification and classification of soil biota to species level	
OUTPUT 4	Improved rural livelihoods through sustainable, profitable, diverse and intensive agricultural production systems	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	Partners promoting resilient production systems with multiple benefits (food security, income, human health and environmental services)	Improved resilience of production systems contribute to food security, income generation and health of farmers
Output Targets 2006	Crop components and soil management technologies of improved systems promoted by partners in African hillsides	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	Farmers adopting improved system components, including crops and soil management technologies	
	Management practice options that increase or maintain BGBD in benchmark agroecosystems demonstrated by partners and farmers in seven tropical countries participating in the BGBD project	Researchers from NARS, local universities and farmers	BGBD and land use management strategies that enhance crop yields and ecosystem services produced and documented	
Output Targets 2007	Crop components and soil management technologies of improved systems promoted by partners in acid soil savannas	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers	Farmers adopting improved system components, including crops and soil management technologies	
	Crop-livestock systems with triple benefits tested and adapted to farmer circumstances in hillsides	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	Farmers are testing and adapting improved production systems in at least 15 sites across five countries	

	Outputs	Intended User	Outcome	Impact
	Strategies of BGBD management for crop yield enhancement, disease control, and other environmental services demonstrated in seven tropical countries participating in the BGBD project	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	Farmers and governments adopting BGBD technologies in crop production and ecosystems services	
Output Targets 2008	Improved production systems having multiple benefits of food security, income, human health and environmental services identified	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	Market-led hypothesis is incorporated in systems experimentation; Different partners linking food security, environmental sustainability and income generation to health	
	Crop-livestock systems with triple benefits tested and adapted to farmer circumstances in savannas	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	Farmers are testing and adapting improved production systems in at least 15 sites across five countries	
OUTPUT 5	Options for sustainable land management (SLM) for social profitability developed, with special emphasis on reversing land degradation	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, policy makers	Principles of sustainable land management integrated in country policies and programs	Reversing land degradation contribute to global SLM priorities and goals
Output Targets 2006	Potential for carbon sequestration estimated for at least one tropical agroecoregion	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, policy makers	Regional governments develop CDM projects based on the knowledge of carbon sequestration potential	
	Economic valuation of legume nodulating bacteria and soil structure carried out in at least five countries participating in the BGBD project	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, policy makers	Visibility of BGBD economic viability and BGBD technologies appreciated and used by farmers, and disseminated by local, national and regional governments	
Output Targets 2007	Decision tools (GEOSOIL; Decision Tree) available for land use planning and targeting production systems in acid soil savannas	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, policy makers	Local organizations using the decision tools for land use planning	

	Outputs	Intended User	Outcome	Impact
	Biophysical, social and policy niches in the landscape for targeting SLM technologies and enhanced ecosystem services identified and prioritized	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, policy makers	Methods of SLM are incorporated in the design of landscape research	
Output Targets 2008	Methods for socio-cultural and economic valuation of ecosystem services developed and applied for trade-off and policy analysis used in at least in 2 humid and 2 sub-humid agroecological zones	CGIAR, ARI, researchers from NARS and local universities, BGBD network, NGOs, farmers, regional consortia, policy makers	Methods of SLM are incorporated in the design and evaluation of landscape research	
	In at least four of the countries participating in the BGBD project, policy stimulated to include matters related to BGBD management, and sustainable utilization.	CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, policy makers	Policy issues related to BGBD acquisition, exchange, intellectual property rights (IPR), benefits sharing, etc. included in local, national and regional government policies	

3. RESEARCH HIGHLIGHTS

Output 1: Biophysical and socioeconomic processes understood, principles, concepts and methods developed for protecting and improving the health and fertility of soils

Water harvesting and interactions with dry mixtures of phosphate rock (PR) and water-soluble P in West African Drylands: Collaborative research of TSBF-CIAT with its West African partners (ICRISAT, INRAN, INERA) and with the Financial Support of UNEP-GEF for the DMP project, sorghum production in the dry sahelian zone increased by 300-800% following different technologies combining water harvesting and nutrient management. The water harvesting technologies include use of Zai, halfmoon or stone bounds and these could be accompanied by additions of small quantities of manure, mineral fertilizers or their combination. This research has also shown that nutrients are more important than water even in the dry areas. In 2005, use of Zai alone in Tougouri, Burkina Faso for example, performed better than the use of either nitrogen or phosphorus fertilizer. Combinations of water harvesting and nutrient application highly increased yields due to better utilization of inorganic fertilizers. Even when both Zai and halfmoon technologies were tested with combinations of water soluble P and phosphate rock in farmers' fields, similar yield increases were observed. From the studies, combining ¼ of water soluble P and ¾ of natural PR lead to the same yield as treatment where water soluble P was 100%. Water harvesting through Zai, half moon, use of tied ridges and stone bounds combined with nutrients such as manure, inorganic N and P and phosphate rock are some of the soil improvement technologies being scaled up in DMP West African countries by AfNet-TSBF, ICRISAT and other partners.

Overcoming phosphorus (P) deficiency in West African farming systems through Hill Placement and improving phosphate rock (PR) efficiency: Work done by TSBF-CIAT and its partners for several years with funding from Rockefeller Foundation focusing on phosphorus (P) availability has resulted in technologies that are now being taken up by farmers. The focus on P was because it is the most limiting nutrient to cop productivity in West Africa and about 80% of the African soils have inadequate supply. The technologies include hill placement of small quantities of P rather than broadcasting and combining PR with some water-soluble P. The work has shown that leguminous crops and cover crops in natural and managed fallows can take full advantage of biological nitrogen fixation in the presence of adequate P levels in the soils. It focused on utilizing PR deposits that are plenty in Africa by increasing their activity and suitability for direct application through use of PR together with water-soluble P. For several years, we have observed that the efficiency of Phosphate Rocks (PRK and PRT) can be increased above that of soluble P when a little amount of the soluble P is combined with the PR. Combining PR with 25% water-soluble P in has not shown any differences from its combination with 50%, 75% or 100% water soluble P. This clearly shows that placement of small quantities of water-soluble P fertilizers can improve the effectiveness of phosphate rock. To increase the impact of this outcome, Governments in West African Countries will require to invest more in bringing PR closer to the people or by facilitating this process to be carried out by entrepreneurs.

Strategic research in Latin America contributes to research for development in Africa: A participatory approach and a methodological guide were developed to identify and classify local indicators of soil quality and relate them to technical soil parameters and thus develop a common language between farmers, extension workers and scientists. This methodological guide was initially developed and used in Latin America and the Caribbean-LAC (Honduras, Nicaragua, Colombia, Peru, Venezuela, Dominican Republic), and was later improved during adaptation and use in eastern African (Uganda, Tanzania, Kenya, Ethiopia) through a South-South exchange of expertise and experiences. The aim of the methodological guide is to constitute an initial step in the empowerment of local communities to develop a local soil quality monitoring and decision-making system for better management of soil

resources. Impacts on higher education (Makerere University, Uganda), on a regional organization (African Highlands Initiaive, Tanzania) and on an international NGO (CARE International, Kenya) have been recently documented. Another example highlighted in several 2005 publications includes the use of the In Vitro Dry Matter Digestibility (IVDMD) lab assay as an excellent predictor of decomposition and N release in the soil, especially because it has important implications in resource savings when screening multi-purpose plants to be used as green manures.

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

Determining the effects of tillage systems on soil physical properties, root distribution and maize yield on a Colombian acid-savanna Oxisol: Tillage system may affect many soil properties, which in turn may alter the soil environment and consequently may impact on root growth and distribution, and crop yield. In 1993, a long-term field experiment on sustainable crop rotation and ley farming systems was initiated on a Colombian acid-savanna Oxisol to test the effects of grain legumes, green manures, intercrops and leys as possible components that could increase the stability of systems involving annual crops. Five agropastoral treatments (maize monoculture, maize-soybean rotation, maize-soybean green manure rotation, native savanna, maize-agropastoral rotation) under two tillage systems (no tillage and minimum tillage) were investigated. Lower bulk density and higher total porosity for all treatments and soil layers was found in no-till as compared to the minimum tillage system. Between the two tillage systems, significantly higher maize grain yields were obtained under no-till agropastoral treatments as compared to the same treatments under minimum tillage. Maize yields on native savanna soils were markedly lower than in the rest of the treatments, indicating the need for improved soil conditions in subsoil layers for root growth of maize.

Determining the effects of tillage systems on soil organic matter pools and soil phosphorus fractions and maize yield on a Colombian acid-savanna Oxisol: Soil organic matter and phosphorus fractions play a key role in sustaining the productivity of acid-savanna Oxisols and are greatly influenced by tillage practices. In 1993, a long-term field experiment to test the sustainability of crop rotation and ley farming systems was initiated on the acid-savanna soils of Colombia. Five agropastoral treatments (MMO-maize monoculture, MSR-maize-soybean rotation, MGM-maize-soybean green manure rotation, NSC-native savanna (control) and MAP-maize-agropastoral rotation) under two tillage systems (minus chisel-MC and

plus chisel-PC) were investigated. The effects of chisel (vertical) tillage on soil organic matter (SOM) and phosphorus (P) fractions as well as maize grain yield under the five treatments were evaluated, seven years after establishment of the experiment. Results showed that the weights and nutrient contents of the SOM fractions decreased in the order LL (light Ludox fraction) > LM (intermediate Ludox fraction) > LH (heavy Ludox fraction). Treatment MGM had significantly higher values for the P fractions under both tillage systems. However, PC tillage resulted into slightly higher maize grain yields as compared to MC. Within MC tillage system, the trend of maize grain yield was MGM > MMO > MSR > MAP > NSC, while for the PC tillage system, it was MGM > MSR > MMO > MAP > NSC. Future research should focus on integrated approaches that combine biophysical and socio-economic parameters to evaluate the sustainable productivity of Colombian savanna Oxisols.

Identifying and overcoming the limitations for implementing conservation farming technology in the Fuquene watershed (Colombia) by integrating socioeconomic and biophysical research with financial mechanisms: Reduced tillage, rotations with green manures and direct drilling are agriculture conservation practices selected by CONDESAN, CIAT and GTZ (WFCP project) to be promoted in order to reduce the deposition of sediments, N and P in the Fuquene Lake, which is suffering an advanced process of eutrophication. Previous studies demonstrated that this alternative could reduce the negative environmental externalities by about 50% as the net income and employment opportunities are increased. These studies were: 1) Identification of point and non point sources of pollutants; 2) Prioritization of areas according with their responsibility in the lake eutrophication; 3) Application of experimental economics methodologies to explore willingness of water users and farmers to cooperate for modifying negative environmental externalities, 4) Determination of poverty profiles and how are spatially distributed; and 5) Ex ante impact assessment of changing conventional tillage practices by farming conservation practices. Although, these studies showed that by incorporating conservation agriculture practices the net income is increased, the technological change is not reached readily since farmers' cash flows are unable to cover the required additional investment to incorporate green manures prior to the conventional crop is sown. For these reasons, the project designed a financial mechanism to investigate if the suspected restricted financial capacity of small farmers was constraining a massive technological change in the watershed. To reach this objective CONDESAN-GTZ made an agreement with the regional environmental authority (CAR) to assure the technical assistance needed for the implementation of the practices. Also, two farmers associations were introduced to the partnership acting as direct beneficiaries of the credits and also as intermediaries between CONDESAN and the smallest farmers who do not belong to the associations. These development actions are not only promoting technological changes but are creating in situ research scenarios for investigating the real constrains for using the soils in a sustainable manner. Therefore, this project expects to determine the biophysical ex post impact of these practices on the soils and lake conditions and the social and economic benefits caused by the technological change. If the results are positive, these practices will be incorporated as an alternative that can be compensated by a payment for environmental service (PES) scheme also promoted by the project.

Output 2: Economically viable and environmentally sound soil, water, and nutrient management practices developed and tested by applying and integrating knowledge of biophysical and socioeconomic processes

Progress in defining the key principles behind the successful adoption of Quesungual slash and mulch agroforestry system (QSMAS): The QSMAS is an alternative to the slash and burn management system. It is based on planting annual crops (maize, sorghum, beans) and pastures under an indigenous slash and mulch management system. It combines the regrowth of native forest vegetation with no burning and zero tillage/direct planting operations on a permanent soil cover. More than 6,000 farmers covering an estimated area of 7,000 ha, who have adopted the QSMAS system during the last ten years in Honduras, have increased crop yields by more than 100% (maize from 1200 to 2500 kg/ha, beans from

325 to 800 kg/ha) in comparison with the traditional slash and burn system. In 2004, TSBF-LA and MIS consortium in Central America obtained special project funding from the Water and Food CP to conduct a collaborative research program to determine the key principles behind the social acceptance and biophysical resilience of QSMAS. The specific objectives of the project are: 1) To assess socio-economic and biophysical context of QSMAS; 2) To define QSMAS management concepts and principles and to develop relevant tools to monitor soil and water quality; 3) To evaluate and document potential areas suitable to QSMAS and 4) To develop tools for dissemination, adaptation and promotion of the QSMAS management strategies. During this year, field research and validation activities have been implemented in Honduras and Nicaragua. Preliminary results indicate that soil losses due to erosion are negligible and water conservation is increased because of permanent mulch on the soil. Excess water leaving the system by runoff is almost clean and can be used by downstream users. However, there are methodological challenges to determine water dynamics in the soil because of the high proportion of stones in the soil. Preliminary results from the plot experiments on farmers' fields are showing strong interactions among key factors such as soil fertility, water availability and crop productivity.

Adoption of new soil conservation technologies in the Llanos of Colombia - Arable layer building technology: As a result of CIAT's collaborative research activities with regional partners (Corpoica, Pronatta and Unillanos) and with the financial support from the Ministry of Agriculture and Rural Development (MADR) and Colombian Science Foundation (COLCIENCIAS), a series of soil improvement and conservation practices have been developed. These practices focus on arable layer building technologies —part of the soil profile that can be modified through a combination of biological and physical management— in soils of the well-drained savannas of the Llanos of Colombia. These practices include use of proper crop and pasture rotations in agropastoral systems. Practices for arable layer building include a vertical corrective tillage using rigid chisels, correction of nutrient deficiencies in soil and sowing of acid soil adapted tropical forages with vigorous root systems and field crops with greater yield potential. Farmers in the Llanos region of Colombia are the main users of this outcome. Farmers in the past attempted to establish crops without adequate soils management and used non-adapted pasture and crop germplasm, and consequently experienced large economical failures. In contrast to their previous experiences, utilization of soil conservation methodologies together with the use of improved germplasm have shown significant advantages in productivity and in economic returns to the investments made. Recent impact studies conducted by CIAT and its partners indicated that the productivity gains constitute the principal benefit for those who apply soil conservation practices in the Llanos. Research publications, technical bulletins, extension brochures and progress reports in both English and Spanish documented the development of technologies. It is considered that for achieving wider impacts of arable layer soil management technologies, investment by the Colombian government in improving road infrastructure is critical.

Output 3: Partnerships and tools developed and capacity enhanced of all stakeholders for improving the health and fertility of soils

Strengthening research for development capacity of the AfNet: The year 2005 was marked by a continued growth of AfNet membership to over 350 members. During this period, AfNet continued the implementation of the Network trials located in over 80 sites in different agroecological zones distributed in East, South, Central and West Africa regions. These experiments have increased understanding on the sustainable management of the natural resource base and have generated and demonstrated new technologies that can help boost food production among the smallholder farmers in the continent. AfNet Steering Committees meeting was held during which the role of the Network in achievement of the TSBF Strategy was discussed. AfNet successfully organized two training courses: Participatory Approaches to Research and Scaling Up, attended by 37 participants, and the Decision Support Systems for Agrotechnology Transfer (DSSAT) training workshop attended by 29 participants. AfNet ensured the

review of over 100 papers presented during the Yaoundé Symposium in readiness for the publication of the AfNet Symposium Book and the Special Issue in Nutrient Cycling in Agroecosystems in 2006. Several proposals were also developed of which 10 received funding from various donors. AfNet published the TSBF newsletter, *The Comminutor*, which highlighted research issues in Latin America. The Network continues to be a pan African Network and will continue in its effort to coordinate and promote information sharing for the sustainable and integrated management of natural resources in the continent.

Advances in Conservation and Sustainable Management of Below-ground Biodiversity (CSM-BGBD) Project: The year 2005 was a major milestone for the CSM-BGBD project. It is the year when nearly all partners in the project met in a joint meeting in Brazil to present the results from the BGBD inventory they had carried out in their individual countries. Brazil, Cote d'Ivoire, India, Indonesia, Kenya, Mexico and Uganda were all represented by a minimum of five participants. The meeting also had all the technical advisors, the steering committee members and the project advisory committee members attending and reviewing the project progress. The mid-term reviewers of the project were also in the meeting held in April 2005 in Manaus Brazil. Technical papers were presented covering: Benchmark area descriptions and socio-economic characterization, Inventory of soil macro-fauna, Inventory of nematodes and Meso-Fauna, The inventory of legume nodulating bacteria, arbuscular mycorrhizal fungi and ectomycorrhiza, The inventory of pathogenic and antagonistic fungi and insect pests, Presentation of the standard methods, Ecosystem service and soil quality indicators, Analysis of BGBD at landscape level and in different land use intensities, Output of economic valuation of BGBD for different soil functions and environmental services, Information management and data sharing in the project. The overall conclusion from the technical reviewers during the meeting was that the project had succeeded in agreeing on appropriate standard methods for most of the functional groups mandated and has used them to assemble a unique and comprehensive dataset during the period since the last Annual Meeting in 2004. Apart form these technical observations; the project was subjected to a mid-term review as was required of the project and contained in the project document. The reviewers of the project, Professor Eric Smaling of ITC-The Netherlands and Professor Mateete Bekunda of Makerere University-Uganda, returned a final mid-term review rating of 'Good' for the project and recommended its continuation into the second phase that has now been approved by the Global Environmental Facility (GEF). There is ongoing progress of publishing all the technical papers presented in a Book to be released in late 2006. Partners during the BGBD annual meeting produced a total of 71 papers and four discussion papers in ecosystems services, land use intensity quantification, economic valuation of BGBD and data sharing and intellectual property rights. BGBD scientists participated in three global training workshops, two in Nairobi (ants and termites characterization) and one in India on mycorrhizal fungi. Individual countries organized workshops and training courses for their country partners and project executioners.

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

Scaling out conservation farming experience in Fuquene (Colombia) to other Andean watersheds: Ambato (Ecuador) and Jequetepeque (Peru): Ex-ante evaluation of land use alternatives had demonstrated that conservation agriculture is an SLM alternative for improving environmental services and rural livelihoods. Based on Fuquene (Colombia) experience, the special project "Payment for

Environmental Services" (CONDESAN-GTZ-CIAT) of the WFCP is promoting a capacity building strategy for enhancing other pilot sites farmers' capacities in conservation agriculture. The strategy has started with training courses held in the conservation agriculture pilot site (Fuquene) and subsequent courses held directly at the extrapolation sites. The participants for courses were selected according with their previous commitment to apply the learned practices in their own farms. The project, through its extension partners (GTZ), will provide continuous technical assistance for a year in order to ensure that the technology is properly applied during green manures and commercial crops sowing. In Peru, strategic alliances between the project local partner (CEDEPAS) and the farmers were created in order to establish pilot farms. Complementary research activities are conducted in order to measure the impact of these practices on soil physical properties and incidence of crop diseases. For 2006, pilot implementation of these soil conservation practices was agreed between a community-based organization and the project in Ecuador. The monitoring of impacts will be measured by CONDESAN and CIAT.

Output 4: Improved rural livelihoods through sustainable, profitable, diverse and intensive agricultural production systems

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

Improved decision making for achieving triple benefits of food security, income and environmental services through modeling cropping systems in Ethiopian Highlands: Food security in the Enset-based Ethiopian highlands is constrained mainly by land degradation, land fragmentation and limited access to technologies and skills. Enset (Enset ventricosum) is a perennial herb with edible corm, supporting about 13 million people in Ethiopia. A household survey, supported by field measurements, was conducted over three years (2000–2002) with 24 representative farmers to identify their production objectives and to quantify their available land resources, cropping system, crop yields and market price, for developing models to facilitate their decision making. Farmers identified three major production objectives depending on their household priorities, socio-economic status and resource base. In Scenario I, farmers were primarily interested in producing enough food from their farm. In Scenario II, they wanted food security and to fulfil their financial needs. In Scenario III, farmers were interested solely in generating cash income, regardless of its effect on food production. The change from current production systems to Scenario I offers high quality livestock feed, while Scenario III offers low quality livestock feed whereby about 84% of the feed is coming from coffee husk. Moreover, a shift from the current system to Scenario I would not have any effect on the level of soil erosion, while a shift to Scenario II and III will reduce soil erosion by about 39 and 52%, respectively, mainly as a result of expansion of the area of perennial crops.

Output 5: Sustainable land management for social profitability developed, with special emphasis on reversing land degradation

Evaluation of the Dalhem Desertification Protocol to evaluate land degradation problems drought-prone areas of sub-humid tropics: An international workshop meeting was hosted by the MIS (Manejo Integrado de Suelos) Consortium, in Honduras as part of collaborative activities with ARIDnet, a collaborative research network on desertification supported by the National Science Foundation. The objective of the workshop was to validate the Dalhem Desertification Paradigm (DDP) to prioritise policy and management interventions through an integrated analysis (at multiple spatial scales) of both biophysical (meteorological and ecological factors) and socio-economic (human factors) dimensions of land degradation. The Honduras workshop extended the application of the DDP to land degradation and recovery of steepland agricultural systems in Central America, including an assessment of the unique "Quesungual" slash and mulch agroforestry system. The Quesungual system has already been adopted by 6,000 farmer households in Honduras, resulting in a two-fold increase in crop yields and cattle stocking rates and significant reduction in costs associated with agrochemicals and labour. Working as a team of local and international experts, the workshop addressed a complete DDP-based analysis of the opportunities for -- and limitations to -- the recovery of an agroecological system in the Guarita municipality, and the potential application of the Quesungual slash and mulch agroforestry system. In addition to local dissemination of the results, we plan to synthesize and submit the results of the workshop to a peer-reviewed international journal, with authorship open to all participants.

Watershed analysis to identify niches for sustainable land management and use - two case studies: The special project "Payment for Ecosystem Services" financed by the WFCP is applying in their different pilot sites a methodology for integrated watershed analysis. The results of this analysis are providing guidelines to design economic mechanism for ecosystem services conservation. The watershed analysis consisted of: 1) Hydrological modeling using SWAT (Soil & Water Assessment Tool) 2) Socioeconomic and environmental ex ante evaluation of land use and management scenarios, and 3) Determination of opportunity cost for implementing the proposed land use scenarios and valuation of environmental services. During 2005, this approach was applied in the Colombian and Peruvian pilot sites. In Colombia, the results are oriented towards financial mechanism for promoting conservation agriculture. In Peru, the analysis was conducted for the Mayo River watershed located in the transitional zone between the Andes and the Peruvian Amazon. Here, several micro watersheds supply water to various downstream urban aqueducts. However, the replacement of native forest by farming uses seems to be causing the increment of suspended solids in water flows and therefore, of the water treatment cost. With the hydrological analysis 28 Hydrological Response Unites were identified and 8 were prioritized because of their contribution to the environmental externalities (water flows and sediments) and land use change feasibility. In these areas the following scenarios were evaluated: coffee under shade, reforestation and live barriers in traditional production systems, coffee under shade being identified as the most appropriate alternative. Thus, although all potential scenarios produce less quantity of sediments (reduction of about 50%) than the traditional land use system (slash and burn – corn cropping – pastures), the coffee under shade scenario permits to increase farmers' income by 89% and labor employment by 77%. Regarding the design of a PES (payment for environmental services) mechanism, the value of economic payments was determined for each scenario by calculating the cost of a ton of reduced sediments. Thus, one ton of reduced sediments cost 1.31 tons of sediments or $53.6/ha/year during the first two years since this alternative only requires the initial investment as an incentive to replace the traditional land use. Regarding that the 7136 Moyobamba city families are willing to pay $1.5/month as a contribution for promoting watershed resources conservation. It was calculated that it was only required two month of payments to cover the cost required for promoting coffee under shade in the HRU prioritized in the Miskiyacu micro watershed.

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