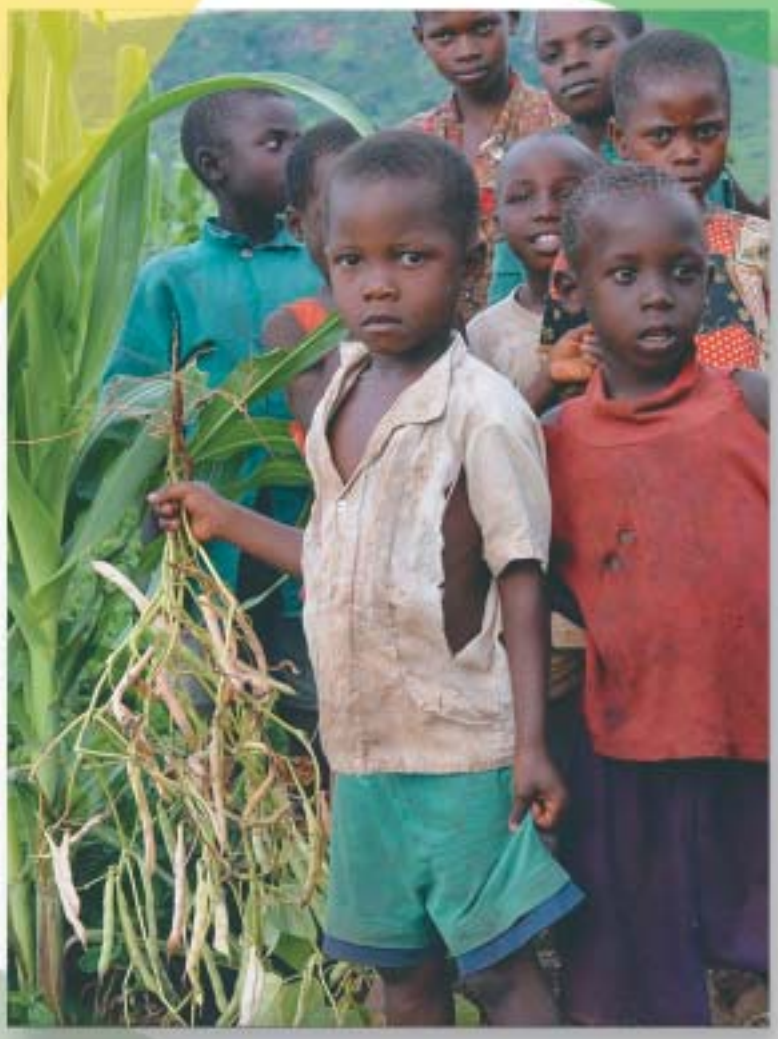
TSBF-CIAT's Strategy and Work Plan, 2005-2010

The Tropical Soil Biology and Fertility Institute of the International Center for Tropical Agriculture (TSBF-CIAT)



Integrated Soil Fertility Management in the Tropics: From Knowledge to Implementation

CIAT
Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

TSBF

About TSBF-CIAT

The Tropical Soil Biology and Fertility Programme (TSBF) was founded in 1984 to develop capacity for soil biology as a research discipline in the tropical regions, and to conduct research on the role of soil biology in maintaining or improving soil fertility and combating environmental degradation, on the premise that biological management of soil fertility is an essential component of sustainable agricultural development.

In 1997, the International Center for Tropical Agriculture (CIAT, or Centro Internacional de Agricultura Tropical) created a soils team in Latin America to focus on identification of strategic principles, concepts and methods for protecting and improving soil quality through the efficient and sustainable use of soil, water and nutrient resources in crop-pasture-fallow systems in tropical savannas and hillsides agroecosystems.

In December 2001, an agreement between CIAT and the TSBF Programme led to the latter's becoming an institute of CIAT (TSBF-CIAT). Today, the Institute operates as an integral part of the CIAT research programme, and the TSBF Director reports to the CIAT Director General. TSBF-CIAT staff are located in two major target areas in the tropics (Africa and Latin America), with the directorate housed on the World Agroforestry Centre (ICRAF) campus in Nairobi, Kenya.

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 also encompasses the **CGIAR's agricultural 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 CIAT's three Development Challenges: 1) Enhancing and Sharing the Benefits of Agrobiodiversity, 2) Improving the Management of Agroecosystems in the Tropics and 3) Enhancing Rural Innovation.

TSBF-CIAT's programme goals are: 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.

TSBF-CIAT utilizes a range of approaches to achieve programme 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 programme: The Institute's activities and outputs undergo periodic critical reviews to ensure high standards and the achievement of the Institute's mission.

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1. Soil fertility. 2. Soil management. 3. Cropping systems. 4. Soil biology. 5. Genetic resources. 6. Land management. 7. Socioeconomic environment. 8. Water management. 9. Capacity building. 10. Sustainability. 11. Organization of research. 12. Budgets. 13. Research projects. 14. Planning. 15. Tropical zones.

AGROVOC descriptors in Spanish:
1. Fertilidad del suelo. 2. Manejo del suelo. 3. Sistemas de cultivo. 4. Biología del suelo. 5. Recursos genéticos. 6. Ordenación de tierras. 7. Entorno socioeconómico. 8. Manejo de aguas. 9. Creación de capacidad. 10. Sostenibilidad. 11. Organización de la investigación. 12. Presupuesto. 13. Proyectos de investigación. 14. Planificación. 15. Zona tropical.

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Contents

Page

Figures

Tables

Boxes

Executive Summary

This document represents the strategy for the period 2005-2010 of the Tropical Soil Biology and Fertility Institute of CIAT (TSBF-CIAT). Since its founding in 1984, TSBF has conducted research on the role of biological and organic resources in tropical soil biology and fertility and its relationship to the natural and social environment, in order to provide farmers with improved soil management practices to sustainably improve their livelihoods.

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, cultural, economic and political.

However, successful resource management and sustainable agricultural productivity need to go still further, addressing socio-cultural realities in the realms of markets, health and policies. 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 equitable income generation and distribution can be bridged. Therefore, TSBF-CIAT's new strategy proposes to take ISFM further forward, by addressing the full chain of interactions from resources to production systems to markets, socio-cultural forces, and policies. Under the new framework, investment in soil fertility management represents a key entry point to sustainable agricultural productivity growth, and a necessary condition for obtaining positive net returns to other types of farm investments.

TSBF-CIAT will pursue the following objectives under the new strategy:

- to improve the livelihoods of people reliant on agriculture by developing sustainable, profitable, socially just and resilient agricultural production systems based on ISFM;
- to develop sustainable land management (SLM) practices in tropical areas while reversing land degradation; and
- to enhance 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 will be organized into six programmatic 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, cultural, and gender dynamics
5. linking farmers to markets; and
6. collaboration and strengthening of NARES capacity.

The above programmatic thrusts contribute to CIAT's Development Challenges:

- Enhancing and sharing the benefits of agrobiodiversity
- Improving the management of agroecosystems in the tropics and
- Enhancing rural innovation.

TSBF-CIAT's strategy will emphasize 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, economic poverty, population growth and a rising demand for food are 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).

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.

By 2010, significant progress will have been made towards generating the following outputs:

- biophysical and socioeconomic processes understood, principles and concepts developed for protecting and improving the health and fertility of soils and people's livelihoods;
- sustainable soil, water, and nutrient management practices developed and tested by applying and integrating knowledge of biophysical and socioeconomic processes;
- improved rural livelihoods through profitable, diverse and intensive, sustainable agricultural production systems;
- sustainable land management practices developed for social profitability, with special emphasis on reversing land degradation; and
- partnerships developed and capacity enhanced among all stakeholders for improving the health and fertility of soils.

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

Agrobiophysical scientists: These include specialists in ISFM, 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.

The estimated funding required for TSBF-CIAT's work is approximately US$5 million per year, for a total budget of about $30 million over the projected 6-year period.

1. Building on the Past, Looking to the Future: TSBF-CIAT's Focus, 1984-2010

1.1. Historical background: TSBF-CIAT's work, 1984-2004

The Tropical Soil Biology and Fertility Programme was established in 1984 to address four broad objectives:

1. Improve understanding of the role of biological and organic resources in tropical soil fertility and their management by farmers, in order to improve the sustainability of land-use systems.
2. Provide land users in the tropics with methods for soil management which improve agricultural productivity while conserving the soil resource.
3. Increase the carbon storage equilibrium and maintain the biodiversity of tropical soils in the face of global change in land-use and climate.
4. Enhance the research and training capacity of national institutions in the tropics in the fields of soil biology and management of tropical ecosystems.

Between 1984 and 2000, TSBF research focused on nutrient cycling, the factors driving agricultural intensification and land degradation, and the dynamics of organic matter management. Organic matter management is as old as the history of agriculture, but has been substantially uninformed by formal science. Correcting this omission has been TSBF's main biophysical challenge, successfully met over the last 2 decades. The focus has been to develop methods—most notably the "synchrony"' concept—for efficient management of organic matter decomposition and nutrient release.

From these origins, the institute was a pioneer in guiding the research for development agenda towards a paradigm of integrated soil fertility management (ISFM; see **Figure 1**). 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, cultural, economic and political. There is a strong emphasis in ISFM research on understanding and seeking to manage the processes that contribute to changes in soil fertility. The emergence of this paradigm, very closely related to the wider concept of integrated natural resource management

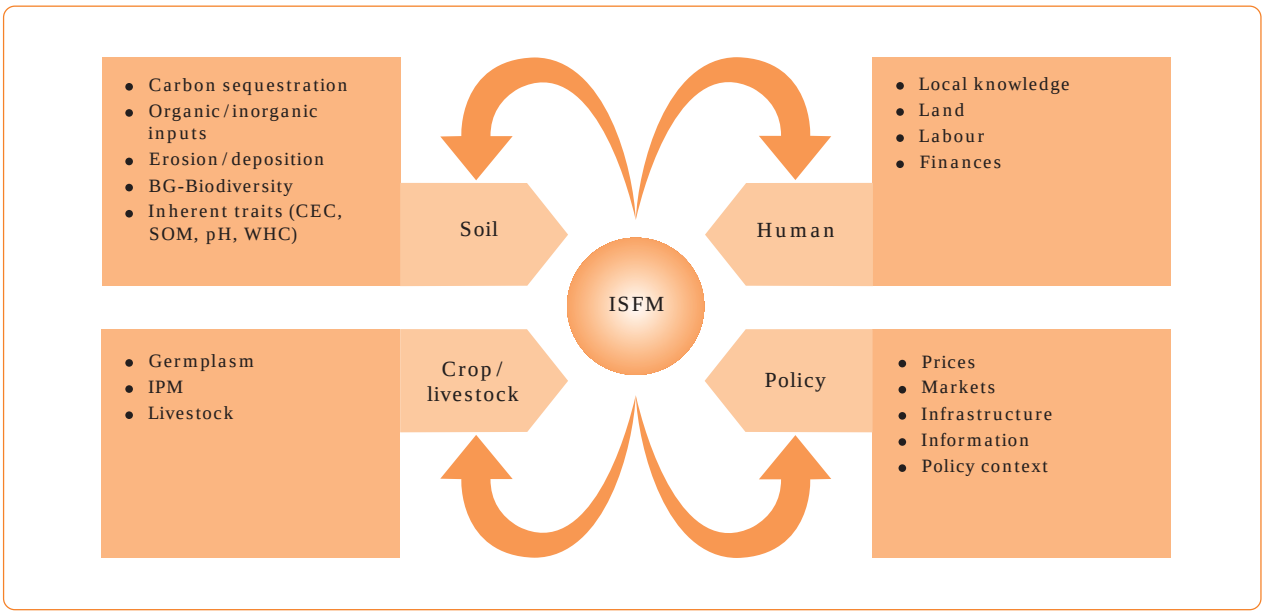

Figure 1. The processes and components of integrated soil fertility management (ISFM) [BG: below-ground; CEC: cation exchange capacity; SOM: soil organic matter; WHC: water holding capacity; IPM: integrated pest management].

(INRM), represents a significant step beyond the earlier, narrower, nutrient replenishment approach to soil fertility enhancement.

Work during the 2000-2004 period focused on developing the technical backbone of ISFM strategies, involving the roles of organic resources, mineral fertilizer, and soil organic matter in providing soil-related goods and services (**Box 1**). Potential positive interactions between these three factors are given special attention, leading to added benefits in terms of higher crop yields, improved soil fertility status, and/or reduced losses of nutrients and C to the environment. Increasing emphasis has been placed on aspects of ecosystem structure and function that operate at the interface between agricultural productivity, resource conservation and environmental services. TSBF-CIAT research in this area has covered such topics as estimation of ecosystem carbon budgets, reduction of greenhouse gas emissions, and increase of soil biodiversity.

During the same period, the social backbone of TSBF-CIAT's research addressed understanding the role of farmer diversity (gender, social differentiation, and general political-economic context) in shaping soil fertility management strategies. Key research activities advanced understanding of changing land-use dynamics under agricultural intensification, produced and studied methods to integrate local and technical knowledge of soils, and investigated the role of social networks and partnerships in scaling up knowledge-intensive soil management technologies.

Box 1. Highlights of TSBF-CIAT research outputs and impacts, 1984-2004

- **Organic Resource Database** (ORD), unique for synthesizing information from numerous sources on decomposition processes and nutrient dynamics to provide organic resource quality parameters (e.g., macronutrient, lignin and polyphenol contents for almost 300 tropical species);
- Data on the climate and soils from ORD sites, as well as decomposition and nutrient-release rates;
- A decision guide for organic nitrogen management based on synthesis of data within the ORD;
- Decision Support System (DSS) for organic N management based on relationships between residue quality and N-mineralization, validated in sub-Saharan Africa on biomass transfer systems with maize;
- A concept on the need for building up an arable layer in savannas to adopt no-till systems;
- A concept of on-farm nutrient recycling to reduce soil erosion and improved food security in hillsides;
- An approach to quantify the potential of arbuscular mycorrhizal fungi to recuperate soil structure;
- An approach of linking soil organic matter fraction to soil phosphorus (P) fraction related to plant available P in the soil;
- Options for improved fallow management;
- A decision tree for targeting production systems based on soil texture, slope and depth;
- A tool for land use planning based on soil quality characteristics (Geosoil);
- Methods for using participatory research techniques to initiate and support community-based experimentation and learning for improved soil management;
- A guide to link local and scientific knowledge systems on indicators of soil quality;
- Publication of books (on Biological Management of Tropical Soil Fertility, Agropastoral Systems, Sustainable Land Management and Soil Biota), and publication of research results in over 200 journal articles and 50 book chapters;
- Capacity building in soils research through training of over 150 undergraduate and 50 postgraduate and graduate students.

In collaboration with a large number of partners, the CIAT Latin American Soils team won the CGIAR's 2001 Excellence in Science Award in the Outstanding Partnership category for their work on "Sustainable Land Management of Acid Soil Savannas".

1.2. Core features of the 2005-2010 strategy

Research on natural resource management (NRM) has been criticised for not addressing the real needs of rural people and hence has often been judged irrelevant. In the march to generate solutions to farmers' problems, research has generated a wide variety of technologies, such as fertilizers, improved legume germplasm and crop rotations. ISFM arose because of the

recognition that addressing the ***interactions*** between components (e.g., water, pests and soils) is as important as dealing with the components themselves. However, improving the natural resource base without addressing issues of marketing and income generation (e.g., the resource-to-consumption logic) seems sterile and is often the reason for a lack of adoption of improved farming practices. Successful resource management and sufficient and sustainable agricultural productivity need to go still further, into the realms of markets, health and policies.

Thus, while building on the ISFM model, TSBF-CIAT's new integrated research agenda proposes to address the full chain of interactions from resources to production systems to markets and polices. The central hypothesis is that NRM research will have more leverage if the apparent gaps between investment in the natural resource base and income generation can be bridged. Investment in soil fertility management is a key entry point to agricultural productivity growth and a necessary condition for obtaining positive net returns to other types of farm investments.

Figure 2 depicts the framework of the proposed strategy, showing how science and technology interventions link to health, market and policy domains. The linkages between

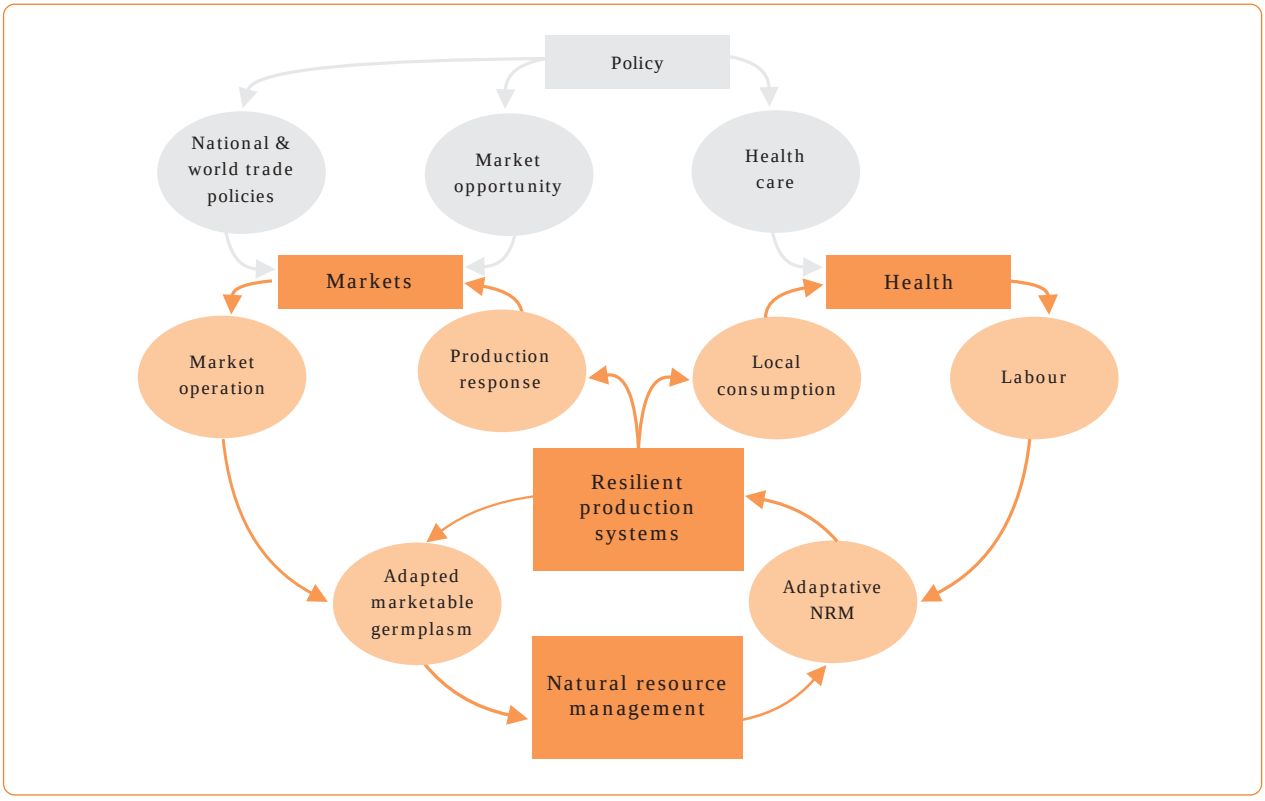

Figure 2. Conceptual framework of the new TSBF-CIAT strategy. The topics shaded in grey are driving forces beyond the control of the Programme. All of the other topics will be addressed by the proposed strategy.

NRM and the creation of resilient production systems are relatively well explored. However, the subsequent links with markets and health and their feedback on NRM still remain poorly understood, thus suggesting the need for a stronger research agenda in the latter domains (**Box 2**).

An important feature of this new strategy is the considerable degree of integration that will be called for between natural scientists, economists and other social scientists. This is driven by the Millenium Development paradigm, which posits that development is accomplished by people and builds on changes in behaviour. Under TSBF-CIAT's proposed strategy, CIAT social scientists will contribute to strategic studies of social and gender differentiation, indigenous soil ecological knowledge, farm-level decision making, power relations and farmers' networks as they relate to soil fertility management and the study of innovation systems.

Box 2. Understanding the context for TSBF-CIAT's evolving directions

Challenges and opportunities related to changes in science

Identifying the most appropriate agenda for a research institution such as TSBF-CIAT requires consideration of recent advances in the basic sciences, new technologies, and the social, political, and economic environment that influence the research mission. These advances provide researchers with new approaches and methods and allow research breakthroughs from one discipline to impact on another more quickly. However, despite the explosion in new methods and the amount of data available to scientists, the ultimate payoff from investment in applied research still relies on synthesis and transformation of information into useful packages of knowledge, tools and strategies.

In the past, most trials involving ISFM approaches have been conducted using either the black box approach or process research that was not relevant to the constraints in any given farming system. The possible mechanisms of biophysical and socio-cultural and economic processes and their modifiers (including policies) are generally well known, but the determination of their level of importance and their quantification in a certain system is often a problem. Researchers and farmers have experienced both positive and negative results of ISFM practices without the necessary knowledge explaining the failures and successes.

To unpack the "black-box" dynamics of soil fertility management, process studies are called for that aim at understanding and quantifying the mechanisms that regulate a system or one of its component parts. This allows extrapolation or prediction of the change in state variables of interest to other cropping systems and environmental conditions.

Two ways to prioritise the process studies that could be carried out under an ISFM framework are: (i) the work should be constraint-related, i.e., the constraints in the ISFM system could be used to evaluate the various processes that may be important to counteract the constraints; and (ii) the mechanisms of interest should be manageable and linked to the outputs on field management practices and ISFM systems development (it does not make much sense to study processes that are not manageable in the short or medium term).

(Continued)

Box 2. (Continued).

Changes in the role and capacity of partners

The agricultural research enterprise has become much more complex over the last 5 years with the emergence of sub-regional research organizations (SROs) that can contribute to planning, prioritisation, and coordination of the agricultural research agenda[1]. Increasingly over the past few years, TSBF-CIAT has made efforts to engage and respond to the research priorities of the sub-regional organizations. Involvement of the SROs in strategic planning and research coordination will become ever more important as TSBF-CIAT and the other CGIAR Centres explore opportunities to increase research efficiency by sharing resources and integrating programmes.

Change in the CGIAR System will affect TSBF-CIAT and its partners through regional research approaches, global challenge programmes and organizational changes. The Institute's strategic planning is coincident with strategic planning initiatives within CIAT and the CGIAR. Prioritisation and implementation of TSBF-CIAT's research agenda also depends on the political, social, and economic environment, both within the mandate region and globally. Moreover, funding for germplasm development and NRM research has been decreasing at a time when issues of food security and natural resource conservation are becoming more complex. Hence, the challenge for research institutions such as TSBF-CIAT is to invest limited resources in activities that promise a high impact and a solid rate of return.

Given all these factors, our strategic direction will focus on TSBF-CIAT's mission and role as a premier international soil research institution in the CGIAR, and will seek to highlight those areas in which TSBF-CIAT can play a leadership role because it has the critical mass and comparative advantage to do so.

1. In Africa, these organizations include the Forum for Agricultural Research in Africa (FARA), the Association for Strengthening Agricultural Research in East and Central Africa (ASARECA), the Southern Africa Centre for Cooperation in Agriculture and Natural Resources Research and Training (SACCAR-SADC/FANR) in southern Africa, and the Conseil Ouest et Centre Africain pour la Recherche et Développement Agricole (CORAF/WECARD) in west and central Africa. TSBF-CIAT's partner networks in Latin America include CONDESAN (Consorcio para el Desarrollo Sostenible de la Ecoregión Andina) and MIS (Manejo Integrado de Suelos).

1.3. Institutional goals and objectives

TSBF-CIAT's goals under the new strategy are:

- To reduce hunger and poverty in the tropics through scientific research leading to new technologies and knowledge (*CIAT Goal and Mission*; *Millennium Development Goal 1*)

- Ensure environmental sustainability through research on the biology and fertility of tropical soils, targeted interventions, building scientific capability and contributions to policy (adapted from *Millennium Development Goal 7*)
- Strengthen national and international capacity to manage tropical ecosystems sustainably for human well-being, with a particular focus on soil, biodiversity and primary production (adapted from *Millennium Ecosystem Assessment*).

To achieve these goals, the following objectives will be pursued:

- 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
- To build the human and social capital of all TSBF-CIAT stakeholders for research and management on the sustainable use of tropical soils.

It is imperative 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 as in the past, it is also ready to support technology dissemination and development activities with partners via regional and global networks.

To achieve its mission, TSBF-CIAT will continue to generate scientific knowledge, provide training and information, and participate in technology generation transfer with a wide range of partners. Work will be organized into six programmatic thrusts, which are related to TSBF-CIAT's objectives as shown in **Figure 3**. The Institute's six strategic thrusts are discussed in the following section. In Section 3, we outline how these thrusts are integrated within the outputs and activities that the Institute plans to pursue over the next 5 years. A more detailed logical framework structuring the Outputs to be carried out under the new strategy is presented in Appendix 1.

These six programmatic thrusts contribute to the three CIAT's key Development Challenges (DCs).

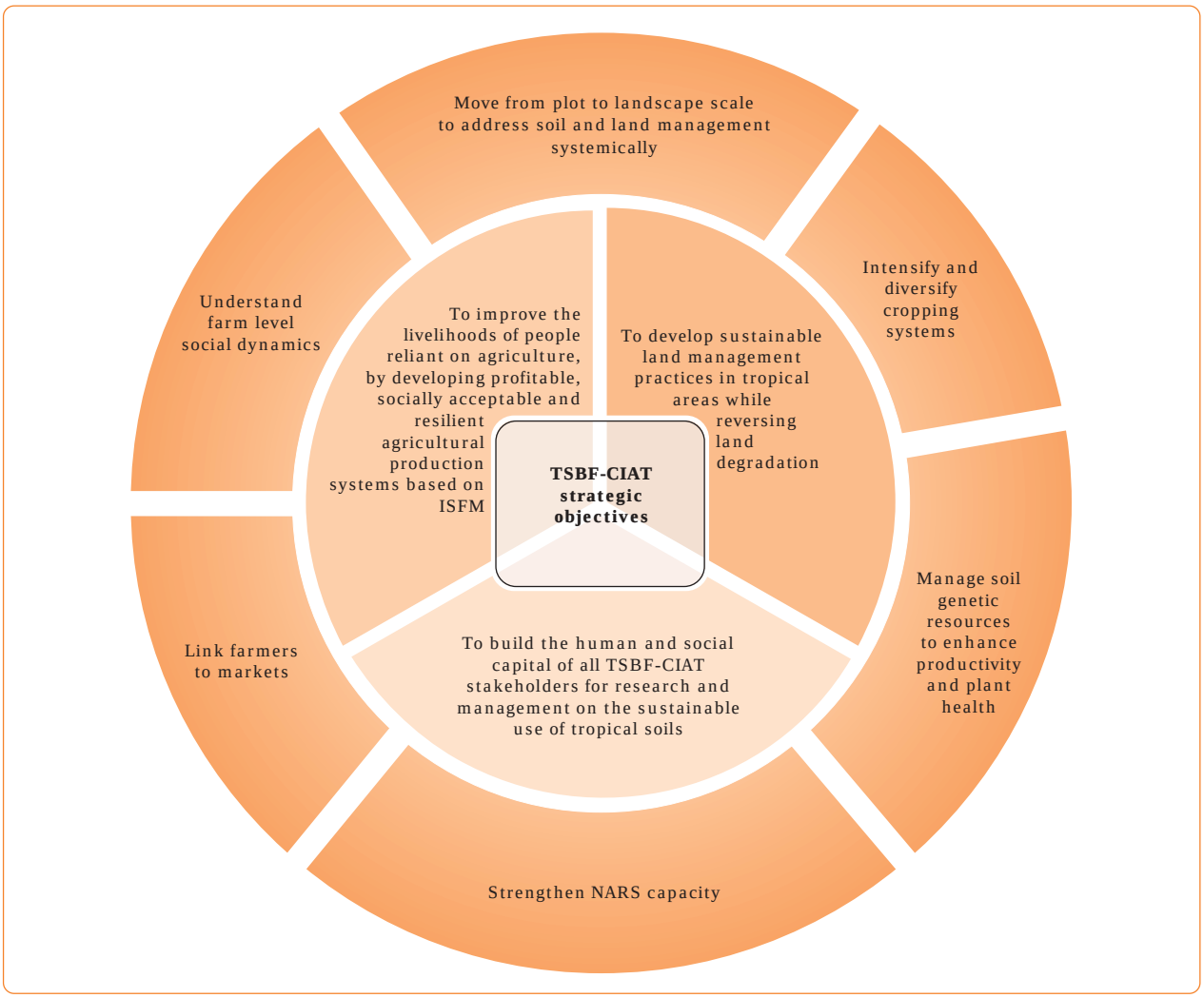

Figure 3. Relationship between TSBF-CIAT's objectives and six strategic thrusts.

DC 1. Enhancing and sharing the benefits of agrobiodiversity

Thrust 1. Intensification and diversification of cropping systems (resilient germplasm as an entry point for ISFM technologies)

Thrust 2. Managing the genetic resources of soil for enhanced productivity and plant health

DC 2. Improving the management of agroecosystems in the tropics

Thrust 1. Intensification and diversification of cropping systems (fertilizer research for practical land management study)

Thrust 3. Moving from plot to landscape scale to address SLM challenges

DC 3. Enhancing rural innovation

Thrust 4. Understanding farm level social dynamics

Thrust 5. Linking farmers to markets

Thrust 6. Strengthening NARS capacity

Similar to the TSBF-CIAT's objectives, these three Development Challenges contribute to reducing poverty through increased agricultural productivity, farmer's income and improved NRM.

2. Strategic Programme Focus, 2005-2010

2.1. Intensification and diversification of cropping systems

TSBF-CIAT's new strategy will emphasize developing and extending technologies that support sustainable intensification of cropping systems, especially in the dry and moist savanna and hillside agro-ecological zones (AEZs) in Africa and Latin America (see Section 4.1 for more detail on this point). In these AEZs, poverty, population growth and a rising demand for food increases pressure on marginal lands and/or remnant forest zones. This is accompanied by a shift towards shorter fallow periods and even continuous cropping. The strategic choice of pursuing sustainable intensification in these AEZs is based on three additional factors. First, large areas in Africa and Central America have already made the transition from crop-fallow to continuous cropping systems, a trend that is likely to accelerate. Second, under low soil fertility conditions, improved germplasm alone is not likely to achieve the required rates of improvements in food production, income, and natural resource conservation. Third, use of inputs to maintain soil fertility and improved germplasm have not been widely adopted, while disease outbreaks and increased pest pressure, especially from weeds and parasites like *Striga*, are often associated with intensification.

The most promising solution to achieving food security and protecting against natural resource degradation lies in sustainable intensification of agriculture on existing cropland. At issue is why existing technologies known to increase yields substantially have not been widely adopted by farmers in these regions, where cropping intensity is increasing and new crops are expanding in production area. The paradigmatic shift described in Section 1.2, designed to dig deeper into the constraints to realizing ISFM, will be operationalized through a combination of biophysical interventions and improved understanding of the socio-cultural and economic context.

Using participatory and conventional research methods, new and better adapted technology-based interventions (resilient germplasm and integrated fertilizer management schemes) will be tailored to the target AEZs.

In this strategy, the entry point for the management of the natural resource base for agriculture will be at the soils level. At the heart of this agenda are traditional elements of

increasing nutrient and water use-efficiency and building long-term fertility through increasing soil nutrients and organic matter. These interventions will be integrated with management of water, pests and other elements of above- and below-ground biodiversity. However, we also believe that improved crop, forage and fallow germplasm constitutes a key entry point. Adapting improved germplasm to soil problems can lead to resilient and sustainable cropping systems, thereby serving as a starting point for the transformation of smallholder farmers from subsistence to market-oriented agriculture. Integration of livestock in these cropping systems also features prominently in the strategy, to increase and diversify income sources and to promote recycling of nutrients. These technology-based interventions will be meshed with biophysical simulation models and will build on the existing capacity of farmers, using a range of participatory techniques to take account of socio-cultural and economic dynamics both at the farm level (Section 2.4) and in the broader economic and policy domain (Section 2.5).

Fertilizer research for practical land management strategies

TSBF-CIAT is consistently asked about its policy on promotion and use of mineral fertilizers. From our perspective, mineral fertilizers are absolutely necessary but not sufficient for the productive and sustainable management of tropical soils. Long-term trials show that nutrient-use efficiency declines over time where mineral fertilizers are applied without organic inputs. An optimal soil management strategy within a given farming system depends on combining appropriate types of fertilizer with appropriate means of managing organic resources, as well as on reducing the costs of both information and fertilizer. TSBF-CIAT has already made numerous contributions to advancing such a strategy, but will continue to research this topic with emphasis on translating existing scientific knowledge into practical land-management strategies.

Our contribution is intended to quantify the use efficiency of mineral fertilizer and to design and evaluate the effects of different management options and technologies on improved nutrient-use efficiency and recycling. Special emphasis will be put on within-farm variability. We hypothesize that, given the appropriate biophysical and socio-cultural and economic context, within-farm soil fertility gradients will be economically large enough to allow a farmer to take these into account when planning the allocation of the available organic and mineral nutrient sources. We expect to deliver a framework that allows farmers to fine-tune the management of their organic and mineral resources following within-farm soil fertility gradients.

Resilient germplasm as an entry point for ISFM technology adoption

Improved crop, forage and fallow germplasm will be used to overcome abiotic and biotic constraints and to create resilient cropping systems. TSBF-CIAT and its partners will continue to evaluate and integrate improved, adapted, resilient and marketable germplasm to tackle soil fertility constraints to crop production with particular emphasis on maize, dual-purpose legumes, and banana-based systems.

Improved germplasm of crops and forages and improved livestock breeds represent a useful entry point through which to introduce better soil management practices.

Breeding and biotechnology can help small farmers to sustainably increase productivity by:

- considering abiotic constraints such as acidity, low P, N and drought.
- selecting crop species, accessions and varieties through on-farm evaluation over a range of soils to identify potential soil-related constraints to production; and
- reducing production risks, via improved drought tolerance, soil acidity tolerance, pest and disease resistance and increased efficiency of N_2-fixation.

TSBF-CIAT and its NARES partners intend to focus on the interaction between new crop germplasm and more efficient natural resource management (NRM) in intensifying food and forage crop systems. Such a combination would consist of the best

variety for a given environment grown in an improved soil using appropriate crop management technologies. Interactions between adapted germplasm and key inputs such as organic residues, mineral fertilizers and water can lead to improved use efficiency of the nutrients and water at a system level. Assessing the combination of the nutrient inputs in organic or mineral form or both in terms of resource quality, nutrient input, C, N and P dynamics and water use efficiency help to identify technology options for increasing farm productivity and system resilience. TSBF-CIAT will work with germplasm development and integrated pest and disease management specialists to evaluate the impact of improved germplasm and ISFM practices on system resilience by monitoring yield stability, profitability, soil quality (physical, chemical and biological) and ecosystem services.

Both the technology and the desired outcomes would be appropriate to the farmers to whom they must be effectively delivered. This paradigm is indeed a bridge between a commodity focus and an ecoregional approach. In addition, steps will be taken to multiply seed of these promising lines for large-scale NGO-led farmer trials. A vital aspect of these strategies is the incorporation of farmers' indigenous knowledge at an early stage of systems' development to enhance the adoption of ensuing technologies.

2.2. Managing the genetic resources of soil for enhanced productivity and plant health

The soil biota constitute a significant proportion of global terrestrial biodiversity, and are responsible for critical ecosystem functions such as the biological control of soil-borne pests and diseases; decomposition; nutrient acquisition, storage and cycling; soil organic matter synthesis and mineralization; soil structural modification; and regulation of atmospheric composition. Research on the biological processes of soil lags behind those related to physical and chemical management such that these functions remain largely underexploited by humans for products and services in agriculture.

Recent advances in the understanding of soil ecology and in molecular methods for the study of soil offer promising ways to reverse the historical neglect of below-ground dynamics. New methods using gene micro-arrays, DNA profiling, DNA and RNA sequencing, and fatty acid analysis represent powerful approaches to understand the relationship between soil microbial communities and biogeochemical processes, equivalent to the genomic revolution in crop improvement. A programme of strategic research is required to realise this potential. A

specific approach likely to yield high impact in the short to medium term is via the exploitation of the interactions between pest and disease management and soil fertility, involving the following lines of research:

- Develop cultural and bio-control practices to manage the interactions of soil fertility with plant vigour, and the reduction of plant pest inoculum;
- Develop quantitative techniques for monitoring and manipulating key functional groups of soil biota and their relationship to ecosystem service functions and plant health;
- Develop and validate management practices for key groups of beneficial soil organisms for small-scale farms; and
- Link local knowledge about biological indicators of soil quality with scientific knowledge to develop robust soil quality monitoring systems that combine precision and relevance.

Contributing to a better understanding of soil ecology and below-ground biodiversity is a central component of TSBF-CIAT's mission and activities.

Below-ground biodiversity

TSBF-CIAT will also continue research on below-ground biodiversity (BGBD) as a means of beneficially managing soil biology, through the GEF-UNEP funded global project on BGBD. The project addresses how BGBD can be managed and conserved in tropical agricultural landscapes. The processes of land conversion and agricultural intensification are a significant cause of biodiversity loss, including that of BGBD, with consequent negative effects both on the environment and the sustainability of agricultural production.

The objective of the GEF-UNEP project is "to enhance awareness, knowledge and understanding of BGBD important to sustainable agricultural production in tropical

Research at the watershed scale is critical in the tropical regions. Environmental services, particularly hydrological response and soil erosion control, can be managed effectively only at larger landscape scales.

landscapes by the demonstration of methods for conservation and sustainable management." The project has a particular focus on tropical forest margins and the complex community of organisms which regulates soil fertility, greenhouse gas emissions and soil carbon sequestration, and which is routinely ignored in biodiversity conservation and assessment projects. The project will explore the hypothesis that, "by appropriate management of above- and below-ground biota, optimal conservation of biodiversity for national and global benefits can be achieved in mosaics of land uses at differing intensities of management and furthermore result in simultaneous gains in sustainable agricultural production." Integrated management of soil pests, diseases and nematodes will be of particular importance in ISFM practices. BGBD research also complements the work on breeding of cereals and legumes for tolerance to soil stresses, particularly drought and low soil fertility.

2.3. Moving from plot to landscape scale to address sustainable land management

Strategic and component research to date has been conducted largely at the plot or field scale, where interactions among various agricultural enterprises are seldom considered. Although

TSBF-CIAT's strength remains at the plot level, the diversity of forces impinging on the plot naturally draws attention towards a hierarchical or nested systems-based approach. The next generation of work will be at higher scales, particularly the farm and landscape scales.

The rationale for working at the farm scale is the need to improve nutrient-use efficiency through better allocation of limited organic and inorganic resources among different enterprises, taking into consideration inherent soil variability within the farming system. Inadequacies in supplies of both organic and inorganic nutrients have created strong fertility gradients even within the smallest farms. Smallholder farmers typically remove harvest products and crop residues from their food producing "outfields" and devote their scarce soil inputs to their smaller market "infields," resulting in large differences in soil productivity over time between these two field types. Understanding how to manage the limited nutrient supplies across such fertility gradients is a key component in raising productivity in fields of staple crops.

Environmental services, particularly hydrological response and soil erosion control, can be managed effectively only at larger landscape scales. Research at the watershed scale is critical in the tropical regions. Given projections that indicate Central America and eastern and southern Africa will be critically short of water in the coming decades, extending TSBF-CIAT's research agenda into this area is warranted. The projects funded by the Water and Food Challenge Program for the Volta basin in West Africa and on the Quesungual systems in Central America offer the opportunity to address constraints related to water and its interaction with soil fertility and other environmental challenges.

The assessment of services provided by agroecosystems at different spatial and temporal scales is an extremely important and challenging research area. 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 services. However, reliable quantification of such services and the development of mechanisms to compensate farmer communities who manage the soils, continue to be major challenges. TSBF-CIAT intends to contribute to filling this knowledge gap through partnerships with other CIAT projects, regional networks/ consortia (e.g., AfNet, Amazon Initiative, CONDESAN, MIS) and global projects (e.g., BGBD). TSBF-CIAT recognizes the exciting intellectual content and potential impact of this research area for sustainable land management and restoration of degraded lands in the tropics.

2.4. Understanding farm-level social dynamics

The importance of social, cultural, and gender priorities and constraints in driving both the processes of land degradation and those that lead to the development of soil fertility management innovations has been acknowledged by TSBF-CIAT since its inception. The role of social scientists in multidisciplinary projects includes strategic social science research as well as collaborating and building linkages with biophysical scientists by identifying and understanding the social factors that limit the appropriateness, and hence the adoption or rejection, of given technologies. Key outputs from strategic social science research have included methods and principles for working with farmers and local knowledge systems. A significant contribution has been the development of typologies of farmers and land users that relate biophysical variability to socio-cultural, economic and gender variability.

TSBF-CIAT has also pioneered research to characterise farmers' knowledge and practices of soil fertility management, with particular attention to how successful components of this knowledge can be scaled up to wider communities. These research methods have generated a better understanding of local knowledge of soil ecology, farmer decision making, and the role of social networks in generating, sharing or withholding of ISFM knowledge. Such results, particularly on how farmers perceive soil variability, degradation and improvement processes, have contributed to the development of more farmer-driven research hypotheses in otherwise biophysically oriented projects.

Future strategic research will continue to focus on the challenges and opportunities faced by the scientific community in interdisciplinary research and processes. We will also ensure that farmers' priorities and constraints are meaningfully integrated within the ISFM research agenda. TSBF-CIAT will move forward on identifying and working with the most vulnerable sectors of society so that our research is relevant to their priorities and constraints, and will sustainably improve their livelihoods.

Farmer group working on integrated soil fertility management in Emuhaya, western Kenya.

2.5. Linking farmers to markets

TSBF-CIAT and partners in Africa and Latin America will collectively contribute to testing the central hypothesis: *"that conservation and efficiency of use of soil and other natural resources will be optimised under conditions of market- and/or policy- and institution-driven productivity."* The TSBF-CIAT strategy proposes that a dynamic market-oriented process be used for identifying research questions, based on the resource-to-consumption (R-to-C) framework developed by the Rural Innovation Institute of CIAT. The R-to-C framework extends the commodity chain to include investment in NRM, and will specifically link ISFM technologies to market opportunities.

The R-to-C approach is an iterative process that responds to crop production opportunities and constraints and NRM concerns identified by farmer groups. The first activity in this framework is a participatory diagnosis to identify potential market opportunities for individuals and communities. This approach develops and implements a "demand-driven" research agenda based on farmers' needs, market demand, and the needs of NARES and NGO partners. We believe this approach will provide an effective process for identifying research targets and for locating the research in the most relevant extrapolation domain.

2.6. Strengthening NARS capacity

TSBF-CIAT's strategy for building NARS capacity must deal with the fact that national funding for agricultural research and extension programmes has decreased significantly during the past 5 years in most countries of Africa and Latin America. A reversal of this trend is not likely to occur in the foreseeable future. TSBF-CIAT recognizes this situation and proposes to work with a broader range of stakeholders, in addition to the NARS, to implement its programmes. In the past 10 years, TSBF-CIAT has moved effectively in this direction to work with NARES, NGOs, farmer groups, and the private sector and this work will be continued into the future.

On the other hand, the largest constraint to increased NARSs research capacity is the lack of operating funds rather than the need for more scientific staff. The scientific staff found in many NARSs are competent and can significantly contribute to TSBF-CIAT's mission, but the lack of operating resources limits the ability of NARSs staff to stay abreast of scientific developments. In particular, training, leveraging of networks, and information dissemination are essential ingredients for NARSs' effectiveness, but most NARSs budgets fail to allocated resources for these activities. Given TSBF-CIAT's limited human and financial resources, it is

crucial for the Institute to develop explicit strategies for both training and information dissemination that take full advantage of the rapid advances in information and communication technologies. There is also a critical need to encourage the participation of women in its training activities and the strengthening of electronic publishing capabilities.

We expect the role of networks to increase in importance in TSBF-CIAT's programme. **Box 3** describes the three regional networks with which TSBF-CIAT collaborates in Africa, Latin America and Asia. Such networks will play an ever more important role as national and international research institutions operating in a given subregion integrate their efforts around common interests. Their function today already goes well beyond regional testing of ISFM technologies, extending into the domains of priority setting, sharing of tasks and extrapolation of technologies to sites where they can be most effectively used. TSBF-CIAT is making full use of this approach, particularly in the areas of ISFM and participatory approach.

Box 3. TSBF-CIAT's networks

The African Network for Soil Biology and Fertility (AfNet), established in 1988, is TSBF-CIAT's implementing agency in Africa. Its main goal is to strengthen and sustain stakeholder capacity to generate, share and apply soil fertility and biology management knowledge and skills to contribute to the welfare of farming communities. AfNet facilitates collaboration among African scientists in order to develop innovative, practical resource management interventions for sustainable food production. AfNet works with partners to identify key research themes or problems of regional or international importance and then develops appropriate experimental methods and protocols for cross-site learning. Predictive interdisciplinary research across environments, using standard methods and experimental designs, reinforces results, enables the drawing and extrapolation of generalized conclusions and enhances modelling capacity, all leading to accelerated progress in essential research areas. Among the research themes covered are:

- nutrient budgets of agroecosystems;
- combining organic and inorganic nutrient sources for increased soil quality;
- the role of legumes in soil fertility restoration;
- use of rock phosphate as capital investment to replenish soil fertility;
- nutrient and water interaction;
- conservation tillage; and
- below-ground biodiversity.

AfNet currently has more than 250 members, drawn from national agricultural research and extension services (NARES) and university researchers from various disciplines (mainly soil science, agronomy, social science and technology exchange). At present, network trials are in place in about 80 sites in 25 countries, with activities covering process research, to applied and adaptive research.

(Continued)

Box 3. (Continued).

The **Manejo Integrado de Suelos (**MIS, Integrated Soil Management) Consortium is TSBF-CIAT's implementing network in Central America. It was created in 1999 to generate, adapt and disseminate options for the sustainable management of fragile soils in Central America. MIS partners focus on three main topics:

- dissemination of knowledge and information generated by the consortium on soil management;
- strengthening linkages with other networks and consortia (AfNet and CRSP) and;
- development of concept notes and proposals to support the consortium's work into the future.

During the past 5 years MIS partners have executed joint activities to collect information, generate and disseminate technology to improve management of soil, water and nutrients in fragile soils of Honduras and Nicaragua. Degree and non-degree training constitute one of the important activities of AfNet and MIS. In addition to co-supervision of students from universities and on-the-job training, AfNet has organized short training workshops on monitoring nutrient flows and evaluating farm economic performance in tropical farming systems (NUTMON) and on participatory research and scaling up/out, among others.

The South Asian Regional Network (SARNet) brings together ecologists, soil scientists and economists, primarily from India but also including colleagues in Sri Lanka and Nepal. SARNet's main research focus has been on soil biota and biodiversity for integrated soil fertility management, and the impacts of land-use change on carbon sequestration and biodiversity. This work has mainly been carried out with the resource-poor farmers of the mountain zones of the Himalayas and the Western Ghats, with some limited activities in the rice–wheat systems of the Indo-Gangetic plains. The SARNet Coordination Unit,[1] established in 1992 with a seed grant from IDRC, led to the launch of an all-Indian coordinated Programme on Biological Maintenance of Soil Fertility. The Coordination Unit supports capacity building in the areas of qualitative and quantitative characterization of soil biology and fertility processes, and promotion of interdisciplinary approaches to soil fertility-related problems.

1. The Coordination Unit is based at Jawaharlal Nehru University in New Delhi, India, and is supported by the GB Pant Institute for Himalayan Environment and Development.

Human capital development will continue to be an integral part of AfNet and MIS, in which the research agenda is achieved through M.Sc. and Ph.D. research conducted at regional public universities and elsewhere, followed by research support for recent graduates on return to their home institutions. TSBF-CIAT is particularly focusing resources allocated to training on providing young scientists in NARES and universities the opportunity to refresh their skills and expertise.

This in turn will help improve their capabilities as TSBF-CIAT collaborators and increase their competitiveness for funding from both within the NARES and with international funding agencies. An innovative initiative between TSBF-CIAT and the International Foundation for Science (IFS) has helped young M.Sc. and Ph.D. graduates throughout sub-Saharan Africa to

ISFM calls for an increasing emphasis on understanding farmers' knowledge of soil fertility dynamics, and tailoring recommendations for improved management practices to farmers' circumstances.

develop project proposals for IFS funding on TSBF-CIAT's major research and development themes. AfNet is involved in ensuring that such scientists are not alienated in isolated research settings due to lack of peer support, resources or recognition. This scheme also increases the research and development capacity of national systems.

Short-term specialized training on subjects such as NUTMON, resource flow maps and participatory approaches in ISFM is organized on demand by members through AfNet. TSBF-CIAT is assisting in soil science curriculum reform as part of a broader curriculum reform process under way in universities in eastern and southern Africa through the Rockefeller Foundation's Forum on Agricultural Resource Husbandry, which is designed to strengthen M.Sc. training.

The relevance and importance of social science contributions within AfNet and MIS are recognized, but so far social science has not been backed by resources or strong champions within the network. As a result, TSBF-CIAT is still perceived amongst partners as essentially a biophysically strong organization with minimal social science input. To counter this misconception, active recruitment of social scientists has begun through networking and proposal development.

The development and worldwide distribution of educational materials via electronic media also warrants concerted attention in TSBF-CIAT's strategy. While many NARES presently do not have access to the Internet, this is likely to change rapidly. TSBF-CIAT is investing in internet linkages with NARES scientists who participate in several of TSBF-CIAT's network programmes, and we will continue a more proactive planning approach for the use of electronic information technology to support training and information dissemination.

3. Outputs and Activities

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

Departing from the past, when TSBF concentrated mainly on biophysical concepts, such as SYNCHRONY and SOM, this output will involve 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 thus increase relevance is an overall strategy for sustainable soil management.

Key research questions

- Can temporal and spatial heterogeneity at the farm, community, and landscape levels be exploited with sustainable land management (SLM) technologies that enhance production and/or improve ecosystem services?
- How does loss of below-ground biodiversity (BGBD) relate to increasing land use intensity and what are the effects on ecosystem functions?
- To what extent is conservation agriculture applicable to different farming systems?
- How can we build increased capacity for ISFM by integrating local and technical knowledge?
- What are the socio-cultural and economic conditions, policies and institutions that influence ISFM?

Activities

1. Define soil-plant processes regulating efficient nutrient cycling, organic matter dynamics and structural stability.
2. Assess the impact of within-farm and within-landscape soil fertility gradients on the functioning of relevant soil-based processes.
3. Define the relationship between agricultural intensification and the abundance, diversity and function of tropical soil biota.

4. Develop an integrated approach to pest and soil fertility management (IPSFM).
5. Define scaling-up and -out processes for improving soil health and fertility.
6. Develop methods for integrating and strengthening local and technical knowledge of soil quality and processes, ecosystem services and BGBD, blending scientific and indigenous knowledge.
7. Identify the key socioeconomic conditions and policies that influence soil fertility management and constrain the adoption of ISFM options.
8. Develop participatory and formal economic methods to put value on soil management practices.

Output 2: Sustainable soil, water, and nutrient management practices developed and tested by applying and integrating knowledge of biophysical and socio-cultural and economic processes

Process and integrated knowledge generated in Output 1 needs to be translated into sustainable soil fertility and land management practices, adapted to the socio-cultural and economical environment in which these practices will be implemented. Output 2 is expected to enhance farmers' capacity to translate best principles for soil 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.

Key research questions

- What are the key components (labour, fertilizers, germplasm, BGBD, etc.) to manage in a given context for increased profitability, system productivity, and resilience?
- How can we optimize the benefits between production and resource conservation?

Activities

1. Develop and test strategies for improved nutrient cycling through legume diversification and intensification.
2. Develop and test strategies for improved nutrient use efficiency through a combination of inorganic and organic inputs.

3. Develop and test practices for managing BGBD indirectly through cropping system design and directly through inoculation strategies.
4. Develop and test management options to enhance soil-based ecosystem services.
5. Develop and test innovations for managing erosion and soil biophysical conditions/ constraints (e.g., conservation tillage, arable layer, water harvesting, organic matter build-up, etc.)
6. Integrate adapted germplasm with ISFM systems for increased impact on agricultural productivity and soil quality.
7. Develop and test formal economic and participatory methods to evaluate and optimize current soil management practices and new ISFM options for improved soil productivity and farmers' income.
8. Identify critical gaps in stakeholders' knowledge of soil, water, and nutrient management so that decision tools for improved soil, water and nutrient management can be developed and tested.
9. Identify socioeconomic and policy constraints to the adoption of ISFM options and test potential solutions.

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

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 activities in Output 3 are founded on building the human and social capital of all TSBF-CIAT stakeholders, research and management on the sustainable use of tropical soils.

Key research questions

- What are the mechanisms and information required for institutionalization of ISFM approaches with partners for scaling-up and increased impact?
- Who are the key stakeholders and partners for SLM?

Capacity building will continue to be an important part of TSBF-CIAT's work.

- What are the relevant learning processes and approaches to improve stakeholders' skills to make improved decisions?
- How can South-South integration facilitate the development of global products?

Activities

1. Strengthen linkages with regional organizations and advanced research organizations.
2. Strengthen networking on ISFM methods.
3. Develop strategic partnerships in capacity building to empower stakeholders.
4. Develop and construct databases and information systems to be shared out among TSBF project partners.
5. Improve dissemination of knowledge on ISFM.
6. Promote awareness of ISFM issues.
7. Improve understanding of adoption and adaptation processes including identification of policy constraints and responses.
8. Initiate dialogue with policy and decision makers to promote awareness of ISFM issues, and to create policy environments that enable the sustainable attainment of TSBF outputs.

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

This output addresses 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 resources 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.

Key research questions

- Which ISFM options are appropriate, where (farm/landscape), and for which farmers (typologies/social capital) to create profitable and resilient agricultural production systems?
- What are the component and system thresholds for improving resilience of target farming systems?
- Where and under what conditions does market orientation lead to increased investment in integrated natural resource management (INRM) and improved livelihoods?
- What information, resources, and knowledge do farmers need for improved decision making?

Activities

1. Evaluate system productivity and determine livelihood impacts of resilient production systems using participatory and formal approaches.
2. Identify drivers of farmer innovation for adaptation and adoption of technologies.
3. Investigate alternate production options using trade-off and scenario analysis tools.
4. Develop profitable agro-enterprises linked to identified market opportunities.
5. Quantify benefits of ecosystem services from farm to community level.
6. Determine livelihood impacts of resilient production systems.

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

This output contributes significantly to the CIAT's Development Challenge on overcoming agroecosystem degradation. The major objective 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.

Key research questions

- What is the minimum set of social, economic and biophysical indicators for preventing and reversing land degradation?
- What are the drivers of land degradation?
- Does hot-spot management provide a driver for wider-scale investment in ISFM?
- What are the stakeholders, technologies, and incentives necessary to enable SLM?
- What are the global benefits (ecosystem services) from SLM?

Activities

1. Identify and characterize biophysical, social and policy niches in the landscape that will inform where different SLM technologies to address land degradation will fit.
2. Develop and validate a minimum set of social, economic, and biophysical soil biological indicators of agroecosystem health.
3. Develop cross-scale practices and working approaches towards collective action to prevent or reverse land degradation and manage agroecosystem services.
4. Develop cross-scale practices for management of soil biota-mediated agroecosystem services.
5. Evaluate trade-offs/win-win situations between agricultural productivity and ecosystem services.

6. Integrate plot-farm-watershed and higher-level information related to the target ecosystem services.
7. Develop local and formal monitoring systems to evaluate the impacts of ISFM options and other land management practices on ecosystem services.
8. Develop or identify systems that contribute to C sequestration.
9. Develop crop, pasture, fallow, water, and soil management strategies that contribute to C sequestration and to minimize sources and/or increased sinks of greenhouse gases.
10. Develop and disseminate decision tools for improved soil, water and nutrient management.

4. Implementation of the Strategy

4.1. Organization of research around agro-ecological zones and benchmark sites

An interacting flow of outputs exists between different farming systems, i.e., between the cereal-legume and livestock systems, between the banana- and the cassava-based systems, and between the Quesungual and other agroforestry systems. These systems have been selected based on their importance and opportunities they offer farmers located in the major agro-ecological zones (hillsides, savannas and forest margins) in both Africa and Latin America.

Box 4 describes the principal features of each of the major agro-ecological zones that TSBF-CIAT will focus on.

TSBF-CIAT has adopted the benchmark approach to help rationalize the difficult task of conducting research within an AEZ framework across multiple countries containing a large number of biophysical, socio-cultural and economic associations. The approach has been central to operating the African Highlands Initiative and is increasingly the focus of work carried out by scientists both in Africa and Latin America. The benchmark approach has several operational advantages:

- It provides locations where on-farm and on-station field research can be carried out in representative environments from which relevant technologies (that is, those likely to be accepted by NARS and to have impact) can be identified and tested;
- It permits us to conduct field research that provides understanding of critical factor interactions that govern technology performance and acceptance;
- It provides a context for participatory development, testing, validation, and monitoring of technologies; and
- It provides a gradient of resource use intensification that allows for an understanding of underlying driving forces and farmer/farm community responses to them. Such an understanding provides the strategic backdrop to the development of technologies and processes that fit specific farmer circumstances and at the same time allow for the identification of key criteria for extrapolation to similar areas in the AEZ outside the benchmark site.

Box 4. Target agroecosystems for TSBF-CIAT interventions

Cereal-legume and livestock systems

Examples of system technologies involve the introduction of new, more productive and sustainable farming systems in Africa and Latin America. New maize cultivars bred for improved N-use efficiency, Striga and stem borer resistance and drought tolerance are rotated or relay cropped with (i) new food/forage legume crops with high vigor (e.g., newly bred common beans resistant to pests and diseases, promiscuously nodulating soybean, and dual-purpose cowpea) or (ii) drought and low P tolerant legumes and forages in smallholdings in Africa. Such an approach will promote sustainable agriculture through the contributions of residual soil N and organic matter to subsequent crops, efficient utilization of minimal amounts of external inputs, reduction of Striga population and other pests and diseases as well as integration with livestock systems. In Latin America, acid soil and/or drought adapted maize is rotated with soybean as part of the agropastoral systems in the tropical savannas. Deep rooted and acid soil adapted forage components in these agropastoral systems are the key components for building-up of the arable layer and to facilitate no-till farming systems. Maize is rotated with common bean in the Andean region and Central America. Identifying market opportunities for higher value crops such as vegetables, multipurpose legumes and fruit trees is important for income generation and for increasing the sustainability and biodiversity of these farming systems. A primary aim of this activity is to synthesize ISFM knowledge and analyze trade-offs of implementing various soil fertility technologies for smallholder farmers in mixed crop/livestock systems. Emphasis will be on efficiency of targeting and use of nutrients and legume-based soil improvement technologies, with outputs evaluated in terms of costs, benefits and compromises in productivity, economic and environmental services. Decision support models like DSSAT, NUANCES and APSIM will be used to conduct trade-off and scenario analysis and to evaluate the change in farm productivity.

Agroforestry systems

The Quesungual Slash and Mulch Agroforestry System (QSMAS) is an approach to restore degraded sub-humid tropical hillsides in Central America. This alternative to slash and burn agriculture strongly builds on local knowledge and has been a critical option to achieve food security by resource poor farmers in the region. The widespread adoption of the QSMAS by more than 6,000 farm households has been driven by a more than 100% increase in crop yields and cattle stocking rates and reduced costs associated with agrochemicals and labour. Contrary to other agroforestry systems tested in sub-humid tropics with long dry seasons, where crops and trees coexist under intense competition for water, farmers recognize that a remarkable feature of the QSMAS is the increased soil water holding capacity and availability. Curiously, two recent extreme events (El Niño drought in 1997 and Hurricane Mitch in 1998) were considered among the best promoters of adoption because areas under QSMAS were minimally affected compared to areas under traditional slash and burn practices. Understanding the socio-cultural, economic and biophysical processes that drive the adoption and successful performance of the QSMAS in sub-humid areas is of critical importance to be able to derive principles that can be extrapolated to similar environments elsewhere. Other important agroforestry systems adopted by farmers especially in Africa will be considered.

(Continued)

Box 4. (Continued).

Banana cropping systems

Declining soil fertility has been cited as a contributory factor to banana production decline in East Africa. According to the Ministry of Agriculture, Ugandan farmers attain approximately 17% of the potential yield from banana (5.9 t/ha compared with on-station levels of up to 35 t/ha). Soil fertility has been handled rather empirically in banana-based cropping systems, leading to recommendations with little opportunities to be extrapolated to different situations. Furthermore, there is growing evidence that the extent of damage caused by pests is influenced by soil fertility. Consequently, addressing only one will not result in increased productivity unless the remedial options serve to address the two limitations. Unfortunately, there is often a tendency toward the polarisation of research on soil fertility and pest management, producing recommendations that are inappropriate for the farmer. We will explore the interactions between pest and soil fertility management in banana and cassava systems. Often, ISFM and pest management technologies fail to address diverse livelihood strategies, particularly of poorer farmers, and have not been linked to income generation and therefore provide no incentives to farmers for further investment in their natural resource base.

The TSBF-CIAT Latin America team has research for development activities in two major agroecosystems (Tropical Savannas and Hillsides). The reference (benchmark) sites for the team are the Llanos for the savannas in Colombia and Cauca for the hillsides in Colombia, San Dionisio in Nicaragua, and Yoro and Lempira in Honduras. The priority production systems for the team are cereal-legumes-livestock in savannas and Quesungual slash/mulch agroforestry systems and cereal/legume/high-value cropping systems in hillsides.

The TSBF-CIAT-Africa team has prioritised work in the following agroecozones: drylands and savannas, highlands, and forests and forest margins. For the drylands and savannas agroecozones, cereal-legumes-livestock systems were identified as priority agroecosystems. For the highlands agroecozone, cereal-legumes-livestock, agroforestry/fallow, and banana/ensete agroecosystems were identified. For the forests and forest margins agroecozones, the following agroecosystems were identified as priorities: cassava-based systems, banana-based systems, fallow systems, and plantation crops.

4.2. Organizational structure and staffing

4.2.1. Research and management structure

An appropriate structure is a necessary but not sufficient condition for implementing a high quality research programme. Ultimately, the quality of the scientists and their commitment to effective collaboration is the basis for a successful research organization. Having said this, the

choice of a particular reporting and planning structure should reinforce the capacity for multidisciplinary research, facilitate research focus, and foster a free market place of ideas. The following issues must be addressed to successfully implement TSBF-CIAT's research agenda:

- TSBF-CIAT's research agenda will be composed of the research priorities of the target AEZs balanced against the human and other resources available to implement this agenda. The research agenda within each AEZ is developed by an AEZ team, with assistance from a stakeholder committee (including representatives of the appropriate subregional organization) to identify highest priorities in each subregion.
- Line authority for planning and reporting should reinforce the AEZ orientation and research project structure, under which AEZ teams are responsible for planning the research agenda and project implementation.
- Strong interdisciplinary collaboration, including both biophysical and social scientists, is required to understand and address the root causes of poverty, food insecurity, and natural resource degradation.
- Effective projects would be accountable to deliver research outputs that address well-defined objectives identified by the AEZ teams. Projects should have a farming system cross-cutting function as a theme. Most projects would have specific activities in two or more AEZ programmes although some projects could be centred in one AEZ.
- AEZs provide an effective framework for prioritizing research and aggregating a portfolio of research project activities into a cohesive programme that can address the highest priority issues. AEZ teams, composed of individual scientists assigned to projects with activities within the AEZ programme, are in the best position to identify research issues and prioritise among them, in collaboration with stakeholders.

The existing research management structure is best described as a farming system/output-based structure with an emerging contribution of AEZs to the research planning and implementation process. Each farming system is lead by a coordinating scientist. The coordinating scientists will aim to strike a balance in the overall portfolio between strategic and applied research in consultation with the partners. Coordinating scientists are also responsible for systematically reviewing each research project once every 18 months and making appropriate adjustments to ensure project relevance and quality. Approval of new projects or termination of existing projects is also the responsibility of coordinating scientists, in consultation with the TSBF-CIAT director.

4.2.2. Staffing the core science programme

Today, TSBF-CIAT has 17 internationally recruited (IRS) and 62 nationally recruited (NRS) staff members. Twelve IRS scientists are located in Africa and five in Latin America. In addition to staff based at the head offices in Nairobi, Kenya, and Cali, Colombia, scientists are located in Kampala, Uganda, and Harare, Zimbabwe, and in Tegucigalpa, Honduras. Institute staff are assigned to three major areas: the Core Science Programme Projects, Networks and Partnerships, and Direction and Support Services.

Leadership for implementation of the research priorities laid out under strategic directions is the responsibility of the core science staff based in Africa and Latin America. Each of the core science officers provides leadership and backstopping for project and network research for the main outputs of the research programme. This is done through collaborative research in specific projects under their own management, as well as by providing support and input to the projects, networks and partnerships active in the programme at any given time. Maintenance of the core science staff is also important as means of leveraging the project funds essential to ensuring the progress of the research and capacity building programme.

The priority core science staff positions for the period 2005-2010 are as follows:

Integrated Soil Fertility Management (ISFM)

Scientific officers provide leadership for the work on process and strategic studies related to the implementation of ISFM in cereal-livestock, banana and quesungual, and other agroforestry farming systems.

Soil Biota Management, Integrated Pest and Soil Fertility Management (IPSFM)

The responsibility of this position is to lead TSBF-CIAT's work on the integrated management of soil biota, particularly with respect to balancing the beneficial and harmful (i.e., pest) effects of soil fauna.

Microbiology

A soil microbiologist leads TSBF research activities on such topics as microsymbiont (N_2-fixation or mycorrhiza) biology, decomposition biology, and microbial diversity.

Soil and Water Conservation

This scientist leads TSBF-CIAT's work on all aspects of soil and water conservation.

Ecosystem Services

The responsibility of this position is to lead TSBF-CIAT's work on all aspects of soil-based ecosystem services (water quality and quantity, carbon sequestration, greenhouse gas fluxes, soil losses and sedimentation) within food-secure land use systems.

Plant Nutrition and Physiology

This scientist leads TSBF-CIAT's work on all aspects of multiple stress-adapted crop and forage germplasm as an entry point for ISFM technology adoption and restoration of degraded lands.

Social Science

Social scientists lead TSBF-CIAT's strategic social scientific research and backstop the work of the Institute and its partners in the social, cultural, gender, and participatory dynamics of innovation, adoption and constraints for the sustainable management of natural resources, especially soils, water, and land.

Agricultural Economics

This researcher provides expertise on the economic evaluation of soil management practices. S/he leads the market led-INRM research, analyses trade-offs within the farming systems, and leads work on valuation of soils' ecosystem services.

AfNet Coordination

The AfNet coordinator provides leadership and management for implementing the TSBF-CIAT research and capacity building programme by providing support to the membership of the African Network for Soil Biology and Fertility.

MIS Coordination

The MIS coordinator provides leadership and management for implementing the TSBF-CIAT research and capacity building programme by providing support to the membership of the MIS consortium.

BGBD Coordination

The BGBD coordinator provides scientific backstopping to the GEF-UNEP funded Below-ground Biodiversity Project. The coordinator also brings GIS and land management expertise to the team.

System Design and Management

This officer leads the BGBD database design and analysis and also brings GIS and land management expertise to the team.

Institute Management

In addition to research administration support, the director is taking the lead on such topics as microsymbiont (N-fixation or mycorrhiza) interactions.

4.3. Working with partners

Working with appropriate NARES and NGO partners ensures that ISFM innovations have a high likelihood of being disseminated. In addition, such partnerships provide opportunities to study the acceptability and performance of improved technologies, provide feedback to research and help guide future research investments. However, TSBF-CIAT is careful to ensure that participation in development projects does not divert focus and resources away from its primary mission of conducting strategic research.

The promotion of high quality social science research within TSBF-CIAT requires strong commitment from its affiliated networks. The numbers of social scientists within AfNet, MIS, and the BGBD Project in particular remain disproportionately low, especially non-economists. Active recruitment of social scientists from a variety of disciplines (economics, sociology, anthropology and geography) is therefore being encouraged, and wherever possible new opportunities for multidisciplinary collaboration are being sought. Recent initiatives involve the creation of new linkages with Africa-based social science networks (OSSREA and CODESRIA), linkages with the University of Wisconsin at Madison's Land Tenure Centre and Institute of Environmental Studies, and recruitment of post-doctoral scientists to lead research on sustainable management in East Africa.

The steady growth of AfNet and MIS has made it necessary to form strategic country and regional multidisciplinary teams. These teams will develop models linking research on ISFM, agricultural production and markets in Africa and Central America regions. AfNet will also prepare the research and development agenda for the sub-Saharan Challenge Programme.

TSBF-CIAT will initiate or participate in development projects on a bilateral basis with some countries, e.g., for promotion, production and marketing of promiscuous soybean in Kenya; combating land degradation in Ethiopia and Livelihood Improvement project in the DR Congo.

We will collaborate with other CGIAR Centres, overseas advanced institutions and NARES in research for development projects in targeted villages either directly or through networks and consortia. For example, TSBF-CIAT staff participate in a number of systemwide and ecoregional programmes such as the Systemwide Programme on Alternatives to Slash-and-Burn, the African Highlands Initiative, and the Desert Margins Programme, as well as Challenge Programmes such as Water and Food and the Sub-Saharan Africa CP. Strong linkages are envisaged between TSBF-CIAT and CIAT's projects on germplasm development (common bean, forages, cassava, rice and tropical fruits), participatory research, watershed management and land use as well as with the ICRAF-led Lake Victoria Project in East Africa. TSBF-CIAT will also continue to play an important role in CIAT's Development Challenge on restoring degraded lands to social profitability.

4.4. Funding the TSBF-CIAT strategy

Funding for ISFM research is needed that recognizes both the urgency of immediate action and the importance of longer-term investment in lasting solutions. At the heart of funding needs is the importance of maintaining a critical mass and diversity of scientists in Africa and Latin America. The number of such scientists employed in both international and national institutions is diminishing. In addition, laboratory facilities for the type of research described in this document are inadequate and are threatened by unstable funding. Loss of this type of infrastructure will make it even more difficult to sustain and enhance the capacity of national systems to conduct ISFM research.

Resource requirements are estimated at around US$5 million per year, allowing the potential for some joint programming across themes and continents. **Table 1** indicates expected funding requirements for the period 2005-2010, disaggregated by research outputs and primary budget items.

In terms of the broad logframe outputs used by the CGIAR, TSBF-CIAT's major focus has been and remains on crop production systems (30% of the total resources), protecting the environment (30%), strengthening NARES (20%) and saving biodiversity (10%). Remaining resources are allocated to enhancement and breeding (5%) and policy (5%). From a geographic perspective, about 50% of resources are invested in activities that primarily target Sub-Saharan Africa, with about 40% in Latin America and the remaining 10% on matters of global relevance.

Table 1. TSBF-CIAT's estimated core budget 2005-2010, by activity and budget item (US$000).

Activity / budget item	2005	2006	2007	2008	2009	2010	TOTAL
Output 1: Biophysical and socio-economic processes understood, principles and concepts developed for protecting and improving the health and fertility of soils							
Staff	650	750	750	750	750	750	
Operating expenses	350	350	350	300	300	300	
Networks, workshops, dissemination	200	200	200	250	250	250	
Subtotal, Output 1	1,200	1,300	1,300	1,300	1,300	1,300	7,700
Output 2: Sustainable soil, water, and nutrient management practices developed and tested by applying and integrating knowledge of biophysical, socio-cultural and economic processes							
Staff	600	550	550	500	500	500	
Operating expenses	400	300	300	250	250	250	
Networks, workshops, dissemination	200	150	150	150	150	150	
Subtotal, Output 2	1,200	1,000	1,000	900	900	900	5,900
Output 3: Partnerships developed and capacity enhanced among all stakeholders for improving the health and fertility of soils							
Staff	500	600	600	600	600	600	
Operating expenses	200	200	200	200	200	200	
Networks, workshops, dissemination	100	100	100	150	150	150	
Subtotal, Output 3	800	900	900	950	950	950	5,450
Output 4: Improved rural livelihoods through sustainable, profitable, diverse and intensive agricultural production systems							
Staff	500	650	650	850	850	850	
Operating expenses	200	250	250	350	350	350	
Networks, workshops, dissemination	100	100	100	100	100	100	
Subtotal, Output 4	800	1,000	1,000	1,300	1,300	1,300	6,700
Output 5: Sustainable land management practices developed for social profitability, with special emphasis on reversing land degradation							
Staff	250	500	500	600	600	600	
Operating expenses	100	200	200	250	250	250	
Networks, workshops, dissemination	50	100	100	150	150	150	
Subtotal, Output 5	400	800	800	1,000	1,000	1,000	5,000
GRAND TOTAL	**4,400**	**5,000**	**5,000**	**5,450**	**5,450**	**5,450**	**30,750**

Most of the core research funds required for the immediate future have been obtained from the Rockefeller Foundation and CIDA-Canada for the Africa work, and from CIAT core funding for the work in Latin America. Other donors for current TSBF projects include IDRC, DIFD, IFAD, DANIDA, BMZ, NORAD, USAID, ACIAR, UNEP-GEF and the consortia of donors to the CGIAR SWPs.

We see opportunities for greater linkages and involvement as technical advisors to major developmental projects funded by international finance institutions such as the World Bank, USAID and IFAD. This is consistent with the CGIAR's new emphasis on stronger partnerships with development organizations and institutions. TSBF-CIAT has already initiated successful linkages with major IFAD, USAID and JICA projects in Rwanda, Democratic Republic of Congo and Kenya.

5. Conclusions and Looking Forward

TSBF-CIAT is on the verge of a new era of leadership and research. Research paradigms are changing to address farmers' challenges in a more holistic fashion. The CGIAR is also considering major changes in how it is organized to carry out its mandate. These changes lead us to believe that the time is right for TSBF-CIAT to assume the mantle as the premier international agricultural research institute in soils research in Africa and Latin America. The strategy described in this document represents a clear vision of TSBF-CIAT's fundamental research priorities, and will serve as the guiding beacon for its specific research plans and for directing its interactions with partners in the years to come.

Appendix 1. Project Log Frame (2005-2010): Integrated Soil Fertility Management in the Tropics

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.	Principles of sustainable development integrated in country policies and programs. Capacity built in tropical countries for sustainable management of natural resources. By 2015, in the major tropical regions where TSBF-CIAT works, together with other partners, contribute technologies and the knowledge to achieve the MDG of reducing the number of rural people in extreme poverty by 50%. Reversal of the losses of environmental resources, especially loss of soil and below-ground biodiversity.	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 just and resilient agricultural **production systems** based on integrated soil fertility management (ISFM); to develop **sustainable land management** (SLM) in tropical areas through	By 2010, at least 50% of farmers in TSBF benchmark areas in at least three countries are adapting and adopting sustainable and resilient production systems with postive impacts on their livelihoods. 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.	Reports of collaborating national and international institutions—in poverty reduction and sustainable development. National agencies surveys, development plans and reports. International agency missions	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

(Continued)

Appendix 1. (Continued).

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
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.	- 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).	and goal statements related to TSBF-CIAT annual reports and accounts.	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, at least three indicators of soil health and fertility at plot, farm and landscape scales identified. By 2008, the social, gender, and livelihood constraints and priorities affecting the sustainable use of soils have been identified, characterized, and documented through case estudies using innovative methods. 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.

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Appendix 1. (Continued).

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
Output 2 Sustainable soil, water, and nutrient management **practices developed and tested** by applying and integrating knowledge of biophysical, socio-cultural and economic processes.	By 2006, decision support framework for ISFM developed, tested with and made available to stakeholders in at least two benchmark countries. By 2008, communities in at least three countries demonstrate and test direct or indirect management options that enhance locally important ecosystem services using BGBD. 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 soil and water conservation as entry point, including crop diversification strategies, tested and adapted to farmer circumstances. By 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. By 2010, local baselines and interviews show that farmers' understanding of soil processes is demonstrably enhanced within community-based experimentation in at least five benchmark sites.	Annual reports/publications. Scientific publications. Soil and crop management guidelines published. Decision support systems 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.
Output 3 **Partnerships** developed and capacity enhanced among all stakeholders for improving the health and fertility of soils.	By 2008, at least two technologies applied in Africa and Latin America because of the South-South alliance between MIS and AFNET. By 2008, farmer-to farmer knowledge sharing and extension through organized field trips and research activities result in farmer adoption of new practices at a minimum of two sites.	Annual reports/publications. Scientific information (theses, publications, workshop reports, project documents) disseminated to network members and all stakeholders. Farmers' assessments and	Continued interest/ participation of NARS and ARO partners, and national and international universities. Continued support for collaborative activities e.g. Challenge programs.

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Appendix 1. (Continued).

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
	By 2010, strengthen partnerships and tools for dissemination and feedback of research knowledge developed by each project. By 2010, at least five synthesis books completed. By 2010, AfNet, MIS, LATNET, SARNET and BGBD Networks strengthened through increased participation and interaction, including South-South collaboration. By 2010, TSBF scientists contribute to appropriate policies and innovative institutional mechanisms. By 2010, 100 M.Sc. and 20 Ph.D. completed within the networks. At least two short-term training courses organized annually.	evaluations of research experiences and capacity building. Network trials planned and implemented with partners. Degree-oriented and on-the-job personnel trained (farmers, NARS, NGOs). Publications (i.e., journal papers, books, extension materials, policy briefs, photo and video appraisals, etc.), workshops, documentaries, field days, from each project.	
Output 4 **Improved rural livelihoods** through sustainable, profitable, diverse and intensive agricultural production systems.	By 2008, improved production systems having triple benefits of food security, income, and environmental services identified. By 2008, farmers are testing and adapting improved production systems in at least 15 sites across five countries. By 2010, validated sustainable, intensive and profitable systems are being demonstrated, promoted by partners and adopted by farmers in at least 10 countries. By 2010, farmers in all TSBF benchmark sites have improved access to key production inputs (fertilizers, organic inputs, soil biota, seeds) and other productive resources (land, cash, information).	Annual reports/publications. Farmer surveys. Regional/national production statistics. Land use surveys (satellite imagery, rapid rural appraisals).	Land survey data available. Farmers adopt new technologies. Socioeconomic conditions are favorable for achieving impact. Adequate resources available for land management research.

(Continued)

Appendix 1. (Continued).

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
Output 5 **Sustainable land management** practices developed for social profitability, with special emphasis on reversing land degradation.	By 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 two humid and two sub-humid agro-ecological zones. By 2010, 30% of partner farmers in pilot sites use SLM options that arrest resource degradation and sustainably increase productivity for improved livelihoods. By 2010, restoration and monitoring of degraded lands available for at least two regions.	Annual reports/publications. Farmers surveys. Regional/national production statistics. Land use surveys (satellite imagery, rapid rural appraisals).	Land survey data available. Farmers adopt new technologies. Socioeconomic conditions are favorable for achieving impact. Adequate resources for soils research.

Acronyms

ACIAR	Australian Council on International Agricultural Research
AEZ	Agro-ecological zone
AfNet	African Network for Soil Biology and Fertility
ASARECA	Association for Strengthening Agricultural Research in East and Central Africa
BGBD	Below-ground biodiversity
BMZ	Bundesministerium fur Wirtschaftliche Zusammenarbeit (Federal Ministry of Cooperation and Economic Development)
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical (International Center for Tropical Agriculture)
CLIFS	Congo Livelihood Improvement and Food Security Project
CONDESAN	Consorcio para el Desarrollo Sostenible de la Ecoregión Andina (Consortium for the Sustainable Development of the Andean Ecoregion)
CORAF/WECARD	Conseil Ouest et Centre African pour la Recherche et Développement Agricole (West and Central African Council for Agricultural Research and Development)
CRSP	Collaborative Research Support Program
DANIDA	Danish International Development Agency
DFID	Department for International Development, U.K.
DSS	Decision support system
FARA	Forum for Agricultural Research in Africa
GEF	Global Environment Fund
IDRC	International Development Research Centre
IFAD	International Fund for Agricultural Development
IFS	International Foundation for Science
INRM	Integrated natural resource management
IPM	Integrated pest management
IPSFM	Integrated pest and soil fertility management
ISFM	Integrated soil fertility management
JICA	Japan International Cooperation Agency
MIS	Manejo Integrado de Suelos (Integrated Soil Management Consortium)
NARES	National agricultural research and extension services
NGO	Nongovernmental organization
NORAD	Norwegian Agency for International Development
NRM	Natural resource management
ORD	Organic Resource Database
SACCAR	Southern Africa Centre for Cooperation in Agriculture and Natural Resources Research and Training
SARNet	South Asian Regional Network
SLM	Sustainable land management
SOM	Soil organic matter
SWP	Systemwide Programme (of the CGIAR)
TSBF	Tropical Soil Biology and Fertility
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development

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