Centro Internacional de Agricultura Tropical
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Outcome line
SUSTAINABLE LAND MANAGEMENT IN THE TROPICS

Annual Report 2008

TROPICAL SOIL BIOLOGY AND FERTILITY INSTITUTE OF THE INTERNATIONAL CENTRE FOR TROPICAL AGRICULTURE (TSBF-CIAT)

OUTCOME LINE

'SUSTAINABLE LAND MANAGEMENT IN THE TROPICS'

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I. PROJECT OVERVIEW

I.1. INTRODUCING SUSTAINABLE LAND MANAGEMENT AS A SECOND OUTCOME LINE UNDER THE TSBF-CIAT PROGRAMME

In 2009 'sustainable land management' was defined as a second outcome line beside the 'integrated soil fertility management'. This was brought forward by the need to enhance programmatic coordination in response to the increasing number of activities (projects) related to sustainable management of soil resources and the need to address processes related to land degradation that take place at a landscape level. It basically elevated elements already mentioned in the TSBF strategic document related to TSBF's objectives and strategic trusts to a separate programme. The objective 'to develop sustainable land management practices in tropical areas while reversing land degradation' has particular elements that related to land degradation that do not necessarily and exclusively related to ISFM. Also the 'to improve the livelihoods of people reliant on agriculture by developing profitable and resilient agricultural production systems' has a clear landscape component to it that we will address in the SLM outcome line, by focussing on agricultural landscapes. The strategic trust to 'move from plot to landscape scale to address soil and land management systematically' will be the main focus of the SLM outcome line, but elements of the other thrust are also included. For example, to manage soil genetic resources will remain an important component in the SLM programmatic work. Further, building human and social capital for research and management on the sustainable use of tropical soils and the strengthening of NARS capacity is an activity that cuts across both outcome lines. There are several linkages between the TSBF - CIAT Strategic Document and the SLM Outcome line lead by TSBF - CIAT as indicated in the table below.

Table 1: Linkages between the TSBF-CIAT Strategic Document and the SLM Outcome line lead by TSBF -CIAT

TSBF-CIAT Strategic Document	SLM Outcome line
Main objectives	
(1) To support the livelihoods of people reliant on agriculture by developing profitable, socially-just and resilient agricultural production systems based on ISFM.	Partially integrated in this outcome line. The concept of soil health is more clearly articulated and incorporated as component of agricultural production systems (i.e. management of soil health at plot and farm level) in this outcome line
(2) To develop Sustainable Land Management (SLM) in tropical areas of Africa through reversing land degradation.	Fully integrated in this outcome line
(3) To build the human and social capital of all CIAT-TSBF stakeholders for research and management on the sustainable use of tropical soils.	Fully integrated, with emphasis on alternative crops and markets, PES strengthening farmer organization for SLM and local service providers

Major outputs	
(i) Biophysical and socioeconomic processes understood and principles, concepts and methods developed for protecting and improving the health and fertility of soils.	Integrated in SLM outcome line, with emphasis on processes at landscape level, land use patterns and associated land degradation, sustainable land use mosaics and sustainable production landscapes; covered under Output 1.
(ii) Economically viable and environmentally sound soil, water, and nutrient management practices developed and tested by applying and integrating knowledge of biophysical, socio-cultural and economic processes.	Integrated within this outcome line, with emphasis on technologies and management options for restoration of degraded land, or maintenance of soil health status. Integrated in output 2.
(iii) Partnerships and tools developed and capacity enhanced of all stakeholders for improving the health and fertility of soils.	Capacity building is included in output 5 of this outcome line. Establishment of partnerships is cross cutting through all output lines as these partnerships are critical in delivering on each of these outputs
(iv) Improved rural livelihoods through sustainable, profitable, diverse and intensive agricultural production systems.	Partially integrated in this outcome line as SLM builds on concept of diverse agricultural productions systems within the landscape.
(v) Options for sustainable land management (SLM) for social profitability developed, with special emphasis on reversing land degradation.	Fully integrated in this outcome line
Strategic pillars	
(i) Improving fertilizer efficiency and developing soil and water management practices.	Not directly included in this outcome line, though improved nutrient use efficiency and water use efficiency is key to sustainable land management. The SLM outcome line will build on results from the ISFM outcome line
(ii) Improved germplasm as an entry point for managing soil fertility.	Not integrated in the SLM outcome line, though again improved germplasm may be key to SLM; build on results from ISFM outcome line.
(iii) Managing the genetic resources of soil for enhanced productivity and plant health.	Fully integrated as far as BGBD and genetic resources are considered to be of vital importance for sustainable and biological production systems
(iv) Understanding farm level social and cultural dynamics.	Important to understand and how people value the landscape they live in and the ecosystem goods and services it provides, as well as preparedness to take communal actions for protecting the landscape
(v) Linking farmers to markets, nutrition, and health.	Partially integrated, as these address some of the ecosystem goods and services generated at landscape level. Enabling environment is considered to include other than these factors though
(vi) NRM strategies to move from plot to landscape scales.	Focus on farm scale to landscape scales. Farm scale is considered more in terms of farm typologies
(vii) Strengthening scientific and institutional capacity of partners for ISFM.	Fully integrated, see output 5.

The strategic adjustment reflects also the increasing number of projects that TSBF-CIAT will have in its portfolio, that have both ISFM and SLM components to it. New projects have been designed to:

a) Test various ISFM options (including increase of fertilizer application) on the effects of BGBD and soil health status in general

b) Mapping soil health status in SSA and constraints and opportunities for application of fertilizers to improve soil and crop management.
c) Collate information on ISFM and SLM technologies and management options and information on fertilizer response and ISFM trials, soil management and conservation experiments to determine the application domain and the improve prediction of response to fertilizers application and ISFM under various conditions
d) Develop a framework for developing soil management recommendations that target different stakeholder groups at different levels of spatial detail.
e) Conducting ISFM and fertilizer response trials to test soil management recommendations under field conditions for a variety of soil health conditions as indicated by the soil health status inventory
f) Develop a major project on the role of fertilizer on the environment in SSA with GEF-UNEP.

The SLM outcome comes into effect as per 2009, and the associated mid-term plan (MTP) therefore covers the period of 2009-2011. It was decided to structure the annual report for 2008 already according to the two outcome lines. This, however, required the existing targets and outputs for 2008 to be divided over the two outcome lines, which may not be a very meaningful exercise. Moreover the process of reporting has not been structured according to the two outcome lines as we have not assigned projects to one or the other outcome line.

Therefore, the annual reports of the ISFM and SLM outcome lines should be considered together. Several outputs of activities could be logically grouped under the SLM outcome line but they are reported under the ISFM outcome line. The focus of this report will be very much on the outputs and results from the Conservation and Sustainable Management of BGBD project, while it still might be too early to report on some of the project mentioned above as they have just started. There may be some duplication in the reporting between both outcome lines, but we have endeavoured to reduce that to a minimum.

One of the major recommendations of the CCER was for TSBF - CIAT to improve access to fertilizer and develop recommendations for its use that are of mutual benefit to all stakeholders involved. TSBF - CIAT should become the lead institution for providing scientific information to the industry on realistic markets. These will incorporate: data on soils, cropping and land use systems, optimal fertilizer formulations for balanced crop nutrition, details on fertilizer packaging and information provided to farmers, practical ISFM concepts, the decision support tools needed for their implementation, and socioeconomic research on needs for fertilizer marketing infrastructure, integration with local knowledge to enhance adoption, economic benefits for farmers, and societal costs as a whole.
Important aspects of this recommendation are being implemented. TSBF - CIAT is playing a key role in the implementation of the recommendations of the African Fertilizer Summit taking specific action to improve farmers' access to fertilizer, quality seeds, extension services, market information and soil nutrient testing and mapping to facilitate effective use of inorganic and organic fertilizers, while paying attention to the environment and especially below-ground biodiversity (BGBD). Enhanced fertilizer use will be an important consideration in the strategy for sustainable land management. The SLM outcome line will therefore work in close collaboration with the ISFM outcome line on the above activities, with the emphasis for the SLM outcome line on the (improved) targeting of soil management recommendations and development of decision support tools.

I.2. RATIONALE

Land degradation has been described as one of the major constraints to food security and income generation in developing countries. Despite proposals for a diversity of solutions and the investment of time and resources by a wide range of institutions it continues to prove to be a substantially pervasive problem. The rural poor are often trapped in a vicious poverty cycle between land degradation, fuelled by the lack of relevant knowledge or appropriate technologies to generate adequate income and opportunities to overcome land degradation. Intensification and diversification of agricultural production on smallholdings is required to meet the food, feed and income needs of the poor.

There are different pathways and intervention options to achieve **sustainable intensification and diversification of agricultural production** and these interventions can only be successful if they take account of the environmental and socio-economic conditions and if there is an enabling environment in terms of input - output markets, institutions and policies in place. Intensification and diversification requires sustainable land management practices and technologies but adapted to local circumstances, improved targeting of these interventions and support functions that will enable the adoption of these technologies and management options. Recognition that areas are of varied potential for agricultural production will have to shape decisions regarding intensification and diversification of the agricultural production and promotion of sustainable agro-ecological intensification for these different situations.

In order to address land degradation we need to look at the larger **agricultural production landscape** (that comprises the bio-physical, socio-economic and the cultural and political landscape). The production landscape needs to be understood, not only in terms of agricultural production, but in terms of the provision of environmental (or ecosystem) goods and services (of which food production is only one). We embrace the concept of **soil health** that indicates the capacity of the soil ecosystem to provide soil related ecosystem goods and services. Of interest is then the productive capacity of these landscapes that is directly linked to its resource base. Of concern is the eroding resource base in many of these production landscapes in Africa (and elsewhere) that can be expressed in terms of soil biological, chemical and physical degradation. The erosion of the resource base is not only a concern of the farmer but of the wider stakeholder community as ecosystem services are affected. Solutions for land degradation need therefore involve both the farmer communities as well as the wider stakeholder groups. In many cases farmers have options to counteract the eroding resource base, by intensifying the production system (applying fertilizer, mechanization of the tillage operations for example). However, the trade-offs are evaluated at a different scale. As options are available to the farmer, the challenge might actually be to develop technologies and intervention options for **intervening at the landscape level**, to maintain or improve the resilience of the productive capacity of the soil to **climate and environmental change** and to apply the concept of integrated natural resource management (INRM) to the larger landscape.

The SLM outcome line aims to identify domains of potential adoption and improvement of technologies for improving soil productivity, preventing degradation and for rehabilitating degraded lands and one major outcome will refer to tools and methods to be able to identify

these domains. In line of the above, thresholds for assessing soil health status need to be identified. These thresholds need to inform about whether soil degradation has progressed beyond a stage where the soil is no longer responsive to management options available to the farmer and where soil restoration or rehabilitation is needed that will generally require the intervention of (or regulation by) government authorities or other stakeholders. The interventions need to be designed accordingly.
To improve soil quality and sustain increases in productivity and provision of environmental services through greater understanding of **processes that govern soil quality** and trends in soil quality within the landscape requires us to understand how the landscape functions as an integrated system and tools and techniques for integrated natural resources management need to be based on the recognition that addressing the interactions between components is as important as dealing with the components themselves. The components refer to land use, soils, water and pest, and the ('vertical') interactions describe the system at each particular location, at the same time these components have a spatial extent and can be considered components in the landscape and the 'horizontal' interactions describe the landscape system. It requires understanding of the **spatial and temporal variation in the various aspects of soil health**.

Research challenges remain as how to characterize the landscape as a production system in terms of its configuration and composition of land uses as well as how to **model the interactions between the landscape components** in terms of flow of resources between these components. These resources relate to water, to **organic matter, to biological resources (biodiversity)**, but also to labour and capital. Spatial and temporal variation in soil biodiversity and its implications for the provision a soil related ecosystem services is still virtually unchartered terrain and will remain a focus of the outcome line.

The 'sustainable land management' outcome line aims to contribute to the Research for Development Challenge (RDC) on "People and Agro-ecosystems". The SLM outcome line will link and build upon results obtained from the outcome line on "Markets, Institutions and Livelihoods", to improve the effectiveness of agricultural research and development and the uptake of research results by small scale farmers and will solicit support especially in the field of successful targeting, reaching end users and impact assessment. Strengthening the organizational capacities of farmer organizations (including women's producer organizations) and rural service providers will be instrument to the success of the SLM outcome line. Issues related to social capital will be addressed mainly through this outcome line.

The goal is to strengthen national and international capacity to manage tropical ecosystems sustainably for human well-being, with a particular focus on soil, biodiversity and primary production; to reduce hunger and poverty in the tropical areas of Africa 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 agricultural policy formulation and development.

The objective of the SLM outcome line is "To enhance knowledge and understanding of soil health important to sustainable agricultural production in tropical landscapes, and to demonstrate that by improved targeting of land use and soil management interventions trends in the erosion of the soils resource base can be reversed and benefits can be achieved in gains in sustainable agricultural production through enhance provision of soil ecosystem goods and services

The SLM outcome line has defined 5 outputs to satisfy the objectives and goals defined. For the implementation of activities to generate these outputs the SLM outcome line depends on projects that will address part or some of these outputs. The implementation of the activities planned for the period 2009 – 2011 is partly based on existing project that will mature during the planning period and partly on projects that are either in the pipeline or are in the stage of proposal writing. The following are the **DESIRED OUTPUTS:** related these activities are:

- **Output 1.** Biophysical processes and principles that underlie soil health; processes of soil degradation and drivers and proximate causes of soil degradation understood, principles for restoring soil biological quality and soil health defined, with emphasis on soil biological processes and the interaction with soil physical and chemical components (including soil organic matter) in agro-ecosystems.
- **Output 2.** Economically viable and environmentally sound soil management practices developed and tested, integrating knowledge of biophysical, socio-cultural and economic processes, with emphasis on direct and indirect management of soil biological resources for low- and medium external input agricultural systems.
- **Output 3.** Socio-economic and cultural drivers for land degradation identified and constraints mapped; Options for sustainable land management and reversal of soil degradation for social profitability developed and application domains identified
- **Output 4.** Decision support tools for improved targeting of recommendation for sustainable land management and negotiation support; Institutional environment and support services required for sustainable land management identified and policy recommendations.
- **Output 5.** Stakeholder capacity to advance the development and adaptation of recommendations for improved land management enhanced; effective dissemination of results and advocacy for sustainable land management

The ISFM and SLM outcome lines are strongly interlinked as both aim for sustainable agricultural productions systems, however with **ISFM outcome line** putting an emphasis on the nutrient management for enhanced agronomic efficiency and production, focusing on plot and farm scales, whereas the SLM outcome emphasizes the management of soil biological resources and has a focus on the landscape scale. The SLM outcome line will rely on inputs (or links with) other outcomes lines, especially the **Markets OL** as far as market value chains on tropical fruits and other products/dual purpose crops are concerned, as alternative crops may constitute an important element in the strategy to improve land and soil management; and as far 'Managing risks' is concerned in looking at willingness to invest in soil resources base (farm household decision making and institutional level)

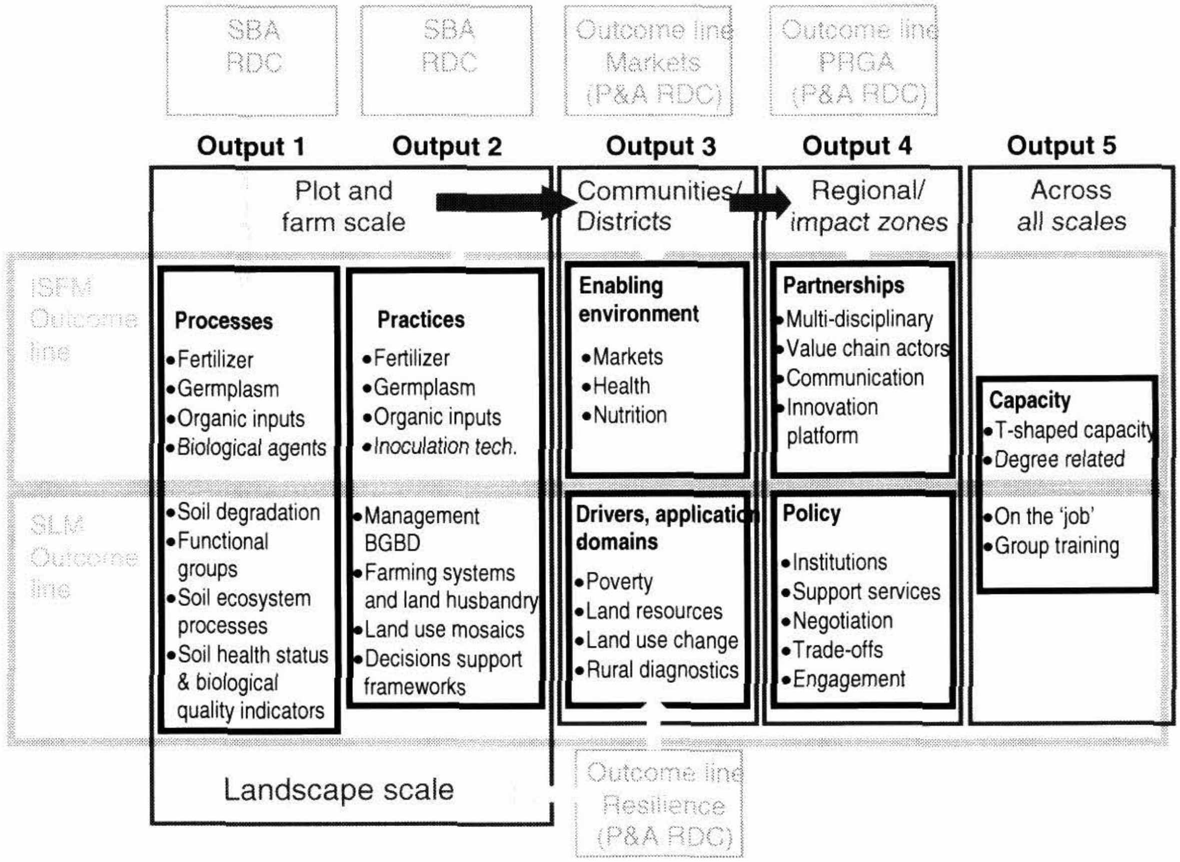


Figure 1: Specific focus areas of the ISFM and SLM Outcome lines and potential linkages between these and the other CIAT Outcome lines under the 'Sharing the Benefits of Agro-biodiversity' (SBA) the 'People and Agroecosystems' (P&A) RDC.

Further, inputs from the **Agro-ecosystems and climate change OL** will be important in shaping "Decisions in landscape, water and soil management". Work on sustainable (integrated) production systems and collective action; trade-off analyses, payment schemes for ES will be important complementary activities; Work on "climate risk and vulnerability" –will indicate climate risks, incidence and crop vulnerability to soil borne pest and diseases for example that will have direct implication for sustainable management of the soil biological resources and support in expected in the development of decision support tools and formulation of policy options. The connections of the SLM outcome line with other outcome lines is depicted in the figure below.

I.3. ALIGNMENT TO CGIAR SYSTEM PRIORITIES:

TSBF-CIAT's outcome line on Sustainable Land Management is housed mainly under CGIAR System Priority Area 4: Promoting poverty alleviation and sustainable management of water, land, and forest resources. Majority of the efforts are dedicated to System **PRIORITY AREA 4A**: *Promoting integrated land, water and forest management at landscape level,* and **PRIORITY AREA 4D**: Promoting sustainable agro-ecological intensification in low- and high-potential areas. With activities contributing to the following specific goals of **PA 4A**:

- **Specific goal 1:** *To develop analytical methods and tools for the management of multiple use landscapes with a focus on sustainable productivity enhancement*

- **Specific Goal 2:** *To enhance the management of landscapes through changing stakeholder awareness and capacity for social-ecological planning at landscape and farm levels*
- **Specific Goal 5:** *Creating multiple benefits and improved governance of environmental resources through the harmonization of inter-sectoral policies and institutions.*

With respect to the System **Priority Area 4D** the following specific goals are being served:

- **Specific Goal 1**: *To improve understanding of degradation thresholds and irreversibility, and the conditions necessary for success in low productivity areas*
- **Specific Goal 3**: *To identify domains of potential adoption and improvement of technologies for improving soil productivity, preventing degradation and for rehabilitating degraded lands*
- **Specific goal 5:** *To improve soil quality to sustain increases in productivity, stability, and environmental services through greater understanding of processes that govern soil quality and trends in soil quality in intensive systems*
- **Specific Goal 7:** *To optimize productivity at high input use (e.g. labour, nutrients, pest control practices, water, seed, and feed) through understanding and managing spatial and temporal variation.*

I.4. IMPACT PATHWAYS

The 5 major outputs described above are the main pathways through which the SLM outcome line aims to generate impact. All the 5 outputs represent enabling conditions that need to be met to affect change in land use and soil management. These conditions include: 1) appropriate information and knowledge on status of land degradation, the accurate diagnosis and understanding of causes, constraints and opportunities surrounding to land degradation, 2) appropriate land and soil management technologies and options for the various stakeholders for intervention at plot and landscape level, 3) enabling environment that addresses the drivers of land degradation and provides incentives for the adoption of improved soil and landscape management; this may refer to proper market infrastructure, access to markets, reward mechanisms for environmental goods and services, access to land and other resources, 4) government policies and support structures (institutes) that allow for the implementation of sustainable soil and land management and finally 5) Capacity building through formal training components as well as stakeholder workshops and generation of international public goods.

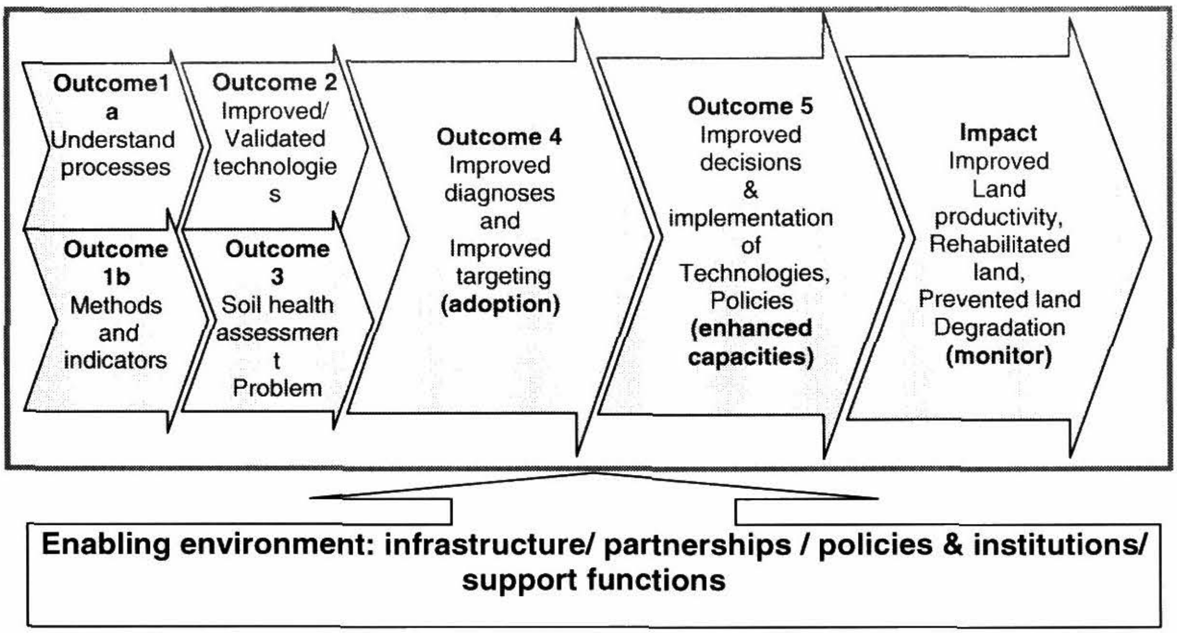


Figure 2: Outcomes of the various activities (outputs) and their relation to the overall goal of the SLM Outcome line indicating the impact pathway

I.5. INTERNATIONAL PUBLIC GOODS

The IPG of the SLM outcome line include the following:

- Improved understanding on soil (biological) processes;
- Inventory of below-ground biodiversity in major tropical eco-regions;
- (Standard) methods for the inventory and characterization of BGBD
- Improved understanding of loss of BGBD in relation to the intensification of land use;
- Improved knowledge on how different stakeholders use and manage landscapes;
- Indicators of soil (biological) quality;
- Improved approaches and practices for managing soil, water and land resources at a landscape level;
- Innovative diversification options of land use within agricultural production landscapes;
- Decision support tools and models to analyze trade-offs among food productivity, ecosystem services and land conservation;
- Institutional innovations and policy options to reduce land degradation and to restore degraded lands.
- Three-tier-approach for sustainable crop and livestock enterprise promotion, linking farmers to market, and rural poverty reduction.

The Institute has a comparative advantage in conducting and coordinating IPG research on soil biology and fertility in a farming system and land use system context, where land degradation undermines local livelihoods. However, while TSBF - CIAT will focus primarily on strategic research, it will support technology dissemination and development activities with partners via regional networks and global projects. TSBF - CIAT SLM will continue research on below-ground biodiversity as a means of beneficially managing soil biology, through the GEF-UNEP funded global project on below-ground biodiversity (BGBD) which is in its second phase of project implementation. Much of the applied research and dissemination of findings, as well as NARSs capacity building, will be done via the Institute's regional partner network — the African Network for Soil Biology and Fertility (AfNet). TSBF-CIAT also collaborates with the South Asian Regional Network (SARNet) on soil fertility research in that region. Efforts will be undertaken to build a similar network for soil biology and fertility research in Latin America

II. ANNUAL REPORT 2008 SUMMARY

II.1. SLM OUTCOME LINE LOGFRAME

Targets	Outputs	Outcome and Impact
Output 1	<u>Description:</u> Biophysical processes of soil degradation and principles that underlie soil health; Root and proximate causes of soil degradation; Principles and concepts for restoring soil biological quality and soil health defined <u>Intended users</u>: CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, and regional consortia	<u>Outcome</u>: Understanding of soil processes important to provide soil ecosystem services informs the development of technologies and management options (see output 2) <u>Impact</u>: Standard methods and indicators help assessment of soil health status in uniform and consistent manner and allow for identification of soil health problem and create awareness of severity of the problem and generate action preparedness among stakeholders.
Output Targets 2009	Practical methods for rapid assessment and monitoring of the soil resource base status in relation to soil nutrients, organic matter, aggregation and soil structure	Standard methods allow for comparing between regions and global and regional assessment of soil health status
	Standard methods for the inventory of BGBD documented (handbook published)	Information on methods for the inventory widely available. Standard methods widely used and cited in inventory studies
	BGBD assessed in 11 benchmark sites across the Tropics and loss of BGBD as result of land use intensification determined; Assessed of soil health status in agric prod. landscapes of major agro-ecological impact zones	Status of BGBD in benchmark sites across major impact zones documented and possible consequences for sustainable production identified; Awareness of the status of the soil resource base increased leads to enhanced action preparedness to protect the soil resource base
	Indicators of soil (biological) quality identified and documented	Tools available for rapid assessment and monitoring of soil health status; Adoption of indicators leads to increased capacity (and awareness) of stakeholders to assess and monitor soil health status
	Concepts of valuating the contribution of soil biota and biotic processes to the provision ecosystem goods and services applied in case studies	Documented value of BGBD and soil biological processes assists in recognition of the importance of soil biodiversity and create willingness to protect these resources
Output Targets 2010	Modelling tools to predict effect of soil management interventions and technologies on soil health status developed and validated	Models help to determine realistic and viable solutions to soil health problems and help to determine possible investment options and decision making
	Methods for evaluating soil health status (provision ecosystem goods and services) developed and accepted	Methods allow attaching value to land and soil degradation and improve decision on intervention.
	The social, gender, and livelihood constraints and priorities affecting the sustainable management of soils identified especially in relation to improved SOM management and management of BGBD	Partners are working to overcome the identified constraints with new proposals and on-going research

Targets	Outputs	Outcome and Impact
Output Targets 2011	Decision support framework for targeting soil management recommendation (ISFM and INRM technologies) at landscape level established	Partners use decision support framework for improved targeting of ISFM and IRNM technologies and increases likelihood of success of the interventions
	Tools and techniques for rapid appraisal of soil health status and gradients at landscape level developed	Partners use tools for assessment of soil health status of various production landscapes
	Tools and methods developed for rapid appraisal of agricultural production landscapes especially with respect to socio-economic drivers for land and soil degradation and socio-economic constraints for improving soil productivity and soil health; mapping of the socio-cultural and policy environment (production potential, social & human, economic, natural capital)	(National) Partners use framework and tools for landscape planning in selected tropical agricultural productions landscapes

Targets	Outputs	Outcome and Impact
Output 2	Description: Economically viable and environmentally sound soil management practices developed and tested, with emphasis on direct and indirect management of soil biological resources for low- and medium external input agricultural systems. Intended users: CGIAR, ARI, researchers from NARS and local universities, NGOs, farmer groups, private sector agents, extension services, and regional consortia, conservation agencies	Outcome: Technologies and soil management strategies available for range of agro-ecological and socio-economic conditions provides viable options for various stakeholder groups and increases adoption of improved technologies Impact: Increased sustainability of productions systems and improved security of farmers in target impact areas.
Output Targets 2009	Local baselines and interviews show that farmers' understanding of soil biological processes and soil health status is demonstrably enhanced in at least 5 benchmark sites	Farmers adopt direct and indirect management options for management of BGBD and soil health
	Direct and indirect options to manage BGBD that enhance locally important ecosystem services demonstrated	Increased awareness among local stakeholders of the benefits of conserving and managing BGBD Evidence based decisions on investment in indirect management for improving soil health
	Alternative production systems like Conservation Agriculture tested and evaluated for effectiveness in maintaining and restoring soil health and with respect to adoptability	Evaluation of CA will contribute to improved targeting of CA as alternative strategy for sustainable agricultural production and increase adoption
Output Targets 2010	Alternative crops and integrated systems investigated for their effectiveness in maintaining soils resource base	Demonstration of success of more integrated productions systems and crop diversity will stimulate farmers to adopt more diverse systems and enhance productivity
	The role of soil organic matter in regulating BGBD and soil health tested across a number of experimental sites in at least 5 countries in the tropics	Partners are adapting soil fertility management practices to support specific soil organic matter-related functions
	Species/strains identified with potential for inoculants development; Direct inoculation in various cropping systems and for various purposes (enhancing productivity, control of soil borne pest and diseases and improving soil structure) tested on persistence, affectivity and competitiveness	Partners explore options for biological means to improve soil productivity and soil health status and possible commercial production of inoculants. Research into use of biological resources for inoculum development strengthened.

Output Targets 2011	Tools for modeling resource allocation within agricultural productions landscapes and optimization of resource reallocation suggested for selected agricultural production landscapes.	Partners realize that measures taken at landscape level may sort better affect and adjust their strategies for soil resource conservations; Collaborative action and community based interventions stimulated Better use of resources leads to enhanced productivity
	Improved production systems (including technologies) and having multiple benefits of food security, income, human health and environmental services documented and characterized in terms of application domains	Documentation on productions systems and technologies (soil and land conservation, inoculation, soil organic matter management, fertilizer technologies etc) easily accessible and allows for consideration of variety of alternative solutions to soil health related problems,

Targets	Outputs	Outcome and Impact
Output 3	Description: Socio-economic and cultural drivers for land degradation identified and constraints mapped; Options for sustainable land management and reversal of soil degradation for social profitability developed and application domains identified Intended users: CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, policy makers	Improved diagnosis of soil health problems informs identification of entry points and targeting of soil and land management interventions.
Output Targets 2009	Methods, protocols and indicators developed to characterize socio-cultural and economic environment and for valuation of soil ecosystem services	Indicators and standard protocols inform rapid rural appraisal and diagnoses of soil health related problems in agricultural productions landscapes
	Socio-economic constraints to soil health management assessed in some agricultural productions landscapes and forest margins of the BGBD project; diagnostic carried out	Information on relative importance on socio-economic constraints informs policy formulation for targeted areas
	Methods developed for socio-cultural and economic (participatory) valuation of ecosystem goods and services developed and implemented in BGBD project sites	Enhanced appreciation by farmers in the study sites of soil related ecosystem services enhances adoption potential for improved soil (BGBD) management. And effective decisions on protection of soil biological resources
Output Targets 2010	30% of partner farmers in pilot sites use SLM options that arrested resource degradation and increased productivity in comparison with non-treated farms	Increased productivity and conservation of degraded landscape
Output Targets 2011	Scale-up research on soil fertility gradient to farm and landscape levels by conducting one or two carefully designed, integrated studies in collaboration with other CIAT scientists	Generalize the findings from on farm level gradients in soil fertility into generic rules and tools that can be used in guiding ISFM in practice across landscapes
	Landscape dynamics assessed, social and economic constraints to improved land and soil management assessed, application domains and options for improved soil and land management identified for the majority of the TSBF project sites	Diagnosis inform long term strategies for improved productivity, soil resource conservation and restoration in the target areas within the impact zones

Targets	Outputs	Outcome and Impact
Output 4	Description: Decision support tools for improved targeting of recommendation for sustainable land management and negotiation support; Institutional environment and support services required for sustainable land management identified and policy recommendations. Intended users: Researchers from NARS, NGOs, Extensions services, policy makers, donor community	Principles of sustainable land management integrated in local and country policies and programs and investment plans; Strategy documents inform Donor community on possible investment options and ultimately reversed land degradation contributes to global SLM goals
Output Targets 2009	Farmer-to farmer knowledge sharing and extension through organized field trips and participatory M&E activities conducted in TSBF SLM project sites	Farmers realize benefits of knowledge sharing; enhanced capacity to adopt and adjust technologies for sustainable land management
	Trade-off analyses conducted and policy recommendation issued for the BGBD benchmark areas	Policy makers aware of the importance of conservation and sustainable management of BGBD; conservation of soil biological resources included in local policies contribute to sustainable utilization of soil biological resources
Output Targets 2010	**Profitable land use innovations scaled out beyond pilot learning sites through strategic alliances and partnerships, and application of alternative dissemination approaches**	Partners incorporating new knowledge and skills in new proposals and on-going research efforts
	Decision support framework for soil and land use management recommendation developed and validated in pilot learning sites in 5 countries in SSA	Application of decision support framework help stakeholders to target interventions and defined their investment plans;
	Strategies for institutionalization of participatory NRM approaches and methodologies established	New institutional arrangement catalyze multidisciplinary work and enhance scaling up of technologies and best practices
Output Targets 2011	Social science aspects are included in the decision-making process and tools to better understand actionable management strategies for landscape management, their knowledge requirements, and economics.	TSBF-CIAT expands its social science activities regional hubs in Southern and Central Africa and few agro-ecosystems of major importance.

Targets	Outputs	Outcome and Impact
Output 5	Description: Stakeholder capacity to advance the development and adaptation of recommendations for improved land management enhanced; effective dissemination of results and advocacy for sustainable land management Intended users: CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, young professionals, policy makers	Partners promoting resilient production systems with multiple benefits (food security, income, human health and environmental services) Improved resilience of production systems contribute to food security, income generation and health of farmers

Output Targets 2009	Web content of the BGBD website enhanced to contain data and information on taxonomy and species identification, methods for inventory and characterization of BGBD, Synthesis reports on inventory, indicators of BGBD loss and soil biological quality indicators and management option and techniques for managing BGBD	Increased number of biodiversity scientists and practitioners use the website as resource base for information on BGBD (for inventory and management)
	Documentation on integrated approach to the management of agricultural production landscapes with respect to soil health and conservation of the soil resource base	Different partners linking food security, income generation, environmental health to human wellbeing at landscape level
Output Targets 2010	Validated intensive and profitable systems are being demonstrated, promoted by partners and adopted by farmers in 10 countries	Increased sustainable productivity and profitability of major cropping systems
	Products of the trade-off analysis are guiding the introduction and evaluation of alternative NRM options, better suited to the farmer production objectives and the environment of the actions sites	Farmers and other stakeholders empowered in use results of trade-off analysis to better negotiate for support services and policy formulation for sustainable production
	Stakeholder workshops in selected productions landscapes involving national and local stakeholders, presenting recommendations for improved soil and land use management	Values attached to ecosystem services are shared by various stakeholder groups and provides basis for collective action to conserve and manage soil resource base.
	Stakeholders in target areas have an improved capacity for collective action and local policy negotiation and implementation of integrated land use practices using integrated agricultural research for development	Improved knowledge sharing and exchange to empower stakeholder to innovate with respect to technologies and best land conservation practices
Output Targets 2011	Improve linkages with the private sector to improve access to fertilizer and develop recommendations for its use by farmers and other stakeholders involved.	Potential adoption and impacts of mineral fertilizers in ISFM by farmers and agro dealers increase
	Demonstration and documentation of successful cases prove approach and methodology used and will generate additional funds for out scaling of the activities (donor buy-in) NGO adopt methodology and will lead to improved adoption and policy formulation	Arrest of resource degradation and restoration of soil resource base in targeted production landscapes and increased productivity and well being of farmer communities; Partners scale up collaborative research on soil health and restoration of soil resource base in well designed and fully integrated studies.
	Degree training (BSc, MSc and PhD) on relevant topics	150 students from developing targeted countries have received degrees through involvement in SLM projects
	Short term training courses (methods for inventory of BGBD, Decision support tools for recommendations on soil and land use management, Economic valuation and PES, etc.)	Scientific capacity in national partner institutions enhanced

II.2. OUTPUT TARGETS FOR 2008

II.2.1 At least three practical methods for rapid assessment and monitoring of the soil resource base status in relation to nutrients, organic matter and biota are adapted for various cropping systems.'

Status: Fully Achieved.

Explanation:
This output target is shared with the ISFM outcome line. AS far as the SLM component is concerned we consider this target to be fully achieved with the publication of the "Handbook of Tropical Soil Biology; Sampling and Characterization of Below-ground biodiversity" (Moreira et al., 2008), practical methods for the assessment of soil biodiversity has been provided. The book contains 11 chapters and provides methods for the inventory of macrofauna, mesofauna, soil nematodes, nitrogen fixing leguminosae nodulating bacteria, arbuscular mycorrhizal fungi, saprophytic and plant pathogenic soil fungi, fruit flies, entomopathogenic fungi and nematodes and finally methods for the inventory and classification of land use relevant to the inventory of below-ground biodiversity.

The book "Biodiversidade do solo em ecossistemas Brasileiros" (Moreira et al, 2008) describes the soil biodiversity in Brazilian ecosystems. It is basically and a synthesis and compilation of previous work. The book contains chapters on the various functional groups of soil organisms like earthworms, ants, termites nematodes etc., including methods of inventory, as well as chapters on management of soil fertility and land use in the Amazonian benchmark site of the BGBD project.

The CSM-BGBD project investigates loss of soil biodiversity in relation to land use intensity. In 2008, 6 papers were published reporting on the results for particular groups of soil organisms for particular benchmark sites.

The CSM-BGBD project was prominently mentioned in a News Feature in Nature, dealing with "What Lies Beneath"

II.2.2 Communities in at least three countries demonstrate and test direct or indirect management options that enhance locally important ecosystem services using BGBD.

Status: *75%* Achieved.

Explanation:
In 10 of the 11 benchmark sites of the CSM-BGBD project in the 7 tropical countries where the CSM-BGBD project is implemented, experiments and demonstrations have been conducted in 2008. These demonstrations and experiments, related to the sustainable management of soil biodiversity, are conducted with the participation of farmers. The farmer participation may relate to active involvement in management of the experiment or in the participatory monitoring and evaluation. The experiments address direct management options like inoculation with rhizobia and mycorrhiza as well as to indirect management options like soil organic matter amendments, improved composting etc., with the aim to improve nutrient availability (and nutrient cycling), improving soil structure and water availability, control of soil born pest and diseases, improving soil biodiversity and biological activity and carbon sequestration. The experiments will be finished in 2009 and reports on the experiments and demonstration are also expected then.
There is a strong link with experiments that are conducted under the auspices of the ISFM outcome line and we hoe we will be able to synthesis results from these experiments across both outcome lines.

II.2.3 Farmer-to farmer knowledge sharing and extension through organized field trips and research activities result practices in at least two sites.

Status: *75%* Achieved.

Explanation:
The knowledge sharing and extension are linked with the experiments and demonstration mentioned above. In all cases participatory monitoring and evaluation is done or farmer exchange visits are held. Next year as the experiments will cease the uptake of alternative technologies and management options will be evaluated. Again this is a common approach across TSBF-CIAT projects and these activities are not only reserved for those conducted under the SLM outcome line.

II.2.4 Web content in the BGBD website enhanced to contain data and information on BGBD taxonomy and species identification.

Status: *75%* Achieved.

Explanation:
All the country project websites are up and running: Brazil, Cote d'Ivoire, India, Kenya, Mexico, Uganda, Indonesia. The project itself also has a functional websites. You can visit the websites at the following URL addresses:

- http://www.bgbd.net
- http://www.biosbrasil.ufla.br/.
- http://www.bgbdci.org
- http://lemlit.unila.ac.id/bgbd
- http://www.tsbfsarnet.org
- http://www.inecol.edu.mx/bgbd
- http://www.uonbi.ac.ke/research_projects/BGBD/
- http://www.bgbd.or.ug

The global coordinating office has been collating the data on the inventory of soil biodiversity from all the benchmark sites and these will be made available on the WEB site in 2009.

II.2.5 Methods developed for socio-cultural and economic valuation of ecosystem services developed and applied for trade-off and policy analysis in at least in 1 humid and 1 sub-humid agroecological zones.

Status: *75%* Achieved.

Explanation:
A number of individual cases studies and papers on the economic valuation of soil biodiversity have been published (or have been submitted). Already in 2005 the proceedings of a workshop on methods for the economic valuation of ecosystem services of below-ground biodiversity was published. This was followed by a study on the future of Rhizobium inoculation technology in Indonesia (technical and economic perspectives). Further, a paper

was presented (and submitted for publication) on the economic benefits nitrogen fixation using promiscuous soybean for the African continent.
However, the CSM-BGBD project steering committee concluded that it is not feasible to develop comprehensive methods for evaluating the economic benefits of managing BGBD, or for trade-off analyses and policy analyses, mainly because of the difficulty in measuring contribution of soil organisms to ecosystem processes and ecosystem services. Therefore a review paper and lessons learned on the economic importance of BGBD and environmental benefits from management and conservation of below-ground biodiversity will be presented in 2009, drawing on the experience in the project.

II.2.6 In at least four of the countries participating in the BGBD project, policy stimulated to include matters related to BGBD management, and sustainable utilization.

Status: *50%* Achieved.

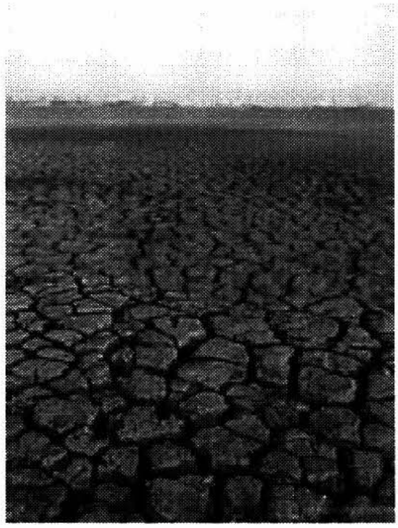
Explanation:
Policy formulation is tried to be influenced through the participation in meetings and events, both at national and international level, concerning the conservation of biological diversity (CBD). This project aims to support and contribute to the Soil Biodiversity Initiative that was established as result of resolution of the COP of the CBD.
In 2008 we participated in a side event during the SBSTTA 13 organized by UNEP/DGEF informing on the outcomes, information generated and technical assistance provided to developing countries by UNEP/GEF projects on conservation and sustainable use of agricultural biodiversity, of which the conservation and sustainable management of below ground biodiversity (CSM- BGBD) project is part.
At national level the CSM-BGBD project participated in (and presentation at) the International Biodiversity Day in Kenya, with carried the theme "Biodiversity and Agriculture".
In Mexico the CSM-BGBD project was represented at the "International Soil Day", where a presentation was given on "Soil biodiversity and its management for the conservation of soil fertility".
However, the project aims to present a number of information products and "lessons learned" concerning soil biodiversity, its importance and options for management as policy briefs in 2009 and at major international events like the COP of the CBD in 2010.

II.3. HIGHLIGHTS FOR 2008

II.3.1 African Soil Information Services project approved

The African Soil Information Services (AfSIS) project was approved in 2008 and officially started as per the first of November 2008. The project is funded by the BMGF and AGRA with a total budget of US$18.1. The official launch was held in January 2009 and it received worldwide and very extensive media coverage. We will report extensively on the event in the annual report for 2009. But as a means of highlighting this major achievement find below the article published in the *New Agriculturalist,* 2009-2. The article was written by Zablon Odhiambo, Kofi Adu Domfeh and George Kalungwe for WREN Media.

Points of view: Saving African soils: grounds for hope?



500 million hectares of farmland in sub-Saharan Africa are moderately or severely nutrient-depleted.
Credit: World Bank

At the recent launch in Nairobi of a new digital map showing soil depletion in Africa, soil scientists decried poor rates of fertilizer application in the continent. Five hundred million hectares of Africa's agricultural land is moderately or severely mined of life, it was reported, yet farmers apply only ten percent of the required soil nutrients to support food production.

Soil scientists in Africa and beyond are now convinced that investments focusing on depleted soils are vital to achieve a turn-around in agricultural productivity. Through the African Soil Information Service (AfSIS), remote satellite imagery and on-the ground efforts will be used to document, analyze and distribute soil data. The service will also establish systems for consistent evaluation of key soil properties, such as its capacity to provide nutrients and hold water.

In *Points of view*, soil and fertilizer experts share their views on how African soils can be saved.

Sharing information on soils
With the right use of extension staff, Africa can increase fertilizer use from 20 to 60 per cent. This will make a very big impact. Africa needs information and scientific evidence on good fertilizer use.
Nteranya Sanginga, director of the Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture (TSBF-CIAT), Kenya

Kenya will benefit from more efficient use of fertilizers. Soil data provided in the past has not been adequately used. We need to make the digital soil maps more user-friendly such that they are easily understood by extension staff. The information can indeed help us understand our soils better and know what's to be done to ensure sustainability.
Wilson A Songa, Agriculture Secretary, Ministry of Agriculture, Kenya

We need to train agro-dealers on making appropriate recommendations. Sometimes we need to back it up by soil testing, so that they know, for example, that in this district the soil is low in nitrogen, it is low in phosphorus, or it is low in potash. Then they should be able to tell the farmers what amount of fertilizer they will require so that they will get optimum yield of whatever crop they are growing.
Francis Tetteh, senior research scientist, Soil Research Institute, Ghana

On small-scale farm plots, organic fertilizer may be sufficient to provide nutrients and maintain soil health. On large areas, chemical inputs are likely to be needed.
Credit: World Bank

There is a high need for fertilizer plants in Africa. When you buy fertilizer from Asia or Europe, port charges and sea-haulage costs as well as local transport make fertilizers more than double their original price. With rising fuel prices, this makes affordability a very big problem. This can be dealt with at the policy level where governments could waive taxes, provide special tariffs and give port rebates to transporters, or implement local fertilizer plants.
Peter Okoth, project information manager, TSBF-CIAT, Kenya

Exploiting natural mineral reserves
Apart from the existence of natural deposits of the key raw materials for producing fertilizers - over 75 per cent of rock phosphate deposits in the world are found in Africa - labour is also relatively cheap.
Jonas Chianu, TSBF-CIAT

Tanzania has a natural reserve of rock phosphates - *minjingu* - which can be used to process synthetic phosphates. There are also other potential raw materials for fertilizer production: diatomite deposits in Kenya also seem to have important nutrients for crop growth and development which should be investigated further.
Peter Okoth, project information manager, TSBF-CIAT

The overriding constraint in African soils with phosphorus. The *minjingu* reserve in Tanzania provides an opportunity for the continent to exploit local resources to increase access to affordable fertilizers for its farmers.
Keith D Shepherd, principal soil scientist, World Agroforestry Centre, Kenya

Financing for fertilizers - credit, vouchers and availability
For Africa's very poor farmers, even if the banking system was working, they can't really afford to get credit. For those, you need smart subsidies on seed and fertilizers supplied through the rural input shops. But for others, you work with banks. And AGRA for example, is working to give loan guarantees so that banks can lend to farmers and agro-dealers, and we try to reduce the rate of interest that banks charge them.
Akin Adesina, vice president, policy and partnership, Alliance for a Green Revolution in Africa (AGRA)

African governments must address nutrient depletion if the current food crisis is to be solved.
Credit: World Bank

Like the success stories in Malawi, the voucher system must now be considered by African governments. The system has also been practiced in the US under the Contracted and Early Payment System where producers are paid 50 per cent of a crop's anticipated value at maturity. For Kenya, the National Cereals and Produce Board could pay farmers 50 per cent of the value and recoup the sum at the harvest season.
Peter Okoth, TSBF-CIAT

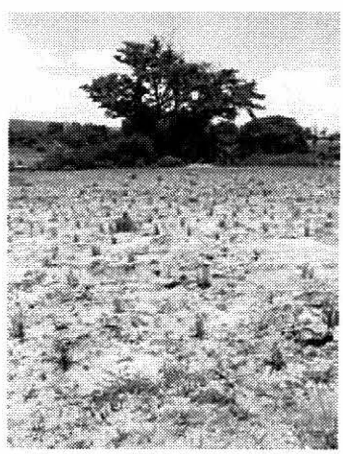
The main problem is that most of our agro-dealers do not have enough money at the time when fertilizers are cheap on the international market, so they are not able to stock enough fertilizer before the rains start. If we had enough demand from the farmers, if farmers were well-organized, they would be able to give the agro-dealers an effective demand, and the agro-dealers would have the confidence to supply the fertilizer.
Vincent Wandale, principal business officer, Ministry of Agriculture, Malawi

The problem is actually getting fertilizers to the rural areas. That is why we have to first change the farmers, put them in groups, what we now call farmer based organizations. Put them in groups, and train them well to know the importance of fertilizer.
Francis Tetteh, Soil Research Institute

There are ongoing efforts led by the African Development Bank (ADB) to reduce logistics costs that make fertilizers very costly in Africa.
Namanga Ngongi, president, AGRA

Top-level lobbying and policy dialogue are being used, based on the conviction that a move towards reducing hunger on the African continent must begin by addressing its severely depleted soils. Improving the overall fertilizer procurement process could reduce the price of fertilizer in sub-Saharan Africa.
Jonas Chianu, TSBF-CIAT

Increasing efficiency of crops and inputs



A lot of work has been done on micro-dosing in West Africa, with very good results as well. Many of these initiatives are isolated attempts, but there are some attempts to scale this out.
Jeroen Huising, TSBF-CIAT

Farmers in Africa only use 10 per cent of the fertilizer needed to maintain adequate food production.
Credit: WRENmedia

You should firstly be able to identify nutrient-efficient crop varieties. Then you have to target the application carefully such that you give it in small doses over a period of time. Of course you must also understand the biology of the crop, that at a particular time, whether you apply it or not, it will not take it up. So this kind of training must go along with the technology.
Lawrence Narteh, senior research scientist, Crop Research Institute, Ghana

There are some small initiatives that specifically look at appropriate fertilizers. *Mavuno*, for example, combines macro and micronutrients and farmers report to have very good results with it.
Jeroen Huising, TSBF-CIAT

There are many cases where soils require organic amelioration first before responses to mineral fertilizers can be obtained. Finding ways to identify such soils through soil tests and mapping these soils is a high priority. It is also important to identify soils that have inherent constraints so that these constraints can be corrected before encouraging farmers to use inputs such as improved seeds and nitrogen fertilizers.
Keith D Shepherd, World Agroforestry Centre

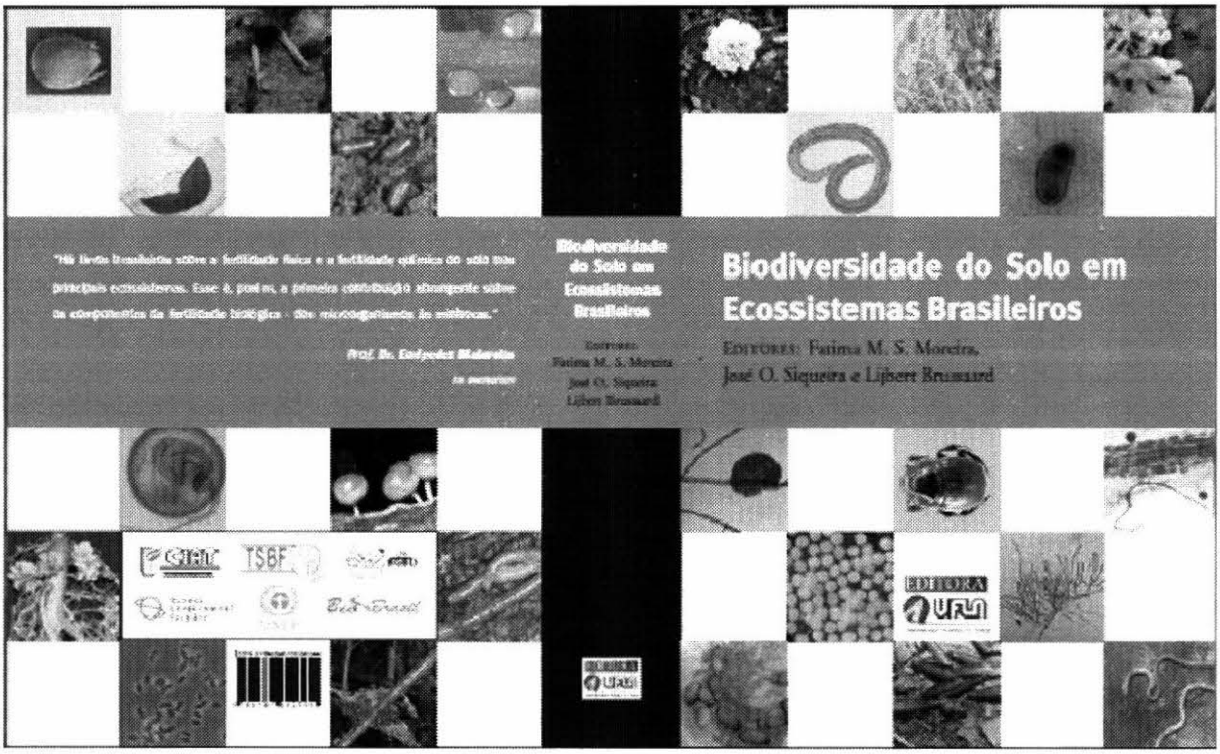
The question is really, how do we get nutrients in the system in an effective and economic way? The solution will be integrated systems where you combine fertilizer input with other sources of nutrients: organic matter, but also the use of *rhizobia* to fix atmospheric nitrogen, together with measures to stimulate root development and use of *mycorrhizae* that may enhance nutrient uptake of the plants.
Jeroen Huising, TSBF-CIAT

High priorities - investment and effort
The strategy will very much depend on the local conditions. There is no specific technology that is applicable everywhere. So, further development and adoption of these technologies by farmers will require massive investment and coordinated effort.
Jeroen Huising, TSBF-CIAT

The capacity of soil science in Africa is going down. Labs that exist do not function. Some countries lack capacity to give this knowledge. Soil management in sub Saharan Africa must be improved dramatically if we are to reduce poverty, feed growing populations and cope with the impact of climate change on agriculture. Achieving this requires accurate, up-to-date information on the state of Africa's soils.
Nteranya Sanginga, TSBF-CIAT

II.3.2 Launch of the Brazilian BGBD review in Portuguese "Biodiversidade do Solo em Ecossistemas Brasileiros

This book, edited by F.M.S. Moreira, J.O. Siqueira, and L. Brussaard, L. was published in 2008 by Editora UFLA, Lavras, Brazil. This book is a further elaborated version of the BGBD review that appeared in 2006, under the title of **"Soil biodiversity in Amazonian and other Brazilian ecosystems"** and that was published by CABI. The 11 chapters of this previous book were updated and translated into Portuguese. Eight chapters were added, broadening the information on an increased number of relevant groups of soil organisms. With this book BIOSBRASIL, that is how the CSM-BGBD project component is called in Brasil, hopes to reach a wider and diverse audience in Brazil aiming to contribute to an increasing awareness of the importance of soil biodiversity that represents and valuable source of genetic resources that can be applied for different uses, including that of medicine.



II.3.3 Workshop on global data analysis for the inventory of BGBD

The CSM- BGBD Project organized a training and data analysis workshop on the application of multivariate statistical analysis (MSA) for the interpretation of BGBD inventory data for purpose of the synthesis reporting on the inventory on BGBD. The workshop was held at the "Institut de Recherché pour le Developpment" (IRD), Bondy-Paris, France. It was the first time that we had representatives from the 7 BGBD countries working together on the analyses of the data aiming to produce a 'global' synthesis. The participants were professor Jerome Tondoh from Cote d'Ivoire, professor Kottapalli Sreenivasa Rao from India, professor Fatima Moreira from Brazil, Dr. Isabelle Barois from Mexico, Dr. Argus Karyanto from Indonesia, Mr. Brian Isabirye from Uganda and Dr. Joyce Jefwa from Kenya. Further the participants included the project coordinator Dr. E. Jeroen Huising, the project Information manager Dr. Peter F. Okoth and the project data analyst Steve Ichami. Resource persons for this workshop were Dr. Elena Vasquez from Colombia, Professor Patrick Lavelle from France (IRD) and Ms. Nuria Ruiz (IRD).
The Participants received training on using ADE4 (a software) which enabled the participants to competently perform various multivariate analyses such as principal component analysis (PCA) and co-inertia analysis, and including IndVal which allows for the calculation of indicator species. The attendees were awarded with certificates of participation at the end of the training.
Soil quality indicator was the main BGBD output addressed in the statistical analysis and training seminar. The conventional definition of soil quality is "the fitness of a specific kind of soil, to function within its capacity and within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation". A more holistic concept of soil quality recognizes soil

as part of a dynamic and diverse production system with biological (including BGBD), organic, chemical and physical properties that relate to the demand of human society.
Soil Quality Indicators (SQI) were generated form a combination of sub indicators on soil organic, chemical, biological and physical proprieties. The ADE4 software was used to run the multivariate analysis. Each country generated their SQI with the data they had available. We will compare results from the individual countries to see if general indicators of soil quality can be defined that can be used for monitoring the status of soil quality across the benchmark areas. Line graphs plots were generated to indicate possible correspondence of soil quality with land use intensity.
IndVal software allows identifying indicator species for particular assemblages of soil of a particular soil quality. The indicator does not always need to refer to particular species, but might apply to taxonomic groups as well. Further analyses will be done to develop an indicator species value index. From this analysis it would be possible to identify which species in a specific functional group can be used as an indicator of soil quality.

Taita land use distribution as a function of soil chemical properties (0-10 cm depth)

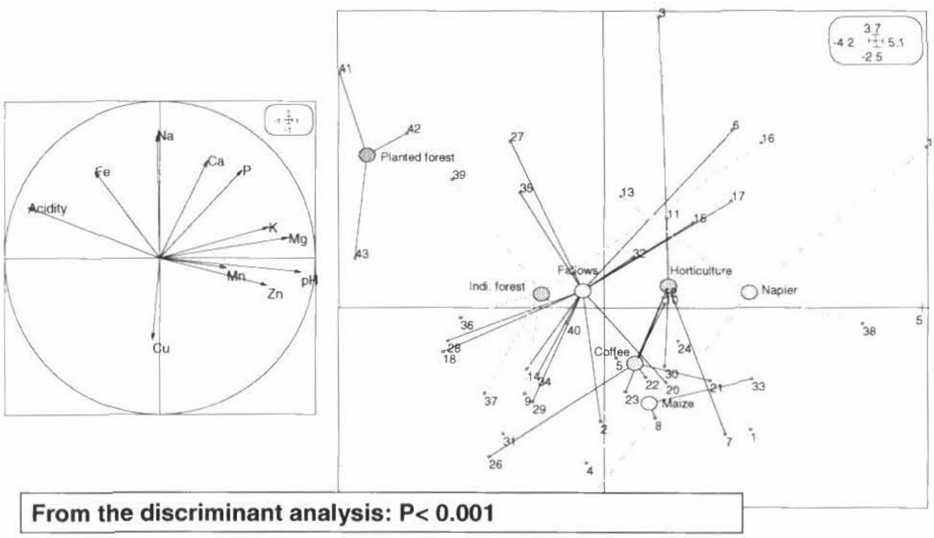
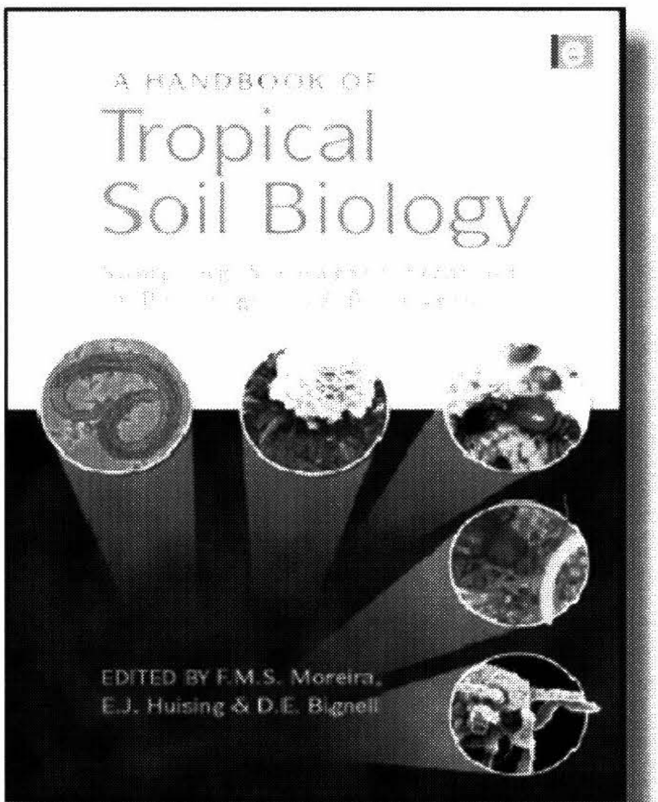


Figure 3: Above is an example of the PCA analysis of the Taita Benchmark site in Kenya, which shows that we find significant differences in soil chemical properties between land use systems. The correlation circle indicates how the chemical properties load on the first and second principal component.

II.3.4 Launch of the Handbook for Tropical Soil Biology: Sampling & Characterization of Below-ground biodiversity

The 'Handbook of Tropical Soil Biology, sampling and characterization of below-ground biodiversity' was published in October 2008, by Earthscan with TSBF-CIAT. It received good reviews from Goetz Schroth of Conservation International, Professor Lijbert Brussaard of the Wageningen University and Professor Sheunesu Mpepereki of the University of Zimbabwe, amongst others. The book is widely available also through internet book stores. The book is viewed as practical manual that will help to unlock further secrets of the rich

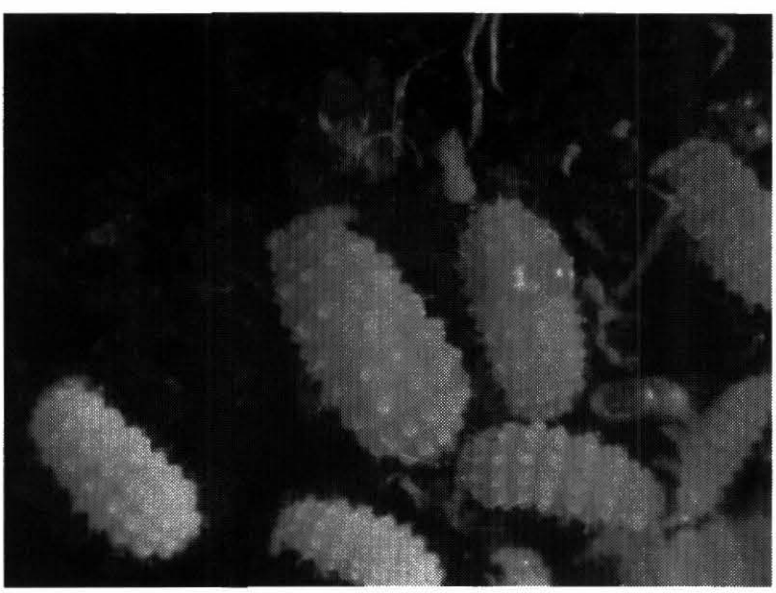
tropical soil biota and the generation of tropical soil fertility, according to Schroth. And Mpepereki adds that it is a valuable practical teaching resource suitable for universities and research institution undertaking laboratory and field level studies in tropical biology.
The methods provide a standardized basis for characterizing soil biodiversity and current land uses in terrestrial natural, semi-natural and agro-ecosystems in tropical forests and at forest margins. The aim is to assess soil biodiversity against current and historic land use practices both at plot and landscape scales and further to identify opportunities for improved sustainable land management through the introduction, management or remediation of soil biota, thus reducing the need for external inputs such as fertilizers and pesticides. The book also contains extensive advice on the handling of specimens and the allocation of organisms to strain or functional group type.
The book was published just a few weeks before the annual meeting of the project steering and advisory committee was held and the book was launched at a special event during that meeting, to be celebrated as one of the major outputs of the project.



II.3.5 International Collembolan Training Workshop

From 24-28 November 2008 the International Collembolan Training Workshop was held at the National Museums of Kenya in Nairobi, organized by the GCO in collaboration with the BGBD Kenya team. The workshop was intended for participants from the BGBD African countries. We were able to get Dr. Arne Fjellberg, who is a world renowned expert on Collembola, from Norway, to teach the course.
The students were given an introduction to Collembola systematics by theoretical and practical approaches. Methods for making microscopic slides were demonstrated, using the glycerol/lactic acid medium ("Gisin") and hand made cavity slides. Students were making their own slides from material partly collected by themselves, partly by the instructor. Also

fresh samples were collected from compost heaps in the garden of the Museum, and analyzed.
Handbooks for identification of African springtails are non-existent. Special publications - like a key to the Hypogastruridae of Kenya - were used. For general training in running identification keys students used a slide collection of European species and identification keys brought by the instructor.
The participants were very positive about the course as it provided them with practical training in the identification of collembolan species, where identification keys and expertise in Collembola are largely lacking in Africa. Collembolans are ubiquitous in all terrestrial biotopes and have an important ecological function. Participants have increased their ability to investigate the collembolan fauna in their respective projects and to include different aspects of collembolan diversity and function in their research, which was the aim of the training course.
Collembola are wingless, insect-like arthropods, ca. 0.5 to 5 mm long. Most species live in the soil or at the soil surface where they may reach densities of up to 100 000 individuals per m^2. Some species can also be found above-ground in the vegetation. World-wide, 7500 species are described and the estimated actual species number could be around 20000 (Bellinger et al. 1996-2000) while ca. 400 species are known from the Nordic countries (Fjellberg 2006). Collembola feed on dead organic matter and microorganisms associated with this substrate. They may also selectively feed on different microorganisms, for example plant parasitic fungi, and some species are known to feed on small soil animals, such as nematodes. They play a central role in the food web of the soil ecosystems since they contribute, directly and indirectly to decomposition and nutrient cycling (Filser, 2002). By feeding on plant pathogens collembolans can be of importance for regulation of plant diseases (Friberg et al. 2005). They can also be important alternative food for natural enemies of pest insects and thereby keep up the populations of these insect so they can be at hand at incidence of pest outbreaks (Settle et al. 1996, Bilde et al. 2000).
This was the last in a series of training workshop organized by the CSM-BGBD project, as part of its capacity building programme. All in all, the project has organized eight of these international training courses on the ecology and systematic of the various functional groups of soil organisms and in data analyses and inoculum production for example.



Slide taken during the Collembola training workshop of Collembola collected from the compost heaps at the National Museum of Kenya (Courtesy Arne Fjellberg)

II.4. PROJECT OUTCOMES 2008

Handbook on Tropical Soil Biology used for training of a wide variety of students in different countries and capacity to produce building effort results in development of new inoculants

The 'Handbook of Tropical Soil Biology, sampling and characterization of below-ground biodiversity' is an output of the CSM-BGBD related to the development of standard methods for the inventory of below-Ground Biodiversity. For the first time there is a book that provides a consistent approach to the inventory of soil biodiversity adopting the inventory of functional groups of soil organisms as a basic principal for assessment of Biodiversity and linking this to ecosystem services and that combines and integrates methods for inventory of these various (functional) groups of soil organisms to come to a comprehensive assessment of soil biodiversity.

We have already received responses of scientist and lecturers that have been using the book as a basis for developing course materials for training purposes. Many of our partners in the CSM-BGD project and especially the universities, are developing training and teaching materials for their own purposes (or have indicates their intent to do so). This applies to the Universitas Lampung (Indonesia), Makerere University (Uganda), Universities of Abobo-Adjamé and Cocody (Ivory Coast), various universities in Brazil and the Institute of Ecologia in Mexico, to name a few. In relation to the latter two, there have been requests and efforts are underway to translate the handbook in Portuguese and Spanish respectively, making the handbook available to readers in Spanish and Portuguese. Those books are expected to be published in 2009. For the first time there is a book on this topic that is focused on the tropics and of which the authors also mainly hail from the tropical countries .We hope this book will become a reference book for the inventory of below-ground biodiversity in the tropics like the handbook of methods on soil biology and soil fertility by Andersons and Ingram has been that for soil analyses in general.

Training and capacity building effort of the CSM-BGBD project have lead to some concrete outcomes. The training in production of mycorrhiza inoculants and investment in lab facilities for microbiology have resulted in the capacity to produce and test mycorrhiza inoculants in Uganda. It is the first facility in its kind in Uganda and at Makerere University. It has resulted in private-public partnership who wants to investigate and invest in the development of mycorrhizal inoculants for various crops.

Other training has focused more on the systematic and identification of particular groups of soil organisms. In case of the collembolan training workshop this satisfied a great demand as expertise is largely lacking in Sub-Sahara Africa. We do expect that this will help in attracting funds for research projects on these particular groups of soil organisms. The project with SLU on food web structure, with specific focus on the role of mesofauna, that collaborates with Kenyan institutes and that makes use of people trained within the project is a illustration of this. There have been other projects as well that make use of people trained in the CSM-BGBD project.

II.5. Publications for 2008

Refereed Journal Articles

Franco-Navarro, F., and Godinez-Vidal, D. (2008) Occurrence of Pasteuria forms from a Biosphere Reserve in Mexico. *Accepted for publication in NEMATROPICA Vol. 38, No. 2*

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II.6. PROPOSALS FUNDED IN 2008

Below, the budget codes and budgets for active projects in 2008 are listed. Most of these projects are also listed in the annual report of the ISFM outcome line, apart from the Conservation and Sustainable Management of Below-ground Biodiversity, which is considered to be purely a SLM project. For the other projects listed both SLM and ISFM components can be identified. The budgets indicated are the total budgets for the projects for 2008, as we did not consider it meaningful to apply percentages corresponding to the SLM and ISFM components.

ACTIVE TSBF BUDGET CODES – 2008				
	Budget Code	**Project title**	**Donor**	**Budget in 2008 (USD)**
1	TS02	CIDA-Funds to Africa	CIDA;	30,000
2	TS10	USAID's Funds to TSBF	USAID	50,000
3	TS15	Bridging funds	CIAT	79000
4	TSA25	France CIRAD Scientist	MOFA – France	30,000
5	TSA30	ICRISAT- Desert Margins Programme with GEF Local Areas on Biological Diversity with Relevance to Climate Change and the Reduction of Land Degradation in the desert Margin Areas	ICRISAT	15,303
6	TSA42	Scaling up livelihood impacts through farmer organization and access to market	KILIMO	227,329
7	TSA58	IFDC - Combating Soil Fertility Decline to Implement Smallholder Agricultural Intensification in Sub-Saharan Africa	Sub-contract from IFDC	153,877
8	TSA67	Increasing Total Farm Productivity in Vulnerable Production Systems in Mozambique through Improved Germplasm Water and Nutrient use efficiencies	AUSTRIA	253,867
9	TSA83	Building adaptive capacity to cope with increasing vulnerability due to climate change	Sub-contract	31,200
10	TSA93	Conservation and Sustainable Management of Below-ground Biodiversity	UNEP/GEF	1,822,454
11	TSA95	Use of Mycorrhizal Fungi to Improve Banana Tissue Culture and as a Component of ISFM for Banana Production in Kenya and Uganda	Rockefeller Foundation	24,315

11	TSA96	IDRC -Strengthening the capacity for research and development to enhance natural resources management and improve rural livelihoods in Sub-Saharan Africa	IDRC	191,408
12	TSA97	Exploring measures to enhance the adaptive capacity of local communities to pressures of climate change	Sub-contract from UZ	36,209
13	TSA99	Going to scale: Developing strategies for scaling out market-oriented organic from farmer group to associate level	Austria	240,889
14	TSB33	Increasing Agricultural Water and Nutrient use Efficiency to meet Future Food Production: An Application of Decision Support Tools and Nuclear Techniques Fellowship Grant	IFAR	11,000
15	TSB35	Publishing of Books by the African Network for Soil Biology and Fertility (AfNet)	FARA	20,000
16	TSB39	Increased understanding and application of Integrated Soil Fertility Management in Africa: Publication of a Reference Manual	Bill & Melinda Gates Foundation	268,556
17	TSB54	A Globally Integrated African Soil Information Service (AFSIS)	Bill & Melinda Gates Foundation	0
18	TSB63	AGRA - Publishing of Book by The African Network for Soil Biology and Fertility (AfNet) for Use in the Development of the Soil Health Program of The Alliance for a Green Revolution in Africa	AGRA	79,750
19	TSB74	Participatory Approaches to Research and Scaling up	CTA	54,516
20	TSB82	Efficient water and nutrient use in cereal grains systems in market based conservation agriculture systems	Sub-contract from IITA SSACP	411,840
21	TSB94	Improving and Strengthening Rural Community Access to Agricultural and Soil Fertility Information in Korogwe District Tanzania	CTA	59,417
		Total		**4,090,930**

II.7. STAFF LIST

TSBF Institute -Director

Sanginga, Nteranya (Soil Microbiologist) (50%)

Senior Staff

Bationo, André (African Network Coordinator (Soil Scientist)) (50%)

Chianu, Jonas (Socio Economist) (25%)

Corbeels Marc (Soil scientist, modeler) (25%)

[1]Delve, Robert (Soil Fertility Management) (25%)

Huising, Jeroen (BGBD Coordinator (GIS Scientist)) (100%)

Jefwa, Joyce (Microbiologist) (50%)

Lesueur, Didier (Microbiologist) 50%)

Ohiokpehai, Omo (Food & Nutrition

Scientist) (0%)

Okoth, Peter (Information Manager) (100%)

Pypers, Peter (Soil scientist) (0%)

Misiko, Michael (Social Scientist) (25%)

Roing, Kristina (Agronomist) (0%)

Thierfelder, Christian (Soil and Water management) (50%)

Vanlauwe, Bernard (Soil Scientist) (25%)

Gert Jan Veldwisch (Social Scientist) (55%)

Zingore Shamie (Soil Scientist) (50%)

Visiting Scientists

Merckx, Roel (Katholiek University,

Maina, Fredah (Asst Scientific Officer) (0%)

Mairula, Franklin (Data Analyst)

Magreta, Ruth (Research Asst, Lilongwe) (0%)

Mapila, Mariam A.T.J. (Research Fellow, Lilongwe) (0%)

Mombeyarara, Talkmore (Research Asst, Harare) (0%)

Technical Staff

Chibole, Livingstone (Field Technician) (0%)

Dzvene, M (Field Asst, Harare) (0%)

Kadzere, Chengetai (Field worker, Harare) (0%)

Kingolla, Brenda (Field Asst-Food Nutrition) (0%)

Kimathi, Martin (Laboratory Assistant) (25%)

Mburu, Harrison (Lab Assistant-Microbiology) (0%)

Mugadi, Doreen (Lab Technician-Microbiology) (0%)

Muthoni, Margaret (Laboratory Assistant) (25%)

Mwangi, Elias (Laboratory Assistant) (25%)

Ngului, Wilson (Laboratory Technician) (25%)

Nyambega, Laban (Field Technician) (0%)

Njenga, Francis (Laboratory Assistant) (25%)

Muranganwa, Francis (Field worker

[1] Left during the year

Belgium) (0%)

Consultants

Woomer, Paul (Soil Scientist. ISFM project) (0%)

Mokunywe, Uzo (Economist, BGBD Project) (100%)

Swift, Mike (BGBD Project) (100%)

Research Assistants

Akech, Caren (Research Asst) (50%)

Kankwatsa, Peace (Research Asst, Kampala) (0%)

Kasareka, Bashikwabo (Research Asst, DR Congo) (0%)

Lodi-Lama, Jean-Paul (Agronomist, DR Congo) (0%)

Lunzihirwa, Julie (Research Asst, DR Congo) (0%)

Mukalama, John (Snr Scientific Assistant) (0%)

Okeyo, Jeremiah (Research Asst) (25%)

Rusinamhodzi, Leonard (Research Asst,

Harare) (25%)

Sanginga, Jean-Marie (Research Asst., DR Congo) (0%)

Waswa, Boaz (Asst Scientific Officer) (25%)

[1]Speciose Kantengwa (CIALCA Coordinator, Rwanda) (0%)

Harare) (0%)

Administrative Staff

Agalo, Henry (Driver / Field Assistant) (50%)

Akuro, Elly (Driver / Field Assistant) (50%)

Chisvino, Stephen (Driver/OA, Harare) (0%)

Kareri, Alice (Administrator) (50%)

Kuya, Sebastien (Driver/Technician, DR Congo) (0%)

Meyo, Rosemary (Administrative Assistant) (50%)

Mulogoli, Caleb (Finance/IT Asst) (50%)

Mutende, Oscar (Finance Assistant) (50%)

Mary Nderitu (Finance Assistant) (50%)

Ngwira, Evelyn (Accounts Asst, Lilongwe) (50%)

[1]Ngutu, Charles (Finance/Admin. Officer) (50%)

Nomsa Nhaoinesu (Admin Asst., Harare) (50%)

Nyamhingura, Isabella (Admin. Asst,

Harare) (50%)

Odongo, Jacqueline (Administrative Asst.) (50%)

Ogola, Juliet (Snr Administrative Asst.) (50%)

Sambo, Margaret (Admininistrative Asst) (50%)

II.8. SUMMARY BUDGET

SOURCE	AMOUNT (US$)	PROPORTION (%)
TSBF		
Unrestricted Core	159,000.00	4%
Restricted Core	0.00	0%
Sub-total Core	**159,000.00**	**4%**
Restricted		
Special projects	2,772,777.00	68%
Sub Sahara Africa Challenge Program	411,840.00	10%
Water and Food Challenge Program	11,000.00	0%
Sub Total Restricted	**3,195,617.00**	**78%**
Direct Expenditures	**3,354,563.00**	**82%**
Non Research Cost	736.367.00	18%
Total Expenditures	**4,090,930.00**	**100%**

III. PROGRESS AGAINST OUTPUT TARGETS 2008 – 2011

III.1. OUTPUT 1 - PROCESSES AND PRINCIPLES UNDERLYING THE FUNCTIONING OF SLM WITHIN THE CONTEXT OF ABOVE CROPPING SYSTEMS, WITH A SPECIAL FOCUS ON FERTILIZER USE AND RESILIENT GERMPLASM.

Outputs (Intended users)	**Outcome (Impact)**
Description: Processes and principles underlying the functioning of ISFM within the context of above cropping systems, with a special focus on fertilizer use and resilient germplasm. Intended users: CGIAR centers, ARIs, researchers from NARES and local universities, and regional consortia	Outcome: Principles, concepts and methods inform technology and system development (Output 2). Impact: Knowledge on principles, concepts, and methods underlying ISFM is used to inform the development of improved ISFM-based soil management practices and cropping system design.

Output 1: Concepts, principles and processes:
The former output on the processes and principles underlying the functioning of ISFM has been integrated in SLM outcome line, with emphasis on processes at landscape level, land use patterns and associated land degradation, sustainable land use mosaics and sustainable production landscapes.
The activities in relation to this output are concentrated around the inventory of soil properties (chemical, physical, soil organic matter and soil biological) and based on this the diagnostic of soil health related problems and the development and testing if methods for the assessment of the soil resource base status. Special attention will be devoted to methods for the inventory of BGBD and the assessment of soil biological quality apart from the soil chemical, physical and SOM quality aspects.
The output target for 2008, viz practical methods for rapid assessment and monitoring of the soil resource bases status in relation to nutrients, organic matter and soil biota is translated into one output target concerning the assessment of the soil nutrient, SOM and soil structural characteristics and methods for the inventory of BGBD. Both targets are defined for 2009. And with the publication of the handbook for tropical soil biology: sampling and characterization of below-ground biodiversity in 2008, this target has already been realized.

The processes that underlie soil erosion and chemical degradations and the direct causes or drivers of these processes are fairly well understood. This may be less so in case of soil physical and biological degradation. Moreover, relatively little is known how to describe land degradation at a landscape level and what the consequences are for the provision of ecosystem goods and services. Sustainable land management requires a concept of sustainable production landscapes and indicators of sustainability. Developing the concept will be done through inventory and characterization of the heterogeneity at land- and soil scape level and investigating (positive and negative) interactions between landscape components (understood both in terms of horizontal and vertical dimensions) within the context of the provision of ecosystem goods and services.. Emphasis will be put on the diagnosis of sustainable land management and identification of constraints for maintaining the soil resource base, and will devote attention to the proximate and root causes (both in the bio-physical and socio-economic domain) of a degrading soil resource base. Much of these processes of land degradation have to be understood in terms of land use change, referring to land use intensification and land use conversion within the context of the bio-physical and socio-economic environment, and these will provide the entry points for s soil and land management interventions and improved targeting of these interventions. A better understanding how the provision of ecosystem goods and services depend on the resource base (including the soil biological resources) will help targeting interventions and indicators will need to reflect the importance of the soil based processes and functions.

Major research questions are:

→ *Which approach and methods should be used for the inventory of Below-ground Biodiversity?*

→ *Which indicators can be used for the assessment of soil quality (soil chemical, physical, SOM and biological quality)?*

→ *What are the tools and approaches to diagnose soil health problems?*

→ *What is the role of soil biota in the provision of ecosystem services and is there a way to assess this and what is the importance of soil biodiversity?*

→ *What can are effective biological technologies or intervention options to enhance soil biodiversity and soil health?*

Output Target 2008: At least three practical methods for rapid assessment and monitoring of the soil resource base status in relation to nutrients, organic matter and biota are adapted for various cropping systems.

COMPLETED WORK

The handbook of Tropical Soil Biology: Sampling and characterization of Below-ground Biodiversity

Moreira[1], F.M.S., Huising[2], E.J., and Bignell[3], D.E. (Eds.)
[1]Federal University of Lavras, Brazil; [2]TSBF- CIAT, Kenya; [3]Queen Mary University, London UK

Society has long known of its dependence on soils, but only recently has considered soils as having a biologically active component. By any measure, soils worldwide are in trouble, and there is a critical and immediate need to apply knowledge about the role of below-ground biodiversity in sustaining soils. This book unquestionably provides the best and most up-to-date effort to document how to assess soil biodiversity in ecosystems that are being rapidly altered by land-use changes.

Intensification is necessary to ensure global food supplies, but as intensification occurs the biological regulation of soil is altered and often substituted by fertilizers and mechanical tillage. This, in turn, frequently results in reduction of soil biodiversity and presents a challenge. Ecologists have long debated the possible importance of soil biotic diversity, citing carbon sequestration in soils, reduction of greenhouse gas emissions, maintenance of soil physical structure and water retention capacity, nutrient provision to plants and control of plant pathogens as specific contributions of soil organisms to soil fertility. The relationship between species diversity and functional diversity of the soil biota remains uncertain, but is the subject of investigation at all levels from the laboratory to the landscape.

This book is intended to provide internationally accepted standard methods for the inventory of below-ground communities and characterization of land use in the humid tropics

The explicit aim is a practical one: to provide a definitive tool to establish a base-line and then to document the loss of soil biodiversity associated with deforestation and the process of agricultural intensification at forest margins.

The inventory of soil biological diversity: concepts and general guidelines.

Swift[1], M.J., Bignell[2], D.E., Moreira F.M.S.[3] and Huising[1], E.J.
[1]TSBF-CIAT, Kenya; [2]Queen Mary University, London UK; [3]Federal University of Lavras, Brazil

In: F.M. Moreira, E.J. Huising and D.E. Bignell (eds), A Handbook of Tropical Soil Biology: Sampling and Characterization of Below-ground Biodiversity, Earthscan, London

Soil is the habitat of an array of organisms in all three taxonomic domains (Sensu Woese et al, 1990) and many phyla. The taxonomic classification of living organisms is still controversial (e.g. Margulis and Schwartz, 1998; Cavalier-Smith, 1998, 2004), especially regarding the taxa to be created at higher levels, and the numbers of such higher categories (such as kingdom) to be considered, in addition to domain. However, whatever classification system is used, the diversity of soil biota is high at all levels of analysis (for reviews, see Swift et al, 1979; Lavelle, 1996; Brussaard et al, 1997; Wall, 2004, Bargett, 2005; Moreira et al, 2006).

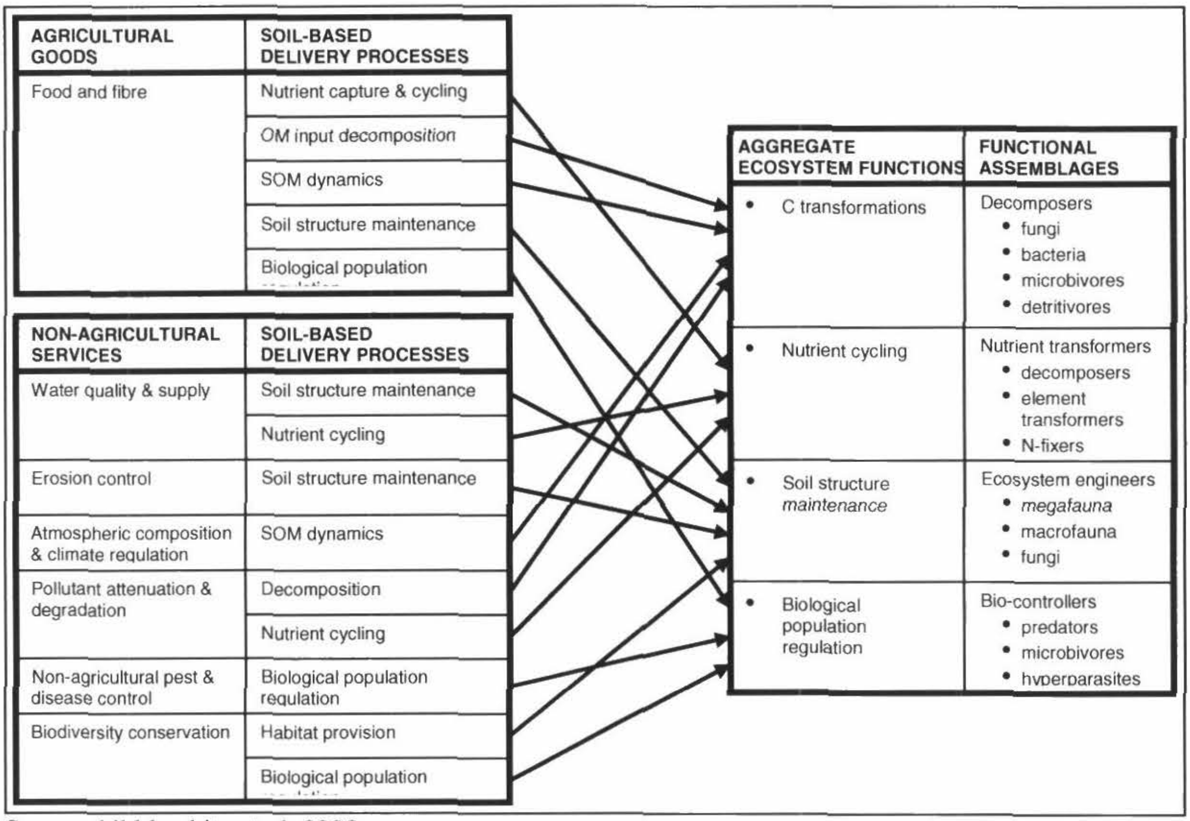
As it is neither practicable nor sensible to address all the organisms present when making an assessment of the biological health of soils (see Lawton et al, 1998), biota have been evaluated (relative to non-biotic agencies and between themselves) for their relative contribution to ecosystem processes (sensu Daily, 1997; Wall, 2004). These processes collectively support the provision of ecosystem services that contribute to the maintenance and productivity of ecosystems by their influence on soil quality and health (Hole, 1981; Lavelle, 1996, Brussaard et al, 1997; Kibblewhite et al, 2008). The processes can be grouped into four main aggregate ecosystem functions:

Decomposition of organic matter is largely brought about by the enzymatic activity of bacteria and fungi, but greatly facilitated by soil animals such as mites, millipedes, earthworms and termites, which shred the plant or animal residues and disperse microbial propagules. Together, the micro-organisms and the animals involved in the process are called decomposers, but the term litter transformers has now come to be used to describe these animals, where they are not also ecosystem engineers (see below). As a result of decomposition, organic C is released into the atmosphere, predominantly as CO_2 or CH_4, but also incorporated into a number of pools within the soil as soil organic matter (SOM). These SOM fractions vary in their stability and longevity, but within a given soil type and environment a characteristic equilibrium exists between the SOM content and the inflows and outflows of C from the system.

Nutrient cycling, which is closely associated with organic decomposition. Here again the micro-organisms mediate most of the transformations, but the rate at which the process operates is determined by small grazers (micropredators) such as protoctists, nematodes, collembolans and mites. Larger animals may enhance some processes by providing niches for microbial growth within their guts or excrement. Specific soil micro-organisms also enhance the amount and efficiency of nutrient acquisition by the vegetation through the formation of symbiotic associations such as those of mycorrhiza and N_2-fixing root nodules. Nutrient cycling by the soil biota is essential for all forms of agriculture and forestry. Some groups of soil bacteria are involved in autotrophic elemental transformations, that is, they do not depend on organic matter directly as a food source, but may nonetheless be affected indirectly by such factors as water content, soil stability, porosity and C content, which the other biota control.

Bioturbation. Plant roots, earthworms, termites, ants and some other soil macrofauna are physically active in the soil forming channels, pores, aggregates and mounds, and moving particles from one horizon to another. These processes of 'bioturbation' influence and determine soil physical structure and the distribution of organic material. In so doing they also create or modify microhabitats for other, smaller, soil organisms and determine soil properties such as aeration, drainage, aggregate stability and water holding capacity. This set of organisms has therefore been called 'soil ecosystem engineers' (Stork and Eggleton, 1992; Jones et al, 1994; Lawton, 1996; Lavelle et al, 1997. Soil structure and properties are also influenced though the production by the animal engineers of faeces, comprising organo-mineral complexes that are stable over periods of months or more (Lavelle et al, 1997). Bioturbation plays a major role in the regulation of the water balance of the soil (infiltration, water storage capacity and drainage) and strongly influences its susceptibility to erosion.

Disease and pest control. The soil biota includes a wide range of viruses, bacteria, fungi and invertebrate animals capable of invading plants and animals (including humans) and causing disease and death. In natural ecosystems, intensive outbreaks of soil-borne diseases and pests are relatively rare, whereas such epidemics are common in agriculture. In healthy soils the activities of the potential pests and pathogens are regulated by interactions with other members of the soil biota, which include microbivores and micropredators that feed on microbial and animal pests respectively, as well as a wide variety of microbial antagonistic interactions. In agro-ecosystems this range of interactions may be reduced because of diminished biological diversity and/or soil environmental changes such as those caused by lowered SOM content.



Source: kibblewhite et al. 2008

Figure 4: shows the contribution made by the soil biota to ecosystem goods and services as a result of the above processes. In particular it should be noted that the interaction between organic matter decomposition, bioturbation and nutrient cycling will determine the balance between the equilibrium amount of carbon sequestered in the soil (see above) and the emissions of greenhouse gases (principally CO_2, CH_4, NO_x, N_2O). Soil organisms thus play an important role in the regulation of atmospheric composition and hence are major players in climate change.

Sampling Strategy and Design to Evaluate Below-ground Biodiversity.

Huising[1], E.J., Coe[2], R., Cares[3], J.E., Louzada[4], J.N., Zanetti[4], R., Moreira[4], F.M.S., Susilo[5], F.X., Konaté[6], S., Noordwijk[2], M., and Huang[3], S.P.
[1]TSBF-CIAT, Kenya; [2]World Agroforestry Centre (ICRAF), Kenya; [3]University of Brasilia, Brazil; [4]Federal University of Lavras, Brazil; [5]Lampung University, Indonesia; [6]University of Abobo-Adjamé, Côte d'Ivoire

In: F.M. Moreira, E.J. Huising and D.E. Bignell (eds), A Handbook of Tropical Soil Biology: Sampling and Characterization of Below-ground Biodiversity, Earthscan, London

The chapter deals with how the location of measurement sites for the inventory of BGBD is determined. The problem of choosing the location of measurement points is one that occurs at several different scales. At one scale, we have to choose where the whole study will be located. At another, we need to choose where at an individual sampling site four cores for soil chemical analysis will be taken. Somewhere between the two is the problem of choosing the sites themselves. The problem can be visualised as choosing the number and location of points in the study landscape at which the measurement protocols will be implemented.
There is a long tradition of sampling in field ecology, and hence much experience has been accumulated. In addition there is a well established theory of sampling which applies anywhere it is attempted (Cochran, 1977). Despite the body of knowledge and experience we have, in any project there will be intense and sometimes divisive discussion of the sampling strategy, because of the following reasons:

1. Application of the full theory, or of methods as extensive as those successfully used in other studies, may conflict with the practical constraints of the study being designed.
2. Application of sampling theory may require information that is not known until the data have been collected.
3. There may be limits to the theory. More importantly, there are common misunderstandings of some of the basic principles, such as why random sampling works or what is meant by replication.
4. The objectives of the study drive the design. However these may not be fully developed, or there may be multiple objectives which suggested different approaches to sampling.
5. Scientists take differing philosophical stands on approaches to sampling, with a dichotomy between those who aim to 'See what is there, then seek to understand it' and those who 'Start with a hypothesis and seek to test it'.

In the chapter some of the options for sampling for below ground biodiversity are described, and the advantages and disadvantages of different approaches, followed by an example of the approach used in the CSM-BGBD project.

Macrofauna.

Bignell[1], D.E., Constantino[2], R., Csuzdi[3], C., Karyanto[4], A., Konaté[5], S., Louzada[6], J.N., Susilo[4], F.X., Tondoh[5], J.E., and Zanetti[6], R.
[1]Queen Mary University, London UK; [2]University of Brasilia, Brazil; [3]Hungarian Natural History Museum, Hungary; [4]Lampung University, Indonesia; [5]University of Abobo-Adjamé, Côte d'Ivoire; [6]Federal University of Lavras, Brazil;

In: F.M. Moreira, E.J. Huising and D.E. Bignell (eds), A Handbook of Tropical Soil Biology: Sampling and Characterization of Below-ground Biodiversity, Earthscan, London

In this chapter methods for the inventory of soil macrofauna are presented. The macrofauna group comprises those soil animals that are more than 1cm long or have a width or diameter of more than 2mm. A diversity of soil organisms is included in this category, but this chapter concentrates on the most significant groups: the earthworms, termites, ants and beetles. The earthworms are probably the most important soil invertebrates in temperate regions, but in tropical environments this role is taken over by termites and ants. Many macrofauna play an important role in soil ecosystems as soil engineers, especially in tropical environments, significantly influencing the physical and chemical properties of the soils they inhabit, especially by the creation of macropores and transformation and redistribution of organic matter. Others are comminuters, shredding organic matter, and a number of groups are macropredators. Because of their important role in ecosystem processes and their sensitivity to the environmental conditions, macrofaunal groups are often used (or proposed) as indicators of soil biological quality and therefore form an important component of the soil biota, indicative of overall soil biodiversity and effects of land use change and management practices. Further, because of their generally high relative biomass they form and important constituent of the food web in the soil.

This chapter describes proposed methods for the inventory of soil and litter macroarthropods and earthworms using the soil monolith, ants and other macrofauna and mesofauna by the Winkler method, beetles and other macrofauna and mesofauna in litter: baited and non-baited pitfalls as they were applied in the CSM-BGBD project.
The starting point for the development of the protocols has been the procedures of Anderson and Ingram (1989, 1993), consolidated and improved by Swift and Bignell (2001) and which are generally referred to as the "TSBF methods" These were based on soil monoliths and a short transect (20/40 x 2m) for termites, to which we have now added pitfall traps (principally for beetles) and some guidelines for casual sampling. New schemes are proposed for the arrangement of monoliths to improve the sampling of earthworms.

Soil Collembola, Acari and Other Mesofauna – The Berlese Method

Karyanto[1], A., Rahmadi[2], C., Franklin[3], E., Susilo[1], F.X., and Wellington de Morais[2], J.
[1]Lampung University, Indonesia; [2]LIPI JL, Indonesia; [3]National Institute for Amazonian Research, INPA, Brazil

In: F.M. Moreira, E.J. Huising and D.E. Bignell (eds), A Handbook of Tropical Soil Biology: Sampling and Characterization of Below-ground Biodiversity, Earthscan, London

Mesofauna comprises animals of body sizes ranging from 0.2 to 2.0mm whose abundance cannot be accurately assessed by means of hand sorting from the soil.

Enchytraeidae, Acari (mites), Collembola (collembolans), Protura, Pauropoda and some Nematoda are typical members of the mesofauna, but larval forms of macrofaunal species also fall within the size range of mesofauna, At each sampling point, soil cores are located in two concentric circles, at 3m and 6m radius respectively, from the monolith, and supplemented by pitfalls located at least 14m from the monolith centre. Mesofauna is collected by using two sampling methods: a) a pooled sample of soil cores and surface litter is extracted either by Berlese-Tullgren or by a modified Berlese, and b) from the fluid contents of pitfall traps. Soil cores are used primarily to collect mesofauna that inhabit the mineral soil beneath the surface litter and the litter itself, whereas pitfall trap methods are applied to collect soil surface dwellers.

The Berlese method as modified by Tullgren, by replacing the water jacket with an electric light bulb to allow for slowly drying the sample in a funnel-type extraction-system and thus allowing for the separation of small arthropods from soil, is proposed. The pitfall method is good enough to catch collembolans that live at the surface of the soil (edaphics). It is not useful to collect oribatid mites (Acari: Oribatida), as these animals are mostly sedentary (except for some Families such as Galumnidae and Scheloribatidae) in contrast to more opportunistic groups such as collembolans. It is suggested that for all normal sampling, both funnel-based extractions and pitfalls should be routinely employed together.

Oribatid mites (also called Cryptostigmata, and referred to as beetle mites) are one of the most numerically dominant (densities can reach several hundred thousand individuals per square meter), and species diverse (undisturbed soil may yield 50-100 species), arthropod groups in the organic horizons of most soils (Norton, 1990). They feed on living and dead plant material and carrion, graze on fungi and algae and some are predaceous (e.g. feed on live nematodes) (Siepel, 1990). Their faecal pellets provide a large surface area for primary decomposition by bacteria and fungi and are in turn and integral component of soil structure. After death they leave important nitrogenous waste. Because of their (regulating) role in decomposition and nutrient cycling as well as soil structure formation, their abundance, species composition and diversity in a particular habitat serve as good indicators of soil "health' (Minor, 2004).

Soil Nematodes.

Cares[1], J.E., and Huang[1], S.P.
[1]*University of Brasilia, Brazil*

In: F.M. Moreira, E.J. Huising and D.E. Bignell (eds), A Handbook of Tropical Soil Biology: Sampling and Characterization of Below-ground Biodiversity, Earthscan, London

Nematodes are mostly small, water-dependent invertebrates considered to be the most abundant, and one of the most diverse of any group of animals, Due their capacity for adaptation, nematodes are present anywhere organic carbon is available, at all latitudes of the planet, and from the bottom of the seas to the top of the mountains. The word nematode is derived from the Greek "nema", meaning in the shape of a thread, since they

possess an elongate and cylindrical body. Evolution adapted nematodes to explore a variety of food sources. The parasites colonize and feed in plant or animal tissues, while the free-living forms are grazers or predators of small organisms, such as bacteria, protozoa, fungi, algae and microinvertebrates.
Nematodes are primarily known as a threat to human, animal and plant health. Nevertheless, they play equally important roles as agents of nutrient cycling, and as regulators of soil fertility through both energy flow and nutrient mobilization and utilization (Procter, 1990). Although nematode biomass in soil is small (10^1 to 10^4mg dry wt m^{-2}), they are responsible for 10 to 15% of the soil animal respiration (Sohlenius, 1980; Petersen, 1982). Besides these ecosystem benefits, nematodes can also provide important agroecosystem services as agents of biological control of insect pests, like entomophilic nematodes such as *Deladenus siricidicola* and entomopathogenic nematodes such as *Steinernema carpocapsae* and *Heterorhabditis bacteriophora*. Their omnipresence and abundance in different types of soil and water environments, as well as their short life cycle and sensitivity to environment alterations, qualify them as powerful bio indicators of environmental conditions.

Soil nematodes live in assemblages usually composed of five major functional groups, plant parasites, bacterial feeders, fungal feeders, predators and omnivores (Plate 2). Therefore nematodes are well represented throughout the soil food web. Although full taxonomic identification of nematodes requires intensive training, in most cases identification at the level of functional groups can be readily accomplished on the basis of morphology of the feeding apparatus. In plant-parasitic nematodes the feeding apparatus includes a needle-like stylet (Plate 2A); plant-parasitic nematodes may cause significant yield losses in several crops. Fungal feeders, mostly equipped with a small and delicate stylet (Plate 2B), feed on hyphae of saprophytic, pathogenic, beneficial and mycorrhizal fungi. Some fungivorous nematodes are facultative plant parasites. Bacterial feeders, without the stylet (Plate 2C), can regulate the available nitrogen and phosphorus for plants, influence *Rhizobium* nodulation, and consume and disseminate beneficial and plant-pathogenic bacteria. As typical r-strategists, bacterial feeding nematodes may see their populations increase under soil disturbance or nutrient enrichment conditions, this being interpreted as an indicator of soil fertility (Ferris et al, 2001). Predators have their mouth cavity equipped with one or more tooth-like structures (Plate 2D) or in some cases one stylet, and prey on other nematodes, microinvertebrates and protozoa, and in some case they eat bacteria and the spores of fungi. Omnivores have their mouth cavity armed with a hollow stylet (Plate 2E); they are polyphagous, feeding in all trophic capacities, as fungal and bacterial feeders, herbivores, and also as predators eating other nematodes.

Some biological characteristics of the nematodes make them suitable indicators of environmental conditions, as recently proposed by Huang and Cares (2006). Some nematodes may occur in a wide range of habitats, whereas others are more restricted. They also differ among themselves in sensitivity to soil disturbances and to chemical pollutants. As proposed by Bongers (1990) and Bongers and Bongers (1998), colonizer nematodes (similar to r-strategists) typically possess a short generation time, produce many small eggs, show the presence of dauerlarvae, and increase their populations under food-rich conditions, being more resistant to soil disturbances and to soil pollutants. On the other hand, persister nematodes (similar to K-strategists) are characterized by a long generation time, production of few but larger eggs, low motility, the absence of dauerlarvae and sensitivity to pollutants and other disturbance factors. Therefore, appropriate analyses of the nematode community, taking in account the diversity, abundance and community structure, may present an index of land-use systems and land-use change, and also measure soil disturbance levels due to pollutants or other factors.

Nitrogen-fixing Leguminosae-nodulating Bacteria.

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In: F.M. Moreira, E.J. Huising and D.E. Bignell (eds), A Handbook of Tropical Soil Biology: Sampling and Characterization of Below-ground Biodiversity, Earthscan, London

Biological nitrogen fixation is one of the most important processes for the maintenance of life on earth as it contributes about 70% of all nitrogen required by natural and agricultural ecosystems (Burns and Hardy, 1975), and is environmentally friendly. Inoculation with NFLNB strains that are highly efficient and adapted to prevailing environmental conditions, to replace chemical N-fertilizers, is currently practiced in some countries for a small selection of legume crop species. In Brazil, inoculation with *Bradyrhizobium* strains completely replaces application of chemical fertilizers for soybean. In 2006, with a soybean yield of 57 million Mg, about US$ 3.3 billion in fertilizer expenses were saved because of this biotechnology. Inoculant strains are sourced from a diversity of strains present in the soil. At the same time soil biodiversity may affect the nodulation behaviour positive or negatively, due to the complex and multiple interactions among soil organisms, and between soil organisms and plants. Thus, the knowledge of NFLNB diversity in the soil environment is the first step in the management and conservation of this valuable genetic resource.

Arbuscular Mycorrhizal Fungi (AMF).

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It is now very well documented that arbuscular mycorrhizal fungi (AMF) improve fitness and growth of plants that are important in agriculture, horticulture and forestry. The soil hyphal network produced by AMF during association with the plant host provides a greater absorptive surface than root hairs alone and thus increases significantly the absorption of relatively immobile ions such as phosphate, copper, and zinc. In most tropical soils, available phosphorus is very low and thereby limiting for plant development. In addition, mycorrhizally infected plants have been shown to have greater *tolerance to toxic metals, to root pathogens, to drought, to high soil temperature, to saline* soils, to adverse soil pH and to transplant shock than non-mycorrhizal plants (Mosse et al, 1981; Bagyaraj, 1990; Bagyaraj and Varma, 1995). Arbuscular mycorrhizal fungi have been reported from natural ecosystems such as deserts, sand dunes, tropical forests, salt marshes and managed systems such as pastures, orchards and field crops (Brundrett, 1991).

In the tropics, agriculture is practiced in areas previously occupied by two main plant species rich natural ecosystems: tropical forests and savannah woodlands. The conversion of these two ecosystems into agro-ecosystems whether related to subsistence agriculture, production of cash crops or industrial forest plantations, provokes changes in the chemical, physical and biological characteristics of the edaphic environment. Sites are usually cleared of multispecies, uneven-aged vegetation and normally planted with a single species of one age-class. For arbuscular mycorrhizal fungi, conversion of natural ecosystems into distinct land use systems influences spore abundance and species composition. Jasper et al (1987) observed a drop in spore numbers and a shift in species composition after disturbance in some Australian sites. Similarly, Mason et al (1992) found that the number of spores of AMF in a plantation of *Terminalia ivoriensis* in Cameroon greatly decreased 3 months after complete clearance and also noticed a change in species composition. Johnson and Wedin (1997), however, found similar species richness in dry tropical forest and monodominant grassland, where 28 AMF morphotypes were detected with *Glomus aggregatum* and two undescribed *Glomus* species observed as the predominant fungi. Also, Picone (2000) demonstrated that spore density and the fungal community available for mycorrhizal formation were relatively similar between pasture and primary rain forest.

Measuring the taxonomic diversity of AMF has relied mostly on direct counting and the identification of field recovered spores. However, this approach fails to detect cryptic species of AMF which are not sporulating at the sampling time (but are still associated with plant hosts) and hampers accurate identification of some species, especially those of the genera *Glomus* and *Gigaspora*. Trapping from field soil has been used successfully to detect and recover cryptic species during AMF diversity surveys in temperate region apple plantations (Miller et al, 1985) and grassland (Bever et al, 1996) and also in desert (Stutz and Morton, 1996). Although it is not commonly reported, measurement of taxonomic diversity should be accompanied by some assessment of the activity of the mycorrhizal community. Mycorrhizal infectivity is easily determined by the Most Probable Number (MPN) method and can serve for comparative purposes (Porter, 1979). The Mean Infection Percentage (MIP) assay (Moorman and Reeves, 1979) and the Infection Unit (IU) assay (Franson and Benthlenfalvay, 1989) are also available.

Saprothytic and Plant Pathogenic Soil Fungi.

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Soil fungi play a key role in decomposition processes that mineralise and recycle plant nutrients. In the soil environment, fungi interact with a complex microbial community, including bacteria, actinomycetes (actinobacteria) and with small invertebrates. Fungi are also an important part of the food chain within the soil environment, mainly for the soil inhabiting mesofauna (Bonkowski et al, 2000). In agro-ecosystems, plant pathogens act in soil and the rhizosphere causing reduction of yield and quality (Wainwright, 1988; Lodge, 1993).

To obtain a confident assessment of diversity of soil fungi there are two basic constraints. Investigations should be designed as long-term studies that engage taxonomic and other specialists in mycology, and, in addition, suitable and precise methodologies must be devised. When a long-term study involving several specialists is not feasible because of limited time and resources, the use of indicator organisms, target groups or predictor sets could be an alternative (Hyde, 1997a and b).

Agricultural activities may affect the diversity of soil-borne organisms, which play an important role in nutrient cycling or mediate the equilibrium between pathogens and their antagonists. The assessment of fungal diversity in tropical soils under different land uses is therefore one objective of the CSM-BGBD project. Broadly accepted standard methods for inventorying fungal diversity or for evaluating the impact under varying agricultural practices and other human activities are not yet available.

Classical microbiological procedures for studying soil fungi rely on culture-based procedures which involve isolation of microbial propagules or active growing hyphae from soil and growing them in axenic culture media for further identification and quantification. Methods used for the isolation of soil, rhizosphere and rhizoplane fungi have been revised by several authors (Frankland et al, 1990; Gray, 1990; Gams, 1992; Singleton et al, 1992; Cannon, 1996; Davet and Rouxel, 2000; Bills et al, 2004). A general overview on methods for studying soil-borne plant pathogenic fungi was given by Singleton et al (1992). Considerable progress has been made using washing techniques, partially selective culture media and additives that reduce the growth of certain groups of fungi.

The methodologies for isolating and culturing fungi from complex ecosystems such as soil show inherent limitations due to the fastidious nature of several species coupled with the inability of culture media to mimic soil habitats exactly (Tsao et al, 1983; Muyzer et al, 1993; Bridge and Spooner, 2001). Even the analysis of relative abundance of cultivable species recovered from soil may not adequately represent the dynamics of soil communities, since culture media impose new selective conditions and can introduce biases to the analyses (Liu et al, 1997). A reliable measure of fungal soil communities without biases requires a laborious program of systematic isolations with different culture media and isolation strategies covering idiosyncrasies from the diverse taxonomic and physiological groups of fungi occurring in soil ecosystems. Nevertheless, generic statements that only 1% of the "microorganisms" in soil are culturable exaggerate the difficulty and do not take into account the huge biological diversity that "microorganisms" really represent (Rondon et al, 2000). Within this group we can find phylogenetically diverse groups such as the many phyla of Eubacteria, as well as quite homogenous groups like the Phylum Glomeromycota, a monophyletic group of obligate root associated fungal organisms (see chapter 7). However, most of the soil inhabiting fungi must be considered saprotrophs and therefore should be able to grow in axenic culture.

Other methodologies now developed are focused on the analysis of fungal activity and their role in the biogeochemical processes occurring in soil environments. For these purposes, methods that rely on the analysis of soil microbial biomass, soil respiration, nitrogen cycling and fungal fatty acid content, or direct observations of actively growing mycelia on soil particles have all been applied (Widden and Parkinson, 1973; Houston et al, 1998; Brodie et al, 2003; Malosso, 2006). However these methods alone give poor information about the fungal species involved in those processes and therefore for a better understanding of soil fungal community structure and function, isolation and traditional identification procedures are still required (Brodie et al, 2003).

The results obtained from a survey of soil fungi depend largely on the methods used. In general every method gives a bias toward specific groups of fungi. Besides this we have to keep in mind that soil is not a substrate, rather an ecosystem composed of a mixture of most diverse substrates including dead and living parts of plants, animals and other microorganisms, along with a mineral portion and water. It is therefore all the more necessary to adopt at least similar methods within cooperative or multidisciplinary projects to guarantee future comparability of data. In this chapter we refer to some of the most commonly used methods but also present some less well established techniques for the assessment and monitoring of fungal communities in the soil environment. Principles and applications of molecular tools for soil fungal community studies are also considered. This approach is not comprehensive but aims to give a good overview on available procedures. Our main objective is to make a contribution towards the establishment of generally accepted standard methods.

Sampling, Conserving and Identifying Fruit Flies.

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In: F.M. Moreira, E.J. Huising and D.E. Bignell (eds), A Handbook of Tropical Soil Biology: Sampling and Characterization of Below-ground Biodiversity, Earthscan, London

Entomophatogenic Fungi and Nematodes.

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There are about half a million described species of insects on the Earth, and the true diversity may be many times this figure (Groombridge, 1992). Approximately 10% of these can be considered agricultural, forestry or urban pests. If we assume that each insect species is susceptible to at least one pathogenic microorganism, often host-specific, we

have an insight into the potential importance of the study of these pathogens in the context of the pest control and biodiversity.
Insect pathology is the science that studies insect diseases, aiming to use them for control of pest species or with the objective of preventing their occurrence in useful insects. Disease is a dynamic process, in which the host (insect) and the pathogen (microorganism) are both adapted morphologically and physiologically, the former for the infection process and the latter for resistance. Microbial control is a form of biological control that deals with the rational use of the entomopathogens, aiming not to eliminate the pest populations but to maintain them at levels below the economic damage threshold. This mimics the natural dynamics between pathogen and host in the field without human interventions. The principal microorganisms used or of potential use in the microbial control of insects are fungi, bacteria, virus, nematodes and protozoan.
Many hundreds of species of entomopathogenic fungi are known, attacking a wide range of insects and mites, with varying degrees of host-specificity (Hajek and St. Leger, 1994; Roy et al, 2006). The fungi produce spores which germinate on contact with the host and invade the body, killing the host between 4 and 10 days later. After death, many thousands of new spores are produced which disperse and continue the fungal life cycle on new hosts. A small number of generalist species, e.g. *Lecanicillium logisporum,* which can be readily cultured and therefore mass produced, have been developed as biopesticides for inundative use on pest populations, but this technology has proved disappointing in practice, because of high cost, poor persistence (especially under tropical conditions) and low efficacy in comparison with chemical (i.e. toxin-based) insecticides.
Entomopathogenic nematodes are about 0.5 mm in length. Juvenile nematodes parasitize their hosts by directly penetrating the cuticle or through natural openings such as spiracles; bacteria introduced with the parasite increase rapidly and kill the host, allowing the nematodes to grow and mature on the decomposing tissue, and reproduce as adults. A new generation of infective juveniles emerges between one and two weeks after the initial invasion of the host (Kaya and Gaugler, 1993). Two families, the steinernematids and the heterorhabditids, are obligate parasites of insects and have been made the basis of a number of biological pesticides designed particularly for use against soil pests such as weevils and fly larvae, but again there are disadvantages related to high cost, low persistence and (in the case of nematodes) to inactivity at low temperatures.
Despite the limited success of entomopathogenic fungi and nematodes as biocidal products, they appear to be both diverse and universal components of soil biotas, where they may be exceptionally virulent (i.e. causing rapid death of the host and high mortality in host populations) and cause periodic epizootics (Chandler et al, 1997; Myers and Rothaman, 1995). Most of the pathogens have a "sit and wait" transmission strategy (sensu Ewald, 1995): the organisms produce infective stages which are released into the environment when the host dies and have the ability to enter diapause or remain dormant until new hosts become available. This is adaptive, as their much larger arthropod hosts are typically patchy in distribution, with a geographically widespread metapopulation and high mobility. Diapause and dormancy decreases dependence on host mobility and may be supplemented by the ability to live saprotrophically in soil, though competitive efficiency against other free-living saprotrophs may be low. Although above-ground arthropods are susceptible to fungi and nematodes as well as below-ground ones, the soil is clearly a reservoir of the infective stages, because it offers a stable microenvironment

with a suitable pore structure for nematodes and organic resources for fungi. There is often no correlation between host density and disease occurrence, again suggesting that the pathogens are very widespread in the soil; in the case of entomopathogenic fungi this is supported by molecular evidence that soil populations are not wholly clonal, despite the absence of overt sexual stages, and that significant gene flow occurs locally (e.g. Bidochka et al, 2001).

Description and classification of land use at sampling locations for the inventory of below-ground biodiversity.

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In: F.M. Moreira, E.J. Huising and D.E. Bignell (eds), A Handbook of Tropical Soil Biology: Sampling and Characterization of Below-ground Biodiversity, Earthscan, London

This chapter provides a structured list of land use attributes to guide observation of land use characteristics in the field at sampling point locations. The system allows for different levels of detail at which the characteristics are described, depending on the data available or obtainable. In most cases the domains of the attribute values are specified, which requires only the proper value to be assessed in the field. This is either done through direct observation or by interview or inquiries. Only in some cases, generally at the higher level of detail, are actual measurements required. The land use classification is facilitated by a hierarchical structure in which the attributes are ordered, but the final land use classes will depend on the selection of attributes to be considered for the classification, depending on the purpose and context of the classification. How land use classes can be defined with respect to land use intensity is illustrated.

Output 1. Processes and principles
Output Target 2009: Practical methods for rapid assessment and monitoring of the soil resource base status in relation to soil nutrients, organic matter, aggregation and soil structure

Output 1 is formulated differently in the SLM logical framework matrix with more emphasis on processes underlying soil and land degradation and principles for restoring soil health.
Part of the work contributing to this output target is the work done in the context of the BGBD project to investigate soil quality indicators including those that related to soil chemical, physical and organic matter characteristics. Please see the section on 'Indicators of soil (biological) quality' below. Otherwise there is quite some other work done on tools for the assessment soil resource base, like the evaluation of field test kits, and the work done on soil aggregate structure, that is reported under the ISFM outcome line, and I refer to that annual report for further details on completed work and work in progress.

Towards a Digital Soil Map of the World

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Although soils are increasingly recognized as major contributors to ecosystem services *(1)*, communicating soils information to diverse audiences is challenging because of technical jargon, outdated methods and pre-computer logic. Other Earth-system sciences (climatology, plant ecology, geology) have become quantitative and taken full advantage of the digital revolution. Conventional soil maps, the main vehicle for conveying geographical information are composed of polygons (mapping units) delineated according to mostly qualitative and static criteria. In most parts of the world, the spatial resolution is too broad to help with practical land management and the often complex conceptual model (each polygon having unmapped soil types) is difficult for users to understand and apply. The digital solution is clear – produce a fine-resolution and three-dimensional grid of the functional properties of soils relevant to land management. Achieving this requires an appreciation of soil science and its history.

Borrowing from public health surveillance *(4)* the main features of soil health surveillance are:

- *Case definitions* define healthy and degraded states with respect to a given use. For example aluminum toxicity and malaria. There are some case definitions. The public health analogy is malaria, defined as
- *Diagnostic tests,* above which there is a case. In soils there are several case definitions with diagnostic tests for soil fertility constraints, for example aluminum toxicity, the main culprit of soil acidity for which the case definition is >60% Al saturation in the top 50 cm *(5)*. The public health analogy is positive identification of red blood cells infected with plasmodium.
- *Risk factors.* Simultaneous measurement of environmental and socio-economic correlates permits degradation risk factors to be identified. One risk factor is soils classified as Oxisols and Ultisols; for malaria is being in a lowland tropical area of Africa.
- *Prevalence* (no. of cases/area), for example the % of an area affected by Al toxicity, high erosion risk or malaria prevalence. This is the baseline.

- *Recommendations (treatment, therapy?):*Interventions such as liming to eliminate Al toxicity, or building soil erosion control structures. In malaria: insecticide-impregnated bed nets and artemisinin medication.
- *Incidence* (no of cases/area/year), confirmed through follow-up surveys that measure changes in cases diagnosed over time.
- *Monitoring (following):* need of controlling the recovering of an affected area through the use of therapies and need to scan the non-infected population before it is damaged.

A number of steps have been identified that will lead to a digital soil map as being envisaged with step 1 being the the production of base maps, assembling and calibrating temporal remote sensing and digital terrain models such as 90 x 90 m resolution data (0.81 hectare pixels) from Shuttle Radar Topography Mission (SRTM, v.3), and the last step being the predicting of more difficult-to-measure soil *functions* such as available soil water storage, carbon saturation deficit and phosphorus fixation, based on the spatially inferred soil *attributes* using pedo transfer functions. Mapping of soils that are responsive and not-responsive to fertilizer inputs, or degraded on not degraded, are examples of useful soil properties for land-management recommendations. These soil *functions* largely determine the capacity of soils to deliver various provisioning and regulating ecosystem services.

A new information system for managing soil health in Sub-Saharan Africa: why and how

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Introduction

Almost 70 years ago Hans Jenny (Jenny 1941) outlined the theoretical framework of the state factors of soil formation, namely climate, organisms, topography, parent material, time, for evaluating the state of the soil system, and in regulating the fluxes of energy, materials and organisms to and from it. As predicted by Jenny, human activity has already altered the first two factors i.e., climate and organisms on a global scale and these processes are expected to accelerate over the next 100 years, particularly in Africa (IPCC 2007).

People depend on soil for a wide range of essential ecosystem services (MEA 2005). Soil is a key resource in the production of food, forage, fuel and fiber. It stores water from rainfall and irrigation and filters toxic substances through clay sorption and precipitation processes that determine water quality. Soil organisms decompose organic materials, cycle nutrients, and regulate gas fluxes to and from the atmosphere. However, as human populations have grown, there has been a strong tendency to trade off increases in the demand for provisioning services (e.g., for food and other commodities), for regulating (e.g., nutrient, greenhouse gas, and hydrological cycling) and supporting services (e.g., biodiversity).

In many places in sub-Saharan Africa (SSA), the resulting positive feedback dynamics have led to a rapid loss in the capacity of soils to deliver ecosystem services. These highly undesirable changes are a major, though largely hidden, cost of development that challenge the prospects of a better future for Africans, trapping them into poverty, and potentially leading to increased conflicts over land..

It is striking how very little we know about the state and trend of soil health in Africa. For example, simple questions about how much water Malian soils can supply for growing plants, how much additional carbon could be stored in Ethiopian soils if management were to change, how much mineral fertilizer and organic inputs would need to be added to increase crop productivity to a level that is economically viable in Angola, are basically impossible to answer at this stage.

Material and Methods

Over the next four years, the newly formed Africa Soil Information Service (AfSIS, see www.AfricaSoils.net), a collaborative project between an international consortium of soil scientists (also see GlobalSoilMap.net), and African scientists led by the Tropical Soil Biology and Fertility Institute of the International Center for Tropical Agriculture (CIAT), based in Nairobi, will attempt to narrow sub-Saharan Africa's soil information gap and provide a consistent baseline for monitoring soil ecosystem services in SSA.

To this end AfSIS survey teams will initially sample this vast area using a, spatially stratified, random sampling approach consisting of 60, 100 km^2 sentinel landscapes, that are statistically representative of the variability in climate, topography and vegetation of the project area. Twenty one of the 60 sites fall into biodiversity hotspots as designated by Conservation International (see www.biodiversityhotspots.org). Ground surveys of the AfSIS sentinel landscapes will provide ~9,600 new geo referenced soil profile observations consisting of more than 38,000 individual soil samples. By comparison, what is possibly the best current international soil profile database for Africa (see ISRIC WISE v1.1 at www.isric.org), contains 1,799 soil profiles. A key innovation of AfSIS is to use both near and mid-infrared spectroscopy for soil analyses. One of the main strengths of using IR for predicting soil properties lies in the application of a double-sampling procedure that greatly reduces the cost and time of laboratory analyses, while typically improving the analytical precision of the resulting landscape level estimates (Shepherd & Walsh 2007). In double sampling only a subset of recovered samples (normally 10-20% of the complete data-set) is characterized with conventional laboratory analyses, and the properties of the remaining samples are predicted from the IR spectra.

AfSIS will be using MODIS, Landsat, ASTER and Quickbird images and SRTM terrain models for soil mapping, land cover change detection and estimation of landscape carbon stocks. By linking field and laboratory data to remote sensing information, digital terrain models, and other existing environmental covariates such as climate surfaces, AfSIS will be able to provide a unique resource for producing a new generation of soil, vegetation, and land cover maps and statistical products for SSA.

Expected outcomes:

In many ways similar to the US National Science Foundation's Long Term Ecological Research (LTER) sites, the AfSIS sentinel landscape network will serve as the geographical core of what we anticipate will be a long-term ecological observatory for SSA, in which changes in soil health, ecosystems and the services that they provide can be explored and documented over time. As the term "sentinel" implies, the AfSIS landscapes are thus intended stand guard and warn of threats to SSA's natural resource base. We also hope that once AfSIS methods are evaluated and disseminated, that African governments and research organizations will establish many more sentinel landscapes to provide an increasingly detailed assessment of Africa's soils and ecosystems over time, resulting in local innovations leading to improvements in soil health. A substantive portion of the project's budget is allocated to building the capacity of African research institutions and a new generation of African researchers to achieve this.

Output 1. Processes and principles
Output Targets 2009: Standard methods for the inventory of BGBD documented (handbook published)

COMPLETED WORK

Please see the section on the output targets for 2008 for further details on the Handbook for Tropical Soil Biology: Sampling and characterisation of Below-ground biodiversity

NO WORK IN PROGRESS

Output 1. Processes and principles
Output Targets 2009: BGBD assessed in 11 benchmark sites across the Tropics and loss of BGBD as result of land use intensification determined; Assessed of soil health status in agric prod. landscapes of major agro-ecological impact zones

COMPLETED WORK

Biodiversidade do Solo em Ecossitemas Brasileiros, *Editora UFLA, Lavras, Brazil, 2008*

Moreira[1], F.M.S., Siqueira[1], J.O. and Brussard[2], L. (Eds)

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The Brazilian BGBD Team has issued their BGBD review in Portuguese. It is a translated and extended version of their BGBD review "Soil Biodiversity in Amazonian and other Brazilian ecosystems" that was published by CAB International Publishers in

2006. This book has 19 chapters, from the 11 chapters in the original book with a total of 768 pages. Following is a short description of the work in Portuguese.

"O equilibrio da vida na terra depende substancialmente do equilibrio do solo. Se a vida no solo patar, a vida na terra acabara em 20 ou 30 anos. A decomposicao de residuos organicos, a ciclagem de nutrientes, a grehacao de particulas do solo e o controle biologico de pragas e doencas, sao importantes funcoes mediadas pela enorme e escondida diversidade de organismos do solo, as quais tornam possivel a vida dos seres humanos e de outros ness planeta. Alem disso, a biodiversidade e uma fonte valiosa e ainda incalculavel de recursos geneticos para usos diversos, inclusive na area medica. Pois pretendiamos atingir um publico mais amplo e diverso no brasil, visando a contribuir para a conscientizacao sobre este assunto tao importante e atual eque diz respeito a todos nos, detentores da maior megadiversidade entre as nacoes tropicais.

No brasil ele e denominado BioSBrasil(www.biosbrasil.ufla.br), a instituicao executora e a UFLA e as instituicoes co-executoras sao: INPA(Instituto national de Pesquisa da Amazonia), UFAM (Universidade Regional de Blumenau), UnB (Universidade de Brasilia), CEPLAC (Comissao Executiva do Plano da Lavoura cacaureira), UESC (Universidade Estadual do Sudoeste da Bahia), CENS (Centro de Energia Nuclear na Agricultura), CEULM (Centro Universitario Luterano de Manus) e ULBRA (Universidade Luteranan do Brasil).

O grupo de pesquisa brasileiro, BIOSBRASIL e dedicado ao estudo da biodiversidade de organismos do solo e como eles podem ser usados para sustentabilidade agricola de communidades tradicionais na Amazonia, pois sao importantes para a recicalagem dos materiais e manutencao da capacidade productiva do solo. O projecto busca o uso e o manejo dessa biodiversidadae para a sustentabilidade de sistemas agricolas de baixo insumo na amazonia.

Com anos de estudo nesta linha, os pesquisadores envolvidos no projeto e outros convidados contribuiram para a publicacao da pbra, resultante da parceria de 47 pesquisadores, de 19 instituicoes, sendo 16 nacionais: UFLA, INPA, UFAM, INC/UFAM, UFRRJ, UNB, FURB, EMBRAPA (Agrobiologia, Pecuaria Sudeste, solos, Florestas, Amazonia Ocidental, Arroz Feijao) UAE,UFU, UniLavras e tres estrangeiras: o institut de Recherche pour le Developpment (IRD), da Franca, o Museu de Historia Natural, dos EUA, e a Wageningen University da Hollanda.

Apes de a Biologia do solo ser urn campo de pesquisa muito antiga, ela e bastante recente no Brasil, e esta obra representa a primeira publicacao que aborde de forma abrangente a diversidade e funcao de diversos grupos-chave que compoem a biota do solo".
Capitulos:

1- Organismos do solo em ecossistemas tropicais: um papel chave para o Brasil na demanda global pela conservação e uso sustentado da biodiversidade.
2- Percepção e utilização da flora nas culturas Ticuna e Cocama na microregião do Alto Solimões, Estado do Amazonas, Brasil
3- Solos e ocupação das Terras na Amazônia Brasileira

4- Manejo da Fertilidade dos solos na Amazônia.
5. Diversidade da macrofauna edáfica no Brasil.
6- *Comunidades da macrofauna do solo na Amazônia Brasileira.*
7- Ecologia e diversidade de minhocas no Brasil.
8- Diversidade de cupins (Insecta:Isoptera) no Brasil
9- Scarabaeinae (Coleóptera: Scarabaeidae) detritivoros em ecossitemas tropicais: diversidade e serviços ambientais.
10- Formigas do Solo nas Florestas da Amazônia: Padrões de Diversidade e Respostas aos Distúrbios Naturais e Antrópicos
11- Moscas-das-Frutas (Diptera: Tephritidae) na Amazônia
12- Mesofauna do solo na Amazônia Central
13- Comunidades de Nematóides de Solo sob Diferentes Sistemas na Amazônia e Cerrados Brasileiros
14- Diversidade de microfungos em solos tropicais.
15- Fungos micorrízicos arbusculares: muito mais diversos do que se imaginava.
16- Diversidade de fungos micorrízicos arbusculares em ecossistemas brasileiros.
17- Diversidade de leveduras em ecossistemas brasileiros.
18- Bactérias fixadoras de nitrogênio que nodulam Leguminosae
19- Métodos moleculares para o estudo de comunidades de bactérias do solo.

Effect of land use on occurrence and diversity of nematode destroying fungi in Taita Taveta, Kenya. ***(2008) Asian Journal of Plant Sciences; Volume 7 (5) 447 – 453. ISSN 1682 – 3974.***

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Abstract: This study was undertaken with the objective of determining the occurrence of nematode destroying fungi in soil under different land use systems, with the ultimate goal of harnessing their potential in the control of plant parasitic nematodes. Soil samples were collected from an indigenous forest, maize/bean, napier grass, shrub and vegetable fields, which represented the main land use types in Taita Taveta district of Kenya. The fungi isolates obtained were grouped into seven genera the species identified were *Arthrobotrys oligospora, A. dactyloides, Monacrosporium cionopagum, A.superba, Harposporium anguillulae, Harposporium sp., Dactyllela lobata, Acrostalagums obovatus, Haptoglosa heterospora and Nematoctonous georgenious.* Occurrence of nematode destroying fungi was significantly (P: 3.81×10^{-7}) different among the land use systems in the study area. Out of the isolates that were positively identified, 33.7, 27.9, 20.9, 11.6 and 5.8% were from fields under vegetable, maize/bean, napier grass, shrub and forest respectively. The diversity of nematode destroying fungi was highest in the maize/bean fields and lowest forest soil. Fungal isolates from vegetable gardens were most diverse but the least even while the forest land use was most even but least diverse. The total richness of nematode destroying fungi was 9, in vegetable and maize/bean fields while was 7, 6 and 3 in napier, shrub and forest habitats, respectively. This study has established that nematode destroying fungi are widely distributed and that land use has a significant effect on their diversity.

El género *Thaumatomyrmex* Mayr 1887 en México (Hymenoptera: Formicidae). The genus *Thaumatomyrmex* Mayr 1887 in México (Hymenoptera: Formicidae) (Accepted for publication) *Acta Zoológica Mexicana (nueva serie)* 25(1) 2009.

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Abstract: In this paper the distribution in Mexico of the ant genus *Thaumatomyrmex* is analyzed. The Los Tuxtlas region in the state of Veracruz represents the most northern locality for this rare Neotropical genus. Body measurements and photographs of the two specimens collected are provided; the status of the species remains unclear due to the lack of definition on the species diagnostic characters. Rarity of the genus in Mexico is discussed.

Occurrence of Pasteuria forms from a Biosphere Reserve in Mexico (Accepted for publication) *Nematropica* Vol. 38, No. 2, 2008)

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Abstract: Three localities and five land uses with different degrees of disturbance were selected inside the buffer zone of the Los Tuxtlas Biosphere Reserve in Veracruz, Mexico, and eight sampling points were located in each one. From each sampling point, one hundred nematodes were randomly collected and mounted for identification and detection of associated Pasteuria forms. Pasteuria endospores infecting nematodes were observed in two of three localities, and in four different land uses (secondary forest, maize fields, white lily and pasture fields). A total of 1200 nematodes belonging to six genera were found as infected by or with adhering endospores of Pasteuria spp., including Helicotylenchus exallus (1116), Pratylenchus (44), Mesocriconema (20), Tylenchus (10), Plectus (6) and Aporcelaimium (4). These findings represent the first report of Pasteuria species from Mexico.

Estudio de caso: la macrofauna del suelo en La Sierra de Santa Marta (Case study: soil macrofauna in la Sierra de Santa Marta) *(2008) (Submitted), In: 40 Años de Investigación en la Región de Los Tuxtlas*

García Pérez[1], J.A., Barois[1], I., Bueno[1], J., Fragoso[1], C., Kram[1], S., Meza[1], E., Morón[1], M., Negrete-Yankelevich[1], S., Rojas[1], P., and de Los Santos y C. Sormani[1], M.,
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Abstract: The Conservation and Sustainable Management of Below-Ground Biodiversity project is being developed since 2003 in Los Tuxtlas Veracruz. Its objective is to know the soil biodiversity and identify and promote sustainable agricultural practices in the tropics to reduce the negative impact on the soil diversity and ameliorate ecological

functions in agriculture. The goals of the project are : i) standardized methodologies for soil biodiversity assessment, ii) achievement of biological inventories, species identification and group indicators, iii) implementation of demonstrative plots for conservation and management of soil biodiversity, iv) economic valuation and integration of the environmental services of the soil organisms in the decision makers and v) design a proposal to replant the public policies of land use and management of its diversity.
In this work we present the partial results related to the macrofauna inventories in different land uses which represent levels of intensification. The most evident effects that result from the conversion of natural ecosystems to agro-pastoral or agroforestry uses in los Tuxtlas are: i) significant decrease of the specific richness of the macrofauna (alpha diversity), ii) decrease of native and increase of exotic species, iii) increase of species replacement for more than 50% (beta diversity), iv) biomass decrease and v) increase of the species richness at the level of the landscape (gamma diversity).

Rhizobial symbioses in tropical legumes and non-legumes (Accepted for publication, 2008). *Soil Biology and Agriculture in the Tropics, Springer Verlag (Soil Biology Series)*

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Abstract: Legume diversity is very large in the tropics, and legume evolution appears to have followed a tropical to temperate direction. Many tropical legumes have been domesticated as crops for human or animal food, but there are many other legumes that are underutilized. The high protein content in legume seeds and leaves appears to be related to the nitrogen fixation that occurs in legumes through their symbioses with rhizobial bacteria. Rhizobial diversity in tropical legumes has been studied, but it is considered that the enormous diversity of rhizobia in the tropics remains largely unknown, as do the molecular mechanisms of their symbioses. Analyses of the nodule bacteria from *Phaseolus vulgaris* bean plants have revealed several new species. Current knowledge suggests that there is not a high degree of specificity in tropical symbioses, and hence many tropical legumes have been classified as promiscuous. This promiscuity has consequences for the use of rhizobia as inoculants for tropical legumes. Rhizobial inoculants have been successfully used for over one hundred years in many places, but inoculation in the tropics has only been successful in a few cases. New interest in biofuels has raised interest in tropical legumes with high oil content, such as *Pongamia pinnata*, which is now being studied for its symbiotic nitrogen-fixing potential. In addition to establishing nitrogen-fixing nodules in legumes, rhizobia have been found as endophytes in a broader taxonomic group of plants. In non legumes like cereals, rhizobia promote plant growth and suppress pathogens. Rhizobia in non-legumes offer a different perspective on plant interactions and knowledge about their molecular interaction is accumulating. The roles of plant defense responses and of the bacterial lipopolysaccharides that represent a barrier to antimicrobial phytoalexins are recognized, and more information about endophytic interactions may help to establish strategies to better use rhizobia in non-legume agriculture. Cereals require large amounts of N-containing chemical fertilizers for their growth, and these could be partially substituted

by bacterial nitrogen fixation in the future; this is especially relevant for farmers in poor countries who can no longer afford fertilizers.

The historical roots of soil degradation: evidence from documents in agrarian archives *(2008) (submitted) Environmental Conservation*

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Abstract: In many tropical regions, after a colonial period and independence, agrarian reforms where executed by granting land to farmers on mountainous areas covered with tropical forest. Agrarian archive documents are an invaluable, yet neglected, source of evidence on how these agrarian reforms have driven the process of soil degradation in the tropics. For example, the archive documents related to three communities in the buffer zone of the Los Tuxtlas Biosphere Reserve in Mexico show that during the process of land endowment (that followed the 1910 revolution) the interaction between farmers, legislation and agrarian authorities promoted short term and small scale visions of soil fertility. The fragmentation of land into ejidos (1960's-1970's) broke traditional ordination of production and had devastating consequences for the soils. Long and imprecise bureaucratic processes fuelled conflicts over land tenure. The Idle Land Law promoted that farmers battled conflicts over land by gaining terrain to the forest and establishing unproductive pastures. The success of today's soil conservation programs in tropical mountains will depend on understanding how local history has shaped farmers views of their land and planning the adoption strategies accordingly. Agrarian archives can constitute a key source to achieve this understanding.

Occurrence of Symphyla (Myriapoda) in different land use systems in the region of High Solimões river basin, Amazonas, Brazil *(2008). International Colloquim on Apterygota (ICA). Positivo University Curitiba - Paraná – Brazil, September 01 - 02, 2008*

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Abstract: Symphyla are tiny and pale soil-dwelling invertebrates, living in the soil, under rocks and decomposing wood. Their economical importance is not well known, but there are registers of considerable harm in agriculture, of attacking mainly roots, and root hairs in of young seedlings. We are making the first registers of abundance and richness of Symphyla in different land use systems, manipulated by communities along the river of the Ocidental Amazonia. The study is part of the "Conservation and Sustainable Management of Below-Ground Biodiversity project, Phase I, which is planned to make the inventory of below-ground biodiversity in seven tropical countries (Brazil, Mexico, Indonesia, India, Uganda, Ivory Coast, and Kenya). The study was developed in the region of High Solimões River, municipality of Benjamin Constant, state of Amazonas. The region is the homeland of most of the remaining indigenous Amazonian people and one of the most important hotspots for the Amazonian agro-biodiversity. We selected five systems: primary forest, secondary forest, crops, agroforestry and pasture. Using six

systems of trails encompassing 300 m², we collected 101 samples of litter with a metallic corer (3.5 x 3.5 x 10 cm) introduced 5 cm deep in the soil. Each sampling place was separated 100 m from each other, distributed in the localities of "Nova Aliança", "Guanabara" and "Benjamin Constant".

The animals were extracted with Berlese-Tullgren method and stored in 70% alcohol. We registered two genera and three species: Hanseniella arborea Scheller, Hanseniella orientalis (Hansen) and Symphylella adisi Scheller. The secondary forest showed the highest density (640 ind/m2). Densities in the primary forest and pasture were similar (16 ind/m2). The density of Symphyla in the secondary forest was significantly higher compared to the other systems (ANOVA; $F = 5{,}997$; $p < 0{,}001$). S. adisi was the most abundant species (336 ind.m2), but was not registered in primary forest. H. arboreae was the most abundant in secondary forest (48 ind.m2), and was not caught in primary forest or pasture. Contrary to what was expected, both density and diversity of Symphyla were higher in secondary forest.

Nitrogen-fixing bacteria communities occurring in soils under different uses in the Western Amazon Region as indicated by nodulation of siratro (Macroptilium atropurpureum), Plant and Soil, doi 10.1007/s11104-008-9855-2

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Abstract: Understanding native communities is a crucial step for the management of biological nitrogen fixation, since they may be either a source of efficient strains or a limiting factor when efficient strains need to be introduced. This work aimed to evaluate the density, diversity and efficiency of Leguminosae nodulating bacterial (LNB) communities and their component strains in soils under various land use systems (LUSs): pristine forest, agriculture, pasture, agroforestry, young secondary forest, and old secondary forest,. The LNB communities were trapped from these soils by using the promiscuous host siratro under controlled conditions. We also studied their relationships with physical and chemical attributes of the soil. Agroforestry and agriculture soil samples induced the highest number of nodules in siratro, while forest soil samples induced the lowest number of nodules. No relationship was found between LNB and Leguminosae species diversity in the LUSs. The soil chemical variables that were most related to differences in nodule number and shoot dry matter weight of plants inoculated with soil suspensions of the LUSs were, respectively: Ca^{2+}, Mg^{2+}, base saturation, exchangeable bases and Cu^{2+}; and pH, cation exchange capacity, B, Cu^{2+} and clay. Although, LNB communities from all LUSs were efficient under controlled and similar conditions, they were found to be composed of strains with variable efficiency: inefficient, efficient, highly efficient and superior efficiency. Efficient strains occurred at the highest frequency in all LUSs. The isolated strains presented similar and new sequences that were phylogenetically related to well known LNB genera in α-and β-Proteobacteria. Unusual genera in these branches, as well as in other branches, which are probably endophytic bacteria, were also isolated from nodules. These data support siratro

as a useful trap species to study the LNB biodiversity of diverse ecosystems in tropical soils. The fact that the highest diversity and nodulation were seen in managed systems such as agriculture and agroforestry suggests a high resilience of LNB communities to changes in land use after deforestation in a region where large forest areas are still preserved and can be a source of propagules.

WORK IN PROGRESS

The global coordinating office of the CSM-BGBD project has received over 80 reports and papers from the Country Project Components on the inventory of BGBD. These papers have been reviewed, revised and most of them have been edited. While we are in the final editing stages, these papers will be returned to the Country Project Components to be compiled into country reports on the inventory of BGBD. The reports will be issued in 2009 and contain chapters on the site characterization (soils, land use, vegetation and socio-economic characteristics) and chapters with results on the inventory of the major functional groups, like macrofauna, meso fauna, LNB, Mycorrhiza and soil fungi.
It would carry us too far to list all the chapters to be contained in each of the reports on the inventory from all the benchmark areas, but a proposal for the content of the these country reports was presented and accepted during the project steering and advisory committee, held in November, 2008

Influence of conservation tillage on soil microbial diversity, structure and crop yields in sub-humid and semi-arid environments in Kenya

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Introduction

Conservation tillage approaches affect soil microbial populations, soil structure and crop performance but the effects within African climate and soil conditions are not well understood. Tillage is known to affect soil aggregation through disruption of macro-aggregates and increased turnover rate of organic resources. In many small-holder farming systems in Africa, crop residue after harvest is either left on the farm as a strategy for soil fertility management or removed to serve varied uses: fodder, fuel etc. We investigated how maize stover retained within the cropping systems affects soil aggregation under conventional and reduced tillage systems. The stover is usually of lower quality than legume residues and their interaction could lead to aggregation differences between cropping systems where legume is included, and those planted with cereal only. In most sub-Saharan Africa, intercropping is the most predominant cropping system within small holder farming systems. However, works reported in literature focus mainly on pure crop stands either in rotation or continuous monocropping with a one-time per season application of some external organic resource. By affecting composition and structure of organic matter (Agnelli et al. 2004), cropping systems could in-turn affect microbial diversity through variability in nutrient and energy sources. In this study therefore we investigated the effect of conservation tillage practices, organic resource application and cropping systems on soil microbial diversity, soil structure and crop yields.

Materials and methods

This study was conducted in two agro-ecological zones; a semi-arid zone (Machang'a in eastern Kenya) and sub-humid zone (Matayos and Nyabeda in western Kenya). The experiment in the semi-arid site was a randomized complete block design with 3 tillage systems (conventional tillage, no-till and tied-ridging) each with two organic applications (2 t ha/ manure applied alone and, 1 t/ha manure plus 1 t/ha crop residue). The experiments in the two sub-humid sites were designed as split-split plots with tillage (conventional and reduced tillage), crop residue (0 and 2 t/ha maize stover) and cropping systems (continuous maize, maize soybean intercropping and rotation) as the main, split and split-split plots respectively. Conventional tillage involved hand hoeing to about 10-15cm depth as done by small-scale farmers, 3 times per season. Tied-ridges were prepared during trial initiation and maintained throughout the experiment, with tillage restricted to refreshment of the ridges. In the no-tillage system, land preparation was done using hand hoes and only hand pulling of weeds in between the season. Under reduced tillage, hoeing was restricted to surface scratching to 3cm depth to remove weeds. Average crop yield data for the first 3, 4 and 8 seasons in Matayos, Machang'a and Nyabeda, respectively, is reported. Soil sampling for microbial analysis and aggregation determination was done during 4^{th}, 5^{th} and 10^{th} seasons in Machang'a, Matayos and Nyabeda, respectively. Aggregation sampling depths were 0-15cm for Machang'a and 0-20cm for Nyabeda and aggregate separation was by wet sieving using a series of 3 sieves (2mm, 250μm and 53μm). Isolation of POM, silt-clay and micro-aggregates within macro-aggregates was done according to the procedure of (Six et al. 2000). Bacteria and fungal diversity were determined from dry-incubated soils for Matayos and Machang'a and fresh soil for Nyabeda, using PCR-DGGE techniques.

Preliminary results

Conservation tillage systems could have similar or lower yields compared to conventional tillage systems. We observed similar yields between Tied-ridge and conventional tillage over 4 cropping seasons in Machang'a, but significantly lower yields in reduced and no-tillage systems (Table 1). In the dryland site also, although no-till yields were lower than conventional system for the initial seasons, they increased progressively and were significantly higher by the fourth season (data not shown). Application of crop residue increased yields by 13% in Matayos and 15% Nyabeda while combination of manure and CR in Machang'a increased yields by 24% over manure only treatments (Table 2). CR is important also in soil water conservation and regulation of soil temperature especially when applied as surface mulch, as often done in reduced tillage. Recently, in order to improve water relations and crop performance in no-till and reduced tillage systems, modifications have emerged including ripping and sub-soiling and the results are promising (Motavalli et al. 2003), but also depending on the rainfall regime.

We also observed the effect of crop residue on yield to vary with tillage and application of inorganic N; application of CR suppressed yields in conventional tillage especially when N was not applied indicating soil inorganic N immobilization, but up to 30% yield increases attributable to crop residue were observed under reduced tillage (data not shown). Reduced and no-till farming can be effective in enhancing soil macro-aggregation. In both sites where aggregate separation was done (Machang'a and Nyabeda), higher aggregation was observed in conserved plots compared to conventionally tilled ones. This demonstrates that avoiding soil disturbance is necessary to improve aggregation of both clay and sandy soils. Although no significant effect of organic resource application on aggregation was observed over the overall soil depths, there was positive effect with combination of manure and crop residue in Machang'a increasing aggregation index by 17% over manure only treatments. And we also observed significant crop residue effect on soil aggregation at the surface 0-5cm soil layer, the zone where much of the CR was located (data not shown) showing that managing soil organic matter remains of great importance for the structural stability of the very surface soil. Among the cropping systems, intercropping had higher aggregation indices compared to the rotation system, but similar with continuous cereal system (data not shown). Continuous presence of a legume in the intercropping system could favour stability or re-formation of macro-aggregates via its root residues and legume organic exudates, its associated microbial community or simply the effect of its higher plant density (maize plus soybean) relative to the other systems. However, under rotation, the macro-aggregates formed during the legume phase likely break up after the legume crop is removed, leading to increased micro-aggregates and silt and clay fractions and hence lower aggregate mean diameter.

Diversity of bacteria is affected by tillage and organic substrates of different sources (Øvreås and Torsvik 1998). Diversity of bacteria in Machang'a and Nyabeda were not affected by tillage but in Matayos, reduced tillage showed higher bacteria diversity over conventional tillage system. Fungi diversity was higher in CT than in RT but nevertheless, we found no difference in the numbers of identified bands. Higher band volume under reduced tillage indicated that few fungal communities dominated this system, leading to the lower Shannon diversity index observed. Also there was significantly low diversity of fungal where crop residue was applied compared to treatments without crop residue, again due to domination by fewer species. Shannon diversity is high only when species numbers are high and evenness fulfilled. It could also be that domination by few species of fungi pushes other existing species to the <1% of microbial cells, usually too few to be detected by PCR-DGGE technique. As observed with soil aggregation, both bacteria and fungi diversity (Shannon index) were higher in intercropping compared to continuous maize system as observed in Nyabeda (data not shown). In Machang'a despite low carbon content, bacteria diversity was higher than in Matayos perhaps due to the towards neutral pH compared to more acidic soils in Matayos. In a continental-scale research involving different sites in North and South

America, diversity of soil bacteria communities increased as soil pH increased from acidic to near neutral (Fierer and Jackson 2006).

Table 2: Effect of tillage on maize grain yield, aggregate mean weight diameter and microbial diversity

Site	Tillage	Maize grain yield (t ha-1)	Aggregate MWD	Bacteria diversity (H')	Fungi
Matayos	RT	1.44^{a}	-	2.05^{b}	-
CT		2.01^{b}	-	1.79^{a}	-
SE		*0.186*	-	*0.085*	-
Nyabeda	RT	3.15^{a}	1.81^{b}	2.02^{a}	1.56^{a}
CT		3.71^{b}	1.47^{a}	2.04^{a}	1.67^{a}
SE		*0.156*	*0.080*	*0.075*	*0.057*
Machang'a	NT	1.74^{a}	0.80^{b}	2.11^{a}	-
TR		2.08^{ab}	0.74^{ab}	2.10^{a}	-
CT		2.30^{b}	0.60^{a}	2.11^{a}	-
SE		*0.124*	*0.053*	*0.090*	-

Bacteria and Fungi Diversity in Conservation Tillage Systems in Humid and Arid Zones in Kenya

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The effect of tillage, crop residue and cropping system on diversity and composition of soil bacteria and fungi was investigated using PCR-DGGE techniques. Soil micro-organisms are vital in soil nutrient cycling and improvement of soil structure. The study was conducted in two agro-ecological zones; a semi-arid (Machang'a in Eastern Kenya) and sub-humid zone (Matayos and Nyabeda in western Kenya). The treatments were combinations of tillage (conventional and reduced tillage), crop residue (0 and 2 t ha^{-1} maize stover) and cropping systems (continuous maize, maize soybean intercropping and rotation) in the sub humid sites, and tillage (conventional tillage, no-till and tied-ridging) and organic resources (manure and crop residue) in the semi-arid site. In the three sites, tillage had the greater effect on the composition of both bacteria and fungi communities while cropping system had greater effect on microbial diversity. Crop residue application had more influence on bacteria populations in reduced tillage than in conventional tillage. Diversity of soil fungi was suppressed ($P<0.01$) by crop residue application (Simpson's index of 0.65 with, and 0.75 without crop residue). Fungi and bacteria indices in Nyabeda were in the order soybean-maize intercropping ≥ rotation ≥continuous maize; the order was variable in Matayos. Applying crop residue from previous crop in the rotation system increased ($P<0.05$) bacteria Simpsons' index of diversity in Matayos. Bacteria diversity was positively influenced by SOC and Mg ($P<0.05$), and negatively by P - when below 6 mg P kg $soil^{-1}$ ($P<0.01$); the influences were only in sites where these nutrients were lowest. Bacteria diversity also increased with soil total N. Bacteria diversity was inversely related to silt and clay while fungi diversity (Simpsons' index) was related to soil macro-aggregates >2mm ($P<0.05$). Combination of reduced tillage and simultaneous supply of low and high quality organic resources is suggested as one of the best strategies to increase diversity of soil bacteria and fungi.

Influence of Conservation Tillage on Soil Microbial Diversity, Structure and Crop Yields in Sub-Humid and Semi-Arid Environments in Kenya

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Conservation tillage is one of the ways to maximize benefits derived from farming mainly through enhanced soil biological and physical conditions as well as better utilization of rain water. In a study conducted over 5 to 10 cropping seasons in two agro-ecological zones in Kenya (three sites), the effect of conservation tillage practices on soil microbial diversity, soil structure, water conservation and crop yield were investigated. The on-farm experiments were laid out as split plot design involving different cropping systems and crop residue management strategies superimposed on the tillage practices. Clearly, higher soil macroaggregation was observed in reduced tillage (by up to18%) and tied-ridges compared to conventional tillage system. Similarly, application of crop residue had positive effects on soil aggregation indices (increase by 13%) in clay soil within sub humid zone while combination of crop residue and manure was better than sole application of manure (by 4%) in a sandy semi arid zone. Among the cropping systems, aggregation indices declined in the order: intercropping> continuous maize > rotation. Conservation tillage practices showed higher diversity of bacterial and fungal populations compared to conventionally tilled plots. In the dryland zone, regardless of tillage system, application of 1tha^{-1} of maize stover and manure, each was the best practice. In the humid zone, although reduced tillage had lower yields than conventional tillage its performance was enhanced when combined with ripping or subsoiling.
Thus from the study, conservation tillage was superior in improving soil microbial diversity and soil structure but low agronomic performance must be overcome though ripping and subsoiling.

Simulation of soil organic carbon response at forest-cultivation sequences using ^{13}C measurements.

P. Gottschalk[1], J. Bellarby[1], C. Chenu[2], B. Foereid[1], M. Wattenbach[1], J. Smith[1], and S. Zingore[3]
[1]University of Aberdeen, UK; [2]INAPG, UMR Bioemco, France; [3]TSBF - CIAT, Malawi

There are few long-term experiments that have used the ^{13}C isotope technique to study the impact of clearing native vegetation for arable cropping on SOC dynamics. This study data from four chronosequence sites was used to evaluate the ROTHC model. The long-term response of SOC to forest clearance is therefore not represented by a single set of measurements from long-term sites but instead from measurements of plots with similar soil and management characteristic but of different cropping ages. To account for the inaccuracies for substitution of time for space, an uncertainty analysis was carried out to estimate the variability in model results. The objectives of this study were to (i) evaluate ROTHC at forest-cultivation sequence sites using ^{13}C abundance measurements, (ii) assess the reliability of the model results due to uncertainties in the input data, (iii) to use ^{13}C natural abundance in conjunction with soil fractionation to evaluate the dynamics of the C pools of ROTHC separately from total C dynamics, (iv) account for soil erosion and (v) implement a simple approach to simulate the dynamics of physically protected C.

While ROTHC accurately predicted the accumulation of maize derived C, it failed to accurately capture the fast decrease in forest C that occurs during the first years of cultivation. However, when the forest and arable soils are at steady-state, the calculated input of plant C to the soil compared well with plant input values obtained from estimates of NPP. This suggested that the model provides good estimates of plant organic matter inputs. Results were in good agreement with recent studies on SOM dynamics that have focused on the biological and physiochemical processes and control of SOM stabilisation and turnover. Our simple approach agrees with the conceptual model of soil C stabilization. The study has further shown that the combination of ^{13}C abundance with SOM particle-size fractionation techniques is an excellent tool to evaluate the performance of a SOM model under land use change conditions.

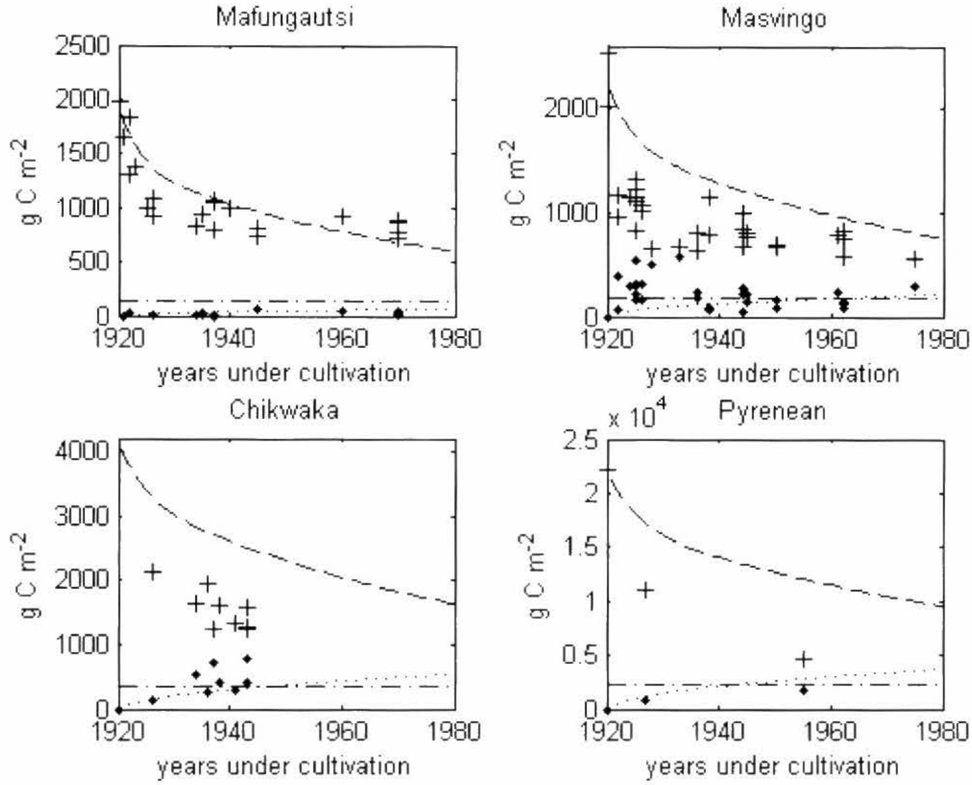


Figure 7: Forest derived C (crosses) and maize derived C (squares) and simulated forest derived C (dashed line) and maize derived C (dotted line) for four chronosequence sites in Zimbabwe. IOM pool calculated using the model default Falloon equation (dashed-dotted line).

Output 1. Processes and principles
Output Targets 2009: Indicators of soil (biological) quality identified and documented

COMPLETED WORK

Soil quality parameters that determine the below ground biodiversity in Los Tuxtlas Veracruz México. *(2008) Presented at the 15th International Colloquium on Soil Zoology, Curitiba, Brasil. 25th-29th August, 2008*

Barois[1], I., Velasquez[1], E., Lavelle[1], P., Negrete-Yankelevich[1], S., García[1], J.A., Santos[1], M., Álvarez-Sánchez, J., Castillo-Campos, G. Cram[3], S. Fragoso, C. Franco-Navarro[2], F., Martínez-Romero[3], E., Meza, E. Morón, M.A., Rodríguez, P., Rojas, P., Sosa, V., Trejo[4], D., Varela, L., Bueno-Villegas, J., Gómez, J.A., and Sormani, C.

[1]Institute of Ecology, Xalapa, Mexico ,[2]Instituto de fitosanidad, Colegio de Posgraduados, [3]Universidad National Autonomia de Mexico, [4]Universidad Veracruzano

Abstract:
In the frame of the project "Conservation and sustainable management of below ground biodiversity (GEF/UNEP- TSBF/CIAT)" soil organism inventories were done in the biosphere reserve of Los Tuxtlas around Santa Martha volcano. 3 Sites (LM, SF and VC) and 4 land use (forest (S), fallow (A), pasture (P) and maize (M) were sampled, in total 89 points. The sampled organisms were the biological nitrogen fixator, the mychorrizal fungi, the nematodes, the macrofauna (earthworms, ants, termites, beetles, cockroach millipedes and centipedes). In each point the samples for the microorganisms and nematodes came from a composite soil sample made of 12 cores of 5 cm diameter and 20 cm height. The macrofauna was sampled with monoliths (25x25x30cm), Winkler bags and Pitfall traps. Some chemical parameters (pH, Na, K, Mg. Ca and P Bray), physical (% H), CE, clay, lime, sand, ad, rd, slope); and organic parameters (C, N, NH4, NO3, litter and deshydrogenase and B-glucosidase activity) were measured in each points from the composed sample.
In order to synthesized the results and to evaluate which parameters of the soil determine the diversity of organisms the general indicator of soil quality (GISQ, Velasquez et al 2007) was build after 4 subindicators that evaluates the physical, chemical, organic matter and the macrofauna data. The construction of the GISQ is made with PCA of each of the 4 sets of variables and a cluster analysis. Also identification of species indicators (Ind Val) and coinertia analysis is carried out.
The PCA of the 4 set of variables showed significant separation among sites and among land uses. LM site had the best soil quality, followed by SF and VC. In the land use system S showed the best soil quality and M the lowest, although in some group of variables P and A uses presented a quality near to S.
The highest GISQ (1.00-0.85) were from LM but in different land uses (S, A and P); the lowest (0.49-0.21 were in VC in maize and pasture and in SF in maize. The cluster analysis did discriminate 8 groups of the sampling points having a similar GISQ.
The IndVal analysis extracted some species indicators many from the ants and the nematodes and few from the earthworms, termites and mycorrhizal fungi.
The co-inertia analysis between soil quality indicators and species richness displayed that some diplopodes and coleoptera and native earthworms required a high soil quality soil. Other coleoptera, ants and exotic earthworms required a less rich soil although with a high quality in organic matter. Finally, the microorganisms (Rhizobia and mycorrhizal fungi), Nematodes and Chilopoda, were more represented in poor quality soils.

Application of soil quality indicators in semi-arid rangelands in South Africa: perspectives for degradation monitoring

A.S. Moussa[1], L. Van Rensburg[1], K. Kellner[1] and A. Bationo[2]
[1] *Potchefstroom Campus of the North-West University, South Africa;* [2] *TSBF - CIAT, Kenya*

Concerns were raised over the past decades on the degradation condition of arid and semi-arid rangelands in South Africa, mainly in areas under communal land management. Changes of vegetation components were often used to characterize degradation, whereas soil quality and degradation processes remain less understood. The integration of soil information in rangeland monitoring cannot be overemphasized. The aims of this study were to characterize and establish baseline indicators of soil quality/health, and to investigate the potential effects of grazing and exclusion management on soil quality indicators, that could be used for reporting on rangeland degradation in semi-arid South Africa. The soil characterization provided some valuable baseline indicators of soil quality (and fertility) at the sites surveyed. Notwithstanding the alarming plea about communal rangeland degradation, similar soil quality indicators were observed between the sites under communal management and surrounding commercial and/or game areas, considered well managed based on the attributed of their aboveground vegetation. This challenges the sole use of vegetation parameters in monitoring and assessing rangeland health. Furthermore, site-specific approach is cautioned when assessing degradation between different rangeland management systems. The results warrant the need to re-examine the "tacit" degradation in communal managed areas rangelands. This warrants the need to re-examine the "tacit" degradation in communal managed areas. The effects of grazing were divergent depending on the soil properties monitored and site-specific characteristics. Last, the integration of both science-experts and community knowledge and understanding is essential to empower local stakeholders in order to support management decisions for sustainable rangeland use.

WORK IN PROGRESS

Soil chemical, phyiscal and biological quality indicators common to varying ecological environments and their behavior in relation to and use intensity.

J. Huising[1], P. Lavelle[2], E. Velasquez[3], P. Okoth[1], S. Ichami[1] and others.
[1]TSBF-CIAT, Kenya; [2]Institute of Ecology, Xalapa, Mexico, and IRD, [3]University of Columbia

Introduction

The project aims to publish the synthesis of the results from the inventory either as a book or as separate papers. The objective of the work is to identify common indicators of soil quality. This comprises soil chemical and physical quality indicators. As far as the soil biological quality indicators are concerned the taxonomic richness will be investigated that comprises all the various taxonomic groups of soil organisms as well as the diversity as per specific functional groups like earthworms for example. The aim is to find indicators of soil biodiversity as being an aspect of soil biological quality, but also to investigate how the soil biological quality relates to soil physical and chemical quality as well as land use. The indicators could then subsequently be used to describe the soil quality status of the benchmark areas and to monitor soil quality at the experimental and demonstration plots. The convectional definition of soil quality is "the fitness of a specific kind of soil, to function within its capacity and within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation"

Materials and Methods:

A Generic Indicator of Soil Quality (GISQ) can be generated form a combination of sub indicators developed from PCA analysis of soil organic, chemical, biological and physical proprieties. It is probably more meaningful to consider the sub-indicators separately rather then the GISQ as they express different qualities. The ADE4 software is used to do the multivariate analysis (PCA) and co-inertia. For each benchmark area the SQIs will be determined in this way and comparative analyses of the results will then reveal whether common patterns across the benchmark area can be observed. INDVAL will subsequently be used for each of the benchmark areas separately whether certain functional or taxonomic groups can be considered as indicators for particular conglomeration of soils of certain soil quality status.

Factor Loadings

Funtional groups	Factor 1	Factor 2
Termite	840	1987
Nematode	2478	1027
Ants	3471	587
Beetle	6490	0
AMF	2605	4812
Macrofauna	1753	1863
Mesofauna	2563	2635

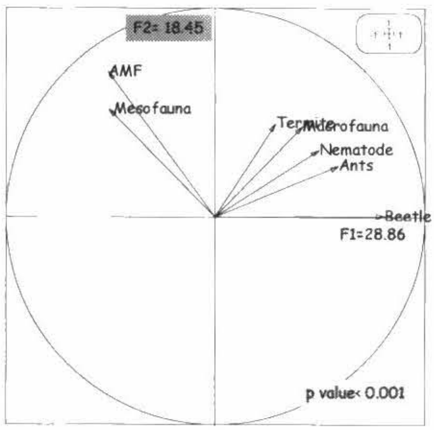


Figure 8a: Brazil taxonomic richness

Factor Loadings

Fuctional groups	Factor 1	Factor 2
Ants	4855	395
Earthworms	1719	55
Termites	3199	17
LNB	276	5985
Pathogen fungi	1626	21
Beetles	4907	758
AMF	1087	4391

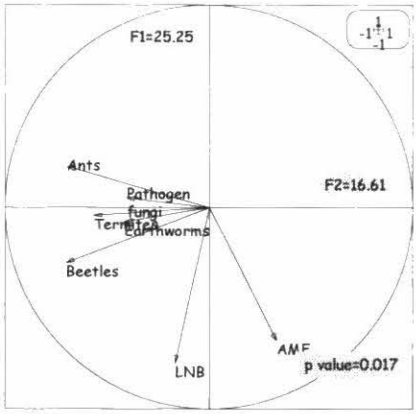


Figure 8b: Uganda taxonomic richness

Factor Loadings

Funtional groups	Factor 1	Factor 2
Myco*	3897	1460
BNF	901	2981
Nematode	5390	1373
Earthworms	1748	405
Coleoptera	8457	128
Ants	4786	999
Termites	4	1800
Diplopoda	257	3924
Chilopoda	3497	847
Collembola	1018	1613
Blattidae	4	1156

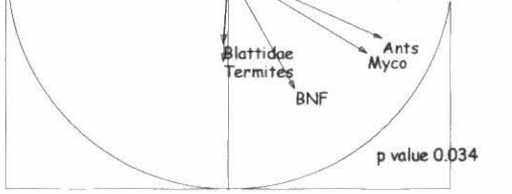


Figure 8c: Mexico correlations between taxonomic richness

Factor Loadings

Functional groups	Factor 1	Factor 2
Ant	5695	1582
Beetle	6827	500
Termite	653	3873
Earthworm	1070	3
Nematode	893	2127
Collembola	545	4625
PPF	72	3913
AMF	5767	82

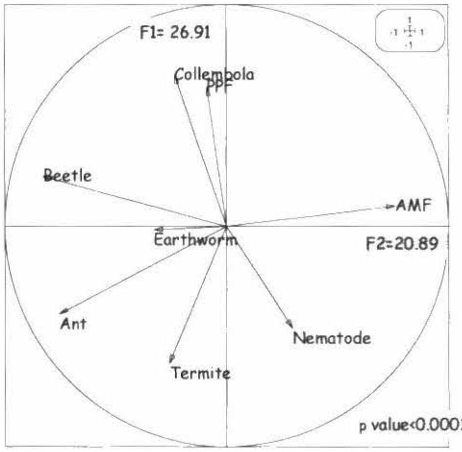


Figure 8d: Indonesia – lamp: richness in relation to land use intensification

Factor Loadings

Funtional groups	Factor 1	Factor 2
Earthworm	4227	1267
Macrofauna	5845	366
Mesofauna	67	8236
AMF	4032	633

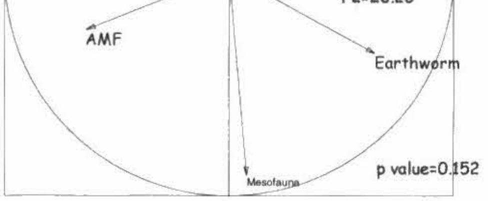


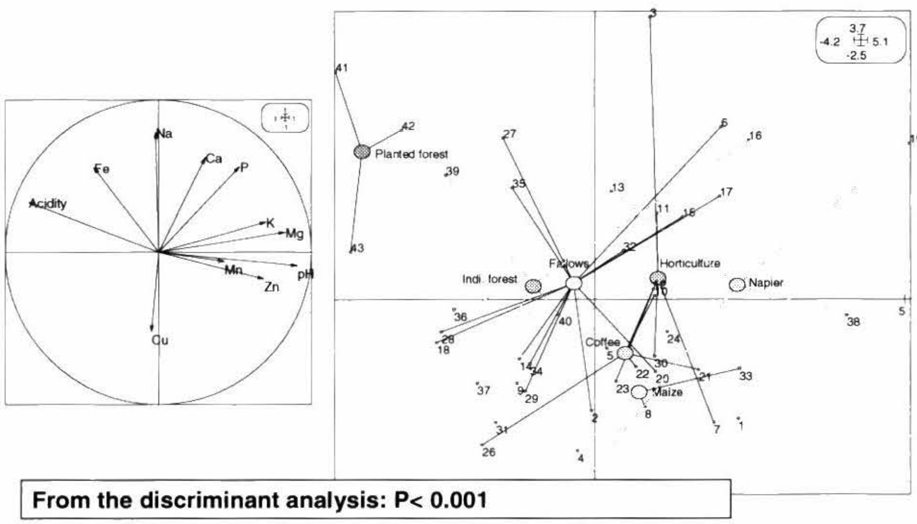
Figure 8e: India – Kar: richness in relation to land use intensification

Preliminary results

Below preliminary results are presented from analyses done on the data matrix of taxonomic richness from 5 benchmark areas. The graphs present correlation circles and indicate a marked difference in the response of taxonomic richness for the different functional groups. For example, the taxonomic richness of AMF does not seem to be correlated with the taxonomic richness of other functional groups like macrofauna and therefore responds differently to environmental factors. The different groups of macrofauna do often cluster nicely indicating that the taxonomic richness of these various groups of macrofauna (earthworm, ants, termites) is correlated.

Also, we do find consistently that soil quality differs significantly between land uses. The example below indicates that the soil chemical quality (or soil chemical properties) differs between the land use systems within the Taita benchmark area. We do find these differences between land uses also in terms of soil biological characteristics. Further analyses have to reveal how the different functional groups respond however.

Taita land use distribution as a function of soil chemical properties (0-10 cm depth)



Soil health related problem in two locations in Mali as determined by diagnostic trials

J. Huising[1], S. Zingore[1], C. Gachengo[1], K. Shepherd[1], B. Vanlauwe[1], and others
[1]*TSBF-CIAT, Kenya*

Introduction

The sentinel landscapes of the AfSIS project will provide a systematic framework for conducting agronomic trials, so that for example fertilizer and organic input response data for crops can be statistically modeled with regard to baselines and the corresponding spatial covariates. Some of these trials will be used for diagnostic purposes, aiming to diagnose soil health related problems that affect the production potential of these soils. The diagnostic trials will be conducted first in the sentinel sites in Mali, in 2009, before moving on to sentinel sites in other countries. The diagnostic trials will give us insight in the sort distance variability in responses of soils to fertilizer applications and other measures and in the factors that cause these variations. Together with results from other sites these trials should provide us with the different criteria and threshold values that enable us to diagnose soil health problems. These diagnostic trials will be multi-locations trials according to a standard design that we still need to agree upon in the project.

Output 1. Processes and principles
Output Targets 2009: Concepts of valuating the contribution of soil biota and biotic processes to the provision ecosystem goods and services applied in case studies

COMPLETED WORK

Economic Value of Nitrogen Fixation in Soybean in Africa: Improving benefits for smallholder farmers

Chianu[1], J., Huising[1], E.J., Danso[2], S.K., Sanginga[1], N., and Okoth[1], P.
[1]*TSBF-CIAT, Kenya;* [2]*University of Ghana, Legon- Accra, Ghana*

Abstract: Although it is common knowledge that soil microorganisms form an important constituent of below ground biodiversity and provide ecosystem services, such knowledge does not often lead to formulation of policies to conserve and manage these soil microorganisms, or to strategies that lead to explicit use of these resources. Applying the knowledge gained from several experimental stations and from on-farm research [supplemented with necessary assumptions on FAO-sourced secondary data on soybean (*Glycine Max*) from 19 countries in Africa], this study attempts to increase the awareness on the importance of these microorganisms by quantifying the economic value of nitrogen fixation of legume nodulating bacteria (LNB) associated with promiscuous soybean. Computation of economic value (of nitrogen fixation) was based on the method of cost replacement or cost savings in terms of mineral nitrogen fertilizer that would have been required to attain the same level of nitrogen fixed biologically. Result shows that the economic value of the nitrogen-fixing attribute of soybean in Africa, especially the

promiscuous varieties, annually amounts to about US$200 million across the 19 countries. With the fertilizer prices of June 2008 this would amount to US$ 375 million, however. The study concludes with recommendations on various ways of increasing the chances of smallholder farmers benefiting from the nitrogen-fixing attribute of LNB, especially since many of them cannot afford adequate quantities of inorganic fertilizers required for increased crop productivity.

WORK IN PROGRESS

The BGBD project aims to issue a review article on the economic valuation of BGBD in 2009, based on the work done in the project over the past few years and based on result from other published work. A lot of wok has been done in the BGBD project on economic evaluation of legumenosae nodulating nitrogen fixing, but we would like to include result from studies on the use of beneficial microbial soil organisms as well as consider the benefits that can be obtained for soil engineers as functional group, mycorrhizal fungi etc.

Output 1. Processes and principles
Output Targets 2010: Modelling tools to predict effect of soil management interventions and technologies on soil health status developed and validated

COMPLETED WORK

There is quite some work done in TSBF on the decision support tools in relation to crop production and, to lesser extent, in relation to soil carbon sequestration. These are both very important aspects of soil health. I refer to work done in the NUANCES project, the work done in relation to use of models like DSSAT, APSIM, NUTMON etc. Please refer to the annual report of ISFM outcome line for further details.

WORK IN PROGRESS

A decision support framework for soil management recommendations

J. Huising[1], S. Zingore[1], P. Okoth[1] and others
[1]*TSBF-CIAT, Kenya*

Decision making on the adoption of soil management recommendations in the context of the AfSIS project
The decision making process consists of establishing goals and objectives (together with problem identification), the formulation of alternative solutions and weighing one option against the other to arrive at a decision for a particular option, the implementation of the decision, the subsequent evaluation of the outcome and feed-back into the decision making process, as depicted in **(Figure 9)**.

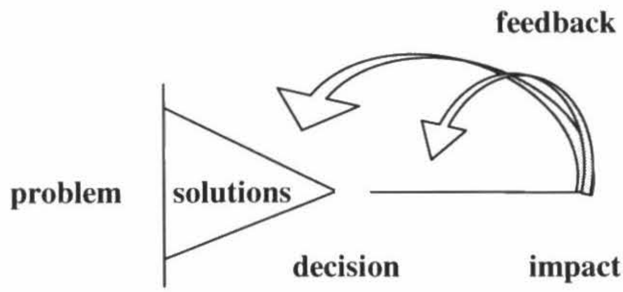


Figure 9: Decision making process

Decision support aims to improve the quality of the decision making process and this can be done at each step in the decision making process; i.e. to improve diagnostics and making objectives more explicit, to define alternative solutions and improved evaluation of these alternatives, assist or guide in the implementation and finally in improving the feed-back or establish lessons learned. In order to model these processes we need to categorize the 'decision maker' and identify the associated problem domains. Can we identify stakeholder groups that face a common set of problems for which there are common solutions?

For the AfSIS project we will elaborate this framework for decisions to be made at various levels of governance to improve soil productivity through integrated soil fertility management. The various stakeholders or stakeholder groups for which the recommendations will apply relate to the target end user of the DSF and to this end various user cases will be defined. The focus will be on the farmer as the primary beneficiary however.

The first step in the process is to derive location specific data and information on the soil health status and inherent constraints to crop production. Diagnostic trials will be an important mechanism to determine soil health problems. The diagnostic trials will inform which soils are responsive to fertilizer applications and which are not and will help to establish rules to determine soil health status based on data on soil properties. Soil pedo transfer functions are used to translate soil properties into soil functional characteristics and another set of rules are used to translate soil functional properties into soil health status.

The next step will be to consider the various ISFM and INRM options for solutions to soil health related problems. For that purpose a knowledge base will be developed that will provide information (expert judgment) on the effectiveness of soil management options to address the observed soil health problems or of ISFM option to enhance crop production under given soil health conditions. We may partly rely on models like the Decision Support System for Agro-technology Transfer (DSSAT), to predict the outcome of proposed interventions.

In determining the suitability of the various management options social and economic factors need to be considered as well. Technical solutions generally require investments, the technology needs to be available and the generally assume a certain level of knowledge and skills to be present. Further the drivers for soil and land degradation need to be considered. If there are social and economic constraints to improving agricultural production and the proposed intervention does not address these constraints the success is likely to be very limited. Also, the proposed solution needs to fit within the farming system, to fit the labour profile etc. More in general the adoption potential of proposed technologies need to be considered and rules need to be defined that govern the diagnoses of social and economic constraints and adoption potential, based on socio-economic data. The project will want to build evidence that the solutions it recommends are effective, since there is a certain degree of uncertainty and reliability associated with each decision and therefore with the risks involved. The project can rely for this purpose on the outcomes of previous and existing studies and trials. However, additional on farm field trails will be carry out to test response to advocated interventions. The evidence will be documented separately and will be linked to the specific application domains.
Factor analysis and multivariate statistics will be the main analytical tools to determine the determinants of crop response to various management regimes, and to the response of soil health, and resource use (nutrients and water) efficiency to varied treatments. Also the response of the farmer (management) to the introduction of a particular ISFM technology or management intervention needs to be investigated for which more qualitative techniques will be applied. Investigations will include ex-ante and ex-post economic assessment of proposed technology looking into the technical feasibility and economic viability, market surveys, socio-economic survey that address social and economic status land ownership etc.; gender is considered a vary important factor and will be emphasized in the project. Farm typologies will be determined based on the set of socio-economic and biophysical factors. Parameters to be considered will include: productivity of labor; productivity of land and capital; land ownership; social and economic status (e.g. gender, age, education and wealth), access to input and output markets, access to credit, access to data and information; labor availability and other. Also here the aim is to construct a decision model and to identify the proper indicator and criteria that can be used in the decision making process.

The decision support framework applies to the different target audiences. However, these target audiences operate from within different contexts. The context is described by the problem domain, the intervention domain and the application domain, graphically presented below.

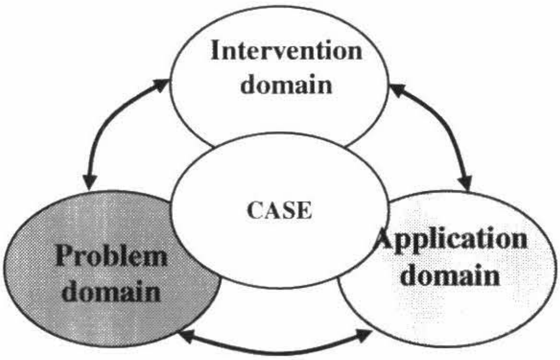
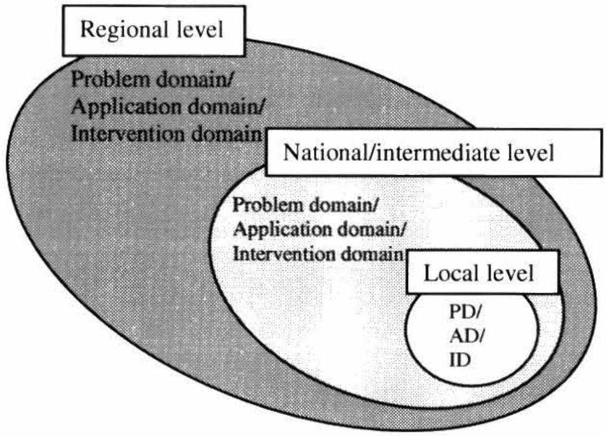


Figure 10: Graphic representation of domains and case definition

Whether actions need to be taken depends on the prevalence of soil related problems. Prevalence data on soil health related problems for the different administrative scales will be one of the major outputs of the ASIS surveillance system. However, it will involve statistical analyses to explain observed variance in the soil health status as explained by the different spatial domains, to determine where the priority for action lies.

The second aspect is that of the intervention domains. The options for interventions are very different for the various stakeholder groups. Local authorities, NGOs and other not directly involved in managing the land and are more concerned with proximate and root courses of land degradation and support functions that are needed to combat land degradation and increase agricultural production.

Again, here the question arises for each stakeholder what are the conditions that it can influence and what are the conditions that they do not have control over.



The sphere of influence determines the type of intervention domain. *Senso stricto* the intervention domain informs about the condition of the target audiences. The application domains inform about the environments to which the proposed technical and management solutions apply. A case is build from the incidence of a particular target beneficiary, a soil health problem and a solution or proposed intervention, the description of which are drawn from the three domains. As there are different (scale) levels of intervention, associated with different target audiences, also the soil health problems occur at different scales (and need to be defined accordingly). The associated possible solutions are therefore scale specific as well. The problem domains, application domains and intervention domains are to a certain extent nested and answer to a particular hierarchy. The project will try to define these hierarchies as well as part of the work on the decision support framework.
The DSF aims to give answers to the questions related to the relative importance of a particular constraint and what the effect or outcome will be of lifting that particular constraint. Thereby it should be realized that those constraints cannot be viewed in isolation and that integrated solutions are required that address the various constraint in conjunction.
The outputs of the work on the decision framework and tools for evidence-based recommendations for land use and soil management will consist of a model of the decision making process, disaggregated according to the scale level and target stakeholder groups, with for each step in the process the provision of tools to support these decisions. The output will include the definition of various domains and provide validated diagnostic criteria for diagnoses of soil health related problems and case descriptions. The premise of the ASIS-DSF is that the three types of domains can be mapped separately (at various scale levels). So the domains also represent spatial domains and where these overlap it will constitute a particular case for which specific recommendation apply.

Output 1. Processes and principles
Output Targets 2010: Methods for evaluating soil health status (provision ecosystem goods and services) developed and accepted

As part of the work on the evidence based and spatially explicit soil management recommendations we aim to include an economic evaluation of the soil health status and land degradation, hoping to provide an economic basis to the recommendations on soil and land management. At this point, no work has been completed or is in progress.
The work done in TSBF on the market-led hypothesis of integrated soil fertility management and NRM feed into this activity and we refer the reader to the annual report of the ISFM outcome line for further details on the progress achieved with that work.

Output 1. Processes and principles
Output Targets 2010: The social, gender, and livelihood constraints and priorities affecting the sustainable management of soils identified especially in relation to improved SOM management and management of BGBD

As part of the work on the evidence-based and spatially explicit soil management recommendations, as well as the work on the sustainable management of BGBD, the work on the socio-economic constraints is singled out as a separate activity. The type of work it involves is described under the Decision Support Framework above. At this point of time there is no ongoing work to report on.
There is related work done in TSBF under the umbrella of the ISFM work. This relates for example to the work in relation to outscaling of organic agriculture in Uganda, the work on innovation platforms for conservation agriculture, the training of agro-dealers in ISFM etc. We refer to the annual report of the ISFM outcome line for further details.

Output 1. Processes and principles
Output Targets 2011: Decision support framework for targeting soil management recommendation (ISFM and INRM technologies) at landscape level established

As indicated the work on the definition and establishment of the decision framework for the soil management recommendations will concentrate in first instance for recommendations for soil management at plot and farm level. However later during the process we aim to concentrate on management and intervention options that are relevant at the landscape level. Currently there is no completed work or work in progress that we can report on.

Output 1. Processes and principles
Output Target 2011: Tools and techniques for rapid appraisal of soil health status and gradients at landscape level developed

Together with the decision support framework, tools and techniques need to be developed that can be applied at the landscape level. This will heavily rely on the tools and techniques used in the AfSIS project to map soil properties over larger areas, using statistical technique to relate the spectral signature of soil samples to the spectral information from satellite imagery to infer information on soil characteristics for larger areas. Though there is earlier work done, there no work completed or work in progress that we can report on for the moment.

Output 1. Processes and principles
Output Target 2011: Tools and methods developed for rapid appraisal of agricultural production landscapes especially with respect to socio-economic drivers for land and soil degradation and socio-economic constraints for improving soil productivity and soil health; mapping of the socio-cultural and policy environment (production potential, social & human, economic, natural capital)

Like the tools for the appraisal of soil health status at landscape level, we also need to develop tools for the appraisal of socio-economic characteristics of the production landscapes. To some extent this work will include validation of approaches adopted by others in identification of development domains and work done by HArvestChoice for example. No completed work or work in progress to report on.

III.2. OUTPUT 2 - ECONOMICALLY VIABLE AND ENVIRONMENTALLY SOUND SOIL MANAGEMENT PRACTICES DEVELOPED AND TESTED, WITH EMPHASIS ON DIRECT AND INDIRECT MANAGEMENT OF SOIL BIOLOGICAL RESOURCES FOR LOW- AND MEDIUM EXTERNAL INPUT AGRICULTURAL SYSTEMS.

Outputs (Intended users)	Outcome (Impact)
Description: Economically viable and environmentally sound soil management practices developed and tested, with emphasis on direct and indirect management of soil biological resources for low- and medium external input agricultural systems. Intended users: CGIAR, ARI, researchers from NARS and local universities, NGOs, farmer groups, private sector agents, extension services, and regional consortia, conservation agencies	Outcome: Technologies and soil management strategies available for range of agro-ecological and socio-economic conditions provides viable options for various stakeholder groups and increases adoption of improved technologies Impact: Increased sustainability of productions systems and improved security of farmers in target impact areas.

Soil health management practices; landscape management

Intensification pathways for low input agriculture will have to target investment in maintaining and improving the natural resource base, i.e. aim to restore ecological functioning especially where intensification of farming practices is to be achieved without increasing the need for external inputs. To this end options for direct and indirect management of below-ground biodiversity will be investigated and evaluated. This will refer to the crop diversification strategies, improved organic matter management, reduced tillage operations and inoculation with beneficial soil organisms in various forms. Sustainable land management practices (or ISFM technologies for that matter) generally target field operations and therefore adaptation of the technologies that takes account of the resource allocation on farm and the consequently possible soil fertility gradients within farm is often considered as necessary step for the adoption of the technologies. However this may be true, large scale adoption will remain problematic because of other constraints to the investment in sustainable land management (*viz* lack of resources or security in various forms). Therefore, other options and strategies need to be considered and these will have to include the allocation of resources at the landscape level. Attention will be devoted to optimal allocation of resources that are available on farm and within the landscape. Tools and techniques for evaluation of ecosystem services from output 1 will result in improved appreciation of critical elements or components within the land use system and the landscape and soil conservation including below-ground biodiversity.

Major research questions are:

→ *What is the soil biological quality of soils under alternative land use systems like conservation agriculture and organic farming and does it differ from traditional agricultural practices?*

→ *What is the effect of indirect management practices, and especially improved soil organic matter management practices on BGBD and how does this effect soil health?*

→ *What is the short term and longer term effect of direct inoculation of various beneficial organisms on BGBD and food web structure ad herewith with the provision of ecosystem services (stability of the food webs)?*

→ *What are the options for improving resource allocation in the various agricultural production landscapes?*

→ *How can land and soil resources be better protected or conserved by improving resource allocation within production landscapes and what are the tools and techniques to model and predict the effects on resource allocation at landscape level?*

Output 2. Economically viable and environmentally sound soil management practices
Output Target 2008: Communities in at least three countries demonstrate and test direct or indirect management options that enhance locally important ecosystem services using BGBD.

NO COMPLETED WORK

WORK IN PROGRESS

In 10 of the 11 benchmark sites of the CSM-BGBD project in the 7 tropical countries where the CSM-BGBD project is implemented, experiments and demonstrations have been conducted in 2008. These demonstrations and experiments, related to the sustainable management of soil biodiversity, are conducted with the participation of farmers. The farmer participation may relate to active involvement in management of the experiment or in the participatory monitoring and evaluation. The experiments address direct management options like inoculation with rhizobia and mycorrhiza as well as to indirect management options like soil organic matter amendments, improved composting etc., with the aim to improve nutrient availability (and nutrient cycling), improving soil structure and water availability, control of soil born pest and diseases, improving soil biodiversity and biological activity and carbon sequestration. The experiments will be finished in 2009 and reports on the experiments and demonstration are also expected to be issued then.
There is a strong link with experiments that are conducted under the auspices of the ISFM outcome line and we hope we will be able to synthesis results from these experiments across both outcome lines.
Please see the section on 'Direct and indirect options to manage BGBD that enhance locally important ecosystem services demonstrated' below for a listing of all the experiments and demonstrations that are being conducted

Output 2. Economically viable and environmentally sound soil management practices
Output Target 2009: Local baselines and interviews show that farmers' understanding of soil biological processes and soil health status is demonstrably enhanced in at least 5 benchmark sites

WORK IN PROGRESS

This work was intended to be carried out in the BGBD project. To some extent this work is deferred, in the sense that systematic baselines were not established in each of the benchmark as far as farmers' perceptions are concerned and it will as such also not be possible to establish quantitatively whether the presence of the BGBD had any effect on the perceptions and attitude of farmers towards more biological farming practices. However there will be stakeholder meetings organized in each of the benchmark sites in the closing year of the BGBD project that will provide insight in the understanding of farmers on soil health.

Output 2. Economically viable and environmentally sound soil management practices
Output target 2009: Direct and indirect options to manage BGBD that enhance locally important ecosystem services demonstrated

WORK IN PROGRESS

In the BGBD project experiments with and demonstrations on direct and indirect management options for the conservation of soil biodiversity are carried out in each of the benchmark areas of the project. Most of these experiments will be concluded in 2009, but some of these will extend beyond the project end date. In any case, in 2009 the project will report on each of these experiments and demonstrations. It carries too far for this report to describe the individual experiments and the intermediate results obtained so far. Below is just a listing by title of each of the experiments and demonstrations. More details can be found in the annual report of the BGBD project 2008.

Evaluation of economic yields and contributions to soil fertility from nine traditional legume crops (Cajanas cajan, Vigna mungo, Vigna unguiculata, Vigna angularis, Macrotyloma uniflorum, Glycine max, Glycine sps, lentil, pea),
Nanda Devi Biosphere Reserve, Himalaya, India

Evaluating the impact of manure quality and life saving irrigation on paddy and wheat
Nanda Devi Biosphere Reserve, Himalaya, India

Evaluating the traditional agroforestry tree management on soil biota, within the context of agricultural productivity

Nanda Devi Biosphere Reserve, Himalaya, India

Evaluating the potential of indigenous Perionyx sps and exotic Eisenia foetida for vermicomposting
Nanda Devi Biosphere Reserve, Himalaya, India

Evaluating the effect of traditional forest tree lopping and litter removal practices on soil biota
Nanda Devi Biosphere Reserve, Himalaya, India

Evaluating the effect of land redevelopment/rehabilitation treatments on soil biota
Nanda Devi Biosphere Reserve, Himalaya, India

Assessment of ecological impacts of legume cover crops viz., Arachis pintoi, Calapogonium muconoides and Sesbania aculeata in coconut plantation system
Nilgiri Biosphere Reserve, Kerala, India

Comparison of Calicopteris floribunda, Eupatorium odoraturm, Ficus asperima, Glycosmis pentaphylla, Helictres isora, Macaranga peltata and Terminalia sps as mulch species in coconut plantation system
Nilgiri Biosphere Reserve, Kerala, India

Evaluating the contribution of beneficial microbes and earthworms in paddy agroecosystems
Nilgiri Biosphere Reserve, Kerala, India

Evaluating the effect of microbial consortia on Chilli crop system
Nilgiri Biosphere Reserve, Karnataka, India

Comparing traditional farmyard manure and vermicompost on cowpea/green gram/soybean system
Nilgiri Biosphere Reserve, Karnataka, India

Linking above-ground and below-ground diversity: Formation of Soil Biopore by Earthworm with Various Quality of Litter Input
Kurniatun Hairiah*, Widianto, Fitri Kusyu Aini, and Nur Hasanah, Indonesia

ABGD-BGBD relationships: Implementation of Various Cropping Patterns and Plant Species Diversity for Maintaining or Enhancing BGBD (Demo-plot)
Agus Karyanto, Rusdi Evizal, and Sugiatno, Indonesia

Linking aboveground and belowground diversity: The role of coffee shading tree on LNB diversity, N balance, and productivity
Irfan D. Prijambada, Donny Widianto, Jaka Widada, Indonesia

Application of fertilizer and litter of various qualities to control parasitic nematodes in the coffee plants in sumberjaya, lampung
I Gede Swibawa, Indonesia

Demonstration of several techniques to control the white-root disease in the rubber ecosystem in penumangan baru area, lampung
Joko Prasetyo, Aron Situmorang, Titik Nur Aeny, Radix Suhadjo, Indonesia

Soil Ecosystem Engineers: its impact on soil structure and water infiltration; Role of Pontoscolex corethrurus and Mucura pruriens cover crop in enhanced productivity of maize, a greenhouse experiment.
E. Alarcon-Gutiérrez , F. Martínez Velasco, O. Palma Arriola, G. Torres Jiménez, Y. Landa Guerrero, J. A. García, M. de los Santos, I. Barois, Mexico

Experimental lily (Lilium longiflorum Thunb.); Plots in soil biodiversity management in Benigno Mendoza, Los Tuxtlas, Mexico
C. Guadarrama, I. Barois, D. Trejo, M. de los Santos, F. Franco, P. Rodríguez, L. Varela, E. Martínez, J.A. García, Mexico

Use of Velvet bean (Mucuna pruriens var. Utilis) to preserve BGBD and increase maize production in summer and winter cycles, Los Tuxtlas, México
A. I. Ortíz-Ceballos, I. Barois, F. Franco, J.A. García, M. de los Santos, E. Alarcón-Gutiérrez, D. Trejo, P. Rodríguez, L. Varela, E. Martínez, Mexico (with the collaboration of Hemenegilda Mateo, Arnulfo Mateo and Santo Franco, maize farmers at San Pedro Soteapan community)

Management of Chamaedorea hooperiana in two communities from Biosphere Reserve of the Los Tuxtlas, Veracruz, México
J.A. García-Pérez, M. de Los Santos-Bailón, Carlos Miranda-Teva, Isabelle Barois, Adolfo López Mateos and San Fernando's farmers, Los Tuxtlas, Mexico

Growth of palm Chamaedorea hooperiana (Hodel) in primary and secondary rain forest and their effect on soil Biodiversity Los Tuxtlas, Veracruz México
J.A. García-Pérez, M. de Los Santos-Bailón, Carlos Miranda-Teva, Isabelle Barois, Adolfo López Mateos and San Fernando's farmers, Los Tuxtlas, Mexico

Growth and activity of savanna earthworms Millsonia omodeoi (Acanthodrilidae) and Hyperiodrilus africanus (Eudrilidae) in two types of soil (savanna and forest) under laboratories conditions
Jérôme Ebagnerin Tondoh, Serge Pacome Kassi, Oumé, Ivory Coast

Farmers' participation, socio-economic evaluation of agricultural production systems et local knowledge in Goulikao (Oumé, Centre-West Côte d'Ivoire)
Jonas Guéhi Ibo, Cyrille Berrah Amani, Ludovic Gohore Bi Gore, Oumé, Ivory Coast

Impact of legume-based cocoa production on soil quality and productivity in Oumé benchmark site (Centre-West, Côte d'Ivoire)
Pascal Téhua Angui, Oumé, Ivory Coast

Sustainable agriculture and conservation of below-ground invertebrates in Oumé benchmark site (Center-West Côte d'Ivoire): the role of herbaceous legumes
Armand Wowo Koné, Romaric Kassi Koua, Oumé, Ivory Coast

Soil biological quality in semi-deciduous forest areas (Oumé, Center-West Côte d'Ivoire)
Jérôme Ebagnerin Tondoh, Arnauth Martinez Guéi, Aurélie Nadège N'Dri, Jean Tia Gonnety, Oumé, Ivory Coast

Laboratory and screen house aburscular mycorrhiza fungi (amf) demonstrations/ experiments,
Uganda

Demonstration of technologies that conserve belowground biodiversity simulateneously increasing agricultural productivity Nutrient acquisition technologies (Legume nodulating bacteria (LNB) and Arbuscular mycorrhizal fungi (AMF)
Uganda

Soil structure modification,
Uganda

Validation of Pest and Disease Control Techniques; Sub-project A: Exploring the potential of local strains of Trichoderma as a biocide against Pythium spp
Gasura, E., Serani, S., Akol, A.M. and Kyeyune, G., Uganda.

Validation of Pest and Disease Control Techniques; Sub-project B: Termite control in maize using mulches as a diversionary tool and Metarhizium anisopliae as a biocide
Akol, A.M. and Alemu, S.O., Uganda

Introduction of a leguminous crop as dual purpose crop in crop rotation or as intercrop to enhance soil biodiversity through increased SOM content, to enhance soil fertility and food production, making effective use of existing LNB strains and AMF
Sidney Sturmer and Fatima Moriera, Benjamin Constant, Brazil

Essays on use of crop residues and green manures for improved soil organic matter management (Vermi-composting)
Sonia Alfaia and Fernanda, Benjamin Constant, Brazil

Integrated pest management of Agroforestry Systems (fruit crops)
Neliton Silva, Alcides Moino and Hiroshi Noda, Benjamin Constant, Brazil

Improved fallow management through enhanced diversity (AGBD-BGBD) –
Fernanda and Sonia Alfaia, Benjamin Constant, Brazil

Effect of Trichoderma on germination of maize and beans
Embu, Kenya

Influence of ISFM on soil Fusarium population
Embu, Kenya.

Nematophagous Fungi- effect of soil fertility on the occurrence and diversity
Kenya

Effect of Bacillus subtilis and fertility treatments on all plant parasitic nematodes
Embu Kenya

Effect of Bacillus subtilis and fertility treatments on Melodoigyne incognita
Embu, Kenya

Effect of Bacillus subtilis and fertility treatments on Pratylenchus spp.
Embu, Kenya

Effect of Bacillus subtilis and fertility treatments on Free-living nematodes
Embu, Kenya

Effect of ISFM Interventions on Maize Yield
Embu, Kenya

Effects of Land use Changes on Diversity of Mites in Soils of Embu and Taita
Embu and Taita, Kenya

Output 2. Economically viable and environmentally sound soil management practices
Output target 2009: Alternative production systems like Conservation Agriculture tested and evaluated for effectiveness in maintaining and restoring soil health and with respect to adoptability

For reports on the work done in relation to Conservation Agriculture as well as Organic farming, please refer to the annual report of the ISFM outcome line.

WORK IN PROGRESS

Does conservation agriculture mitigate the negative effects of climatic change on crop production: a modelling analysis for a case study in Zimbabwe

M. Corbeels[1], C. Thierfelder[2], R.J. Delve[1] and C.H. Porter[3]

[1]TSBF - CIAT, Zimbabwe; [2]CIMMYT, Zimbabwe; [3]University of Florida, USA;

Introduction

Conservation agriculture (CA) is seen as a new paradigm to conventional agriculture that uses soil tillage. Three practices underpin CA: (1) minimizing soil disturbance by reduced or zero-tillage; (2) retaining residues on the soil surface and (3) using crop rotations. There is a consensus among climate specialists that Southern African regions will become dryer with more irregular rainfall over by the end of the 21st century. In the global context, maize in Southern Africa is seen as one of the most important crops in need of adaptation investment. Can CA mitigate these negative effects of climate change on crop production? It is known that the water conserving effect of CA practices can stabilize crop yields under drought conditions, but the same effect exacerbates poor drainage. We developed a simulation modelling approach to better understand the potential role of CA under changing rainfall patterns. We present in this paper the results for a case study in Zimbabwe.

Material and methods

The crop growth model DSSAT-CSM (Jones et al., 2003) was adapted to simulate CA practices, and then calibrated and tested using data from a soil tillage experiment at the Henderson Research Station (17°35' S, 30°38'E, 1136 m.a.s.l.) near Harare in Zimbabwe. The region is characterized by a sub humid subtropical climate with an average annual rainfall of about 880 mm. Rain falls during summer from November until early April. Average annual temperature is about 22°C. The site has a slope of about 5 to 7 % and the soil was classified as a dystric Arenosols. For this study, 2 tillage treatments were considered: (1) the conventional farmer's practice of ploughing the soil to a shallow depth (10 to 15 cm) without retention of crop residues (CT); (2) the no-tillage practice with retention of crop residues (about 2 ton DM/ha) using a direct seeder (CA).

DSSAT-CSM uses daily weather, crop and soil parameters as input to predict growth and yield of a range of crops. Model adaptations included the influence of crop residue cover and tillage on soil surface properties and the soil water balance. With the model we assumed that the following four soil properties vary with tillage: 1) bulk density, 2) saturated hydraulic conductivity, 3) the 'Soil Conservation Service' runoff curve number and 4) soil water content at saturation. The soil properties after a tillage event are input and they change back to a settled value, following an exponential curve that is a function of cumulative kinetic energy since the last tillage operation (Andales et al, 2000). A mulch of crop residues affects three soil water-related processes in the model: 1) rainfall interception by the mulch, 2) reduction of soil evaporation rates, and 3) reduction of surface water runoff.

We ran the model to simulate maize production for water-limited conditions under the present climate using 45 years of daily climatic data (baseline scenario, BS) from Harare and under three plausible future rainfall scenarios for the region (Lobell et al., 2008). These were: (1) a 15% decrease in annual rainfall, RS; (2) a 15% increase in the duration of dry spells, DS; and (3) the combination of scenarios 1 and 2, RDS. Each scenario also comprised a temperature increase of 1.1°C. The scenarios were constructed using the stochastic weather generator LARS-WG (Semenov and Barrow, 1997)

Preliminary results

Using DSSAT-CSM we predicted water-limited maize grain yield for the Henderson site under the 4 weather scenarios (including the baseline climate) and for the 2 tillage treatments (CT and CA). Planting date was during the last week of October. For the baseline scenario (BS) simulated maize grain yield was on average about 720 kg/ha higher under CA then under CT (**Table 3**). This was mainly due to increased water availability as a result of decreased runoff under CA compared to CT. Predicted yields varied broadly, from a minimum of 1003 kg/ha to a maximum of 6483 kg/ha depending on seasonal rainfall amount and distribution. As expected average grain yields for both tillage practices were lower for future climate scenarios **(Table 3)**. The simulation results indicate that the impact of a 15% increase in the duration of seasonal dry spells (DS scenario) is at least as large as that of a 15% decrease in annual rainfall (RS scenario). Under the RDS scenario of decreased rainfall with longer dry spells model predictions suggest a decrease in maize grain yields of about 25 to 30%, which is in agreement with the value (30%) projected for Southern Africa in a broad-scale analysis by Lobell et al (2008). The cumulative distribution functions of simulated maize grain yield for the BS and RDS climate scenarios under CT and CA are presented in **(Figure 11)**. Under the current climate the probability of producing at least 3000 kg/ha grains is 41 and 67 % for respectively CT and CA. Under future climate, due to water stress the probability drops to respectively 15 and 43%. The results indicate that the negative impact of climate change can be mitigated by adopting CA in the 'normal' years, but with a higher risk of lower yields in the 'good' and 'bad' years.

Table 3: Effect of climate change on maize yield (kg/ha) as simulated by DSSAT-CSM under conventional tillage and CA for the Henderson site nearby Harare, Zimbabwe. Variation coefficient in parenthesis

	BS	RS	DS	RDS
CT	3107 (0.39)	2607 (0.35)	2577 (0.41)	2254 (0.43)°
CA	3830 (0.35)	3166 (0.34)	3328 (0.37)	2832 (0.40)

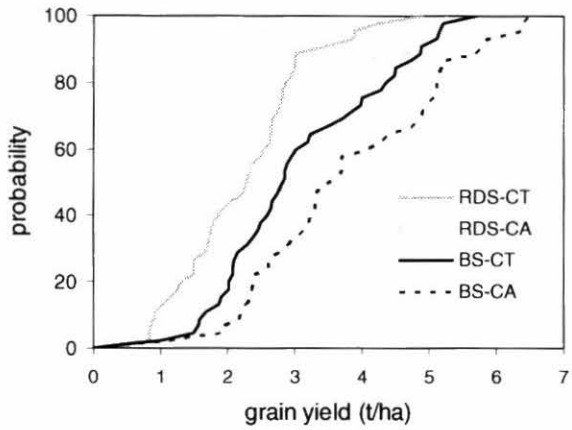


Figure 11: Cumulative probability functions of maize grain yield as simulated by DSSAT-CSM for the BS and RDS climate scenarios under CT and CA practices.

Preliminary conclusions

The simulation results show that climate change will have a major impact on maize productivity in the study region. CA practices have a potential to reduce climatic risk for farmers in southern Africa. However, the question remains how these practices fit in their farming systems. Crop residue mulching profoundly alters the flow of resources at the farm, and there are trade-offs in the use of crop residues at farm level. Crop residues, and in particular cereal stover, is a highly-valued fodder for livestock in smallholder farming systems in Africa.

Output 2. Economically viable and environmentally sound soil management practices	
Output Targets 2010:	Alternative crops and integrated systems investigated for their effectiveness in maintaining soils resource base
	The role of soil organic matter in regulating BGBD and soil health tested across a number of experimental sites in at least 5 countries in the tropics
	Species/strains identified with potential for inoculants development; Direct inoculation in various cropping systems and for various purposes (enhancing productivity, control of soil borne pest and diseases and improving soil structure) tested on persistence, affectivity and competitiveness

Much of the output targets for 2010 relate to work on the direct and indirect options to manage BGBD that enhance locally important ecosystem services that have been reported above. In some of BGBD work we are actually looking at effectiveness of certain strains (of nitrogen fixing bacteria or VAM) sourced from the benchmark areas where the BGBD inventory has been done. The results of this are not expected until 2010.

Furthermore, TSBF is testing commercial inoculum products of various kinds (TRichoderma, ntorigen fixers, etc.). Results of these tests are also not expected until 2010.

Output 2. Economically viable and environmentally sound soil management practices	
Output Targets 2011:	Tools for modeling resource allocation within agricultural productions landscapes and optimization of resource reallocation suggested for selected agricultural production landscapes.
	Improved production systems (including technologies) and having multiple benefits of food security, income, human health and environmental services documented and characterized in terms of application domains

NO COMPLETED WORK

NO WORK IN PROGRESS

III.3. Output 3 - Socio-economic and cultural drivers for land degradation identified and constraints mapped; Options for sustainable land management and reversal of soil degradation for social profitability developed and intervention domains identified

Outputs (Intended users)	Outcome (Impact)
Description: Socio-economic and cultural drivers for land degradation identified and constraints mapped; Options for sustainable land management and reversal of soil degradation for social profitability developed and application domains identified. Intended users: intended users: CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, policy makers	Outcome & Impact: Improved diagnosis of soil health problems informs identification of entry points and targeting of soil and land management interventions.

Intervention domains and enabling environment

ISFM and INRM technologies have been widely researched, but adoption has been generally poor. This is especially true for INRM technologies that require relatively high investments that do not give immediate returns. This requires critical evaluation of the constraints that hinder the adoption of these technologies and management options and careful mapping of the application domains. This relates not only the farmer's context, but also to the wider socio-economic context and policy environment as well as the bio-physical environment. The enabling environment relates to the converse of the drivers and pressures that result in land degradation. Functioning markets and adequate market access will play an important role as well as market prices for agricultural inputs and outputs. However, there may other structural constraints that are equally important in the adoption of alternative land and soil management options, like access to land (size of the land holdings) and other resources as well as poverty and "wealth" distribution. These drivers will be investigated for each of the applications sites and ex-ante analyses will be carried out for each of the considered technology options and interventions and possible impacts will be determined. Also, reward mechanisms for investment in sustainable land management will be investigated. This activity will define and describe the application domains of ISFM and INRM technologies and systems within the landscape context and will contribute to the improved targeting of management interventions and policy recommendations.

Major research questions are:

→ What are the proximate and root causes of the various forms of land and soil degradation?

→ Can we by a structured description of cases and by comparative analyses of these cases determine the relative importance of these causes for land degradation and can we construct a model based on that?

→ What do we consider to be an enabling environment and what tools are available to diagnose this environment?

→ How do we describe rural poverty and how is this linked to land degradation?

→ How does access to input and output markets effect land management and who will benefit from increased market access?

Output 3. Socio-economic and cultural drivers	
Output Targets 2009	Methods, protocols and indicators developed to characterize socio-cultural and economic environment and for valuation of soil ecosystem services
	Socio-economic constraints to soil health management assessed in some agricultural productions landscapes and forest margins of the BGBD project; diagnostic carried out
	Methods developed for socio-cultural and economic (participatory) evaluation of ecosystem goods and services developed and implemented in BGBD project sites

COMPLETED WORK

Scientific evaluation of smallholder land use knowledge in Central Kenya. *(2008) Land Degradation & Development 19: 77–90*

Mairura[1] F.S., Mugendi[2], D.N., Mwanje[2] J.I., Ramisch[1] J.J., Mbugua[3] P.K., and Chianu[1] J.N.

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Abstract: The following study was conducted to determine smallholders' land use management practices and agricultural indicators of soil quality within farmers' fields in Chuka and Gachoka divisions in Kenya's Central Highlands. Data on cropping practices and soil indicators were collected from farmers through face-to-face interviews and field examinations. Farmers characterized their fields into high and low fertility plots, after which soils were geo-referenced and sampled at surface depth (0–20 cm) for subsequent physical and chemical analyses. Farmers' indicators for distinguishing productive and non-productive fields included crop yield, crop performance and weed species. Soils that were characterized as fertile had significantly higher chemical characteristics than the fields that were of poor quality. Fertile soils had significantly higher pH, total organic carbon, exchangeable cations and available nitrogen. Factor analysis identified four main factors that explained 76 percent of the total variation in soil quality. The factors were connected with farmers' soil assessment indicators and main soil processes that influenced soil quality in Central Kenya. Soil fertility and crop management practices that were investigated indicated that farmers understood and consequently utilized spatial heterogeneity and temporal variability in soil quality status within their farms to maintain and enhance agricultural productivity.

The Dynamics of Social Capital in Influencing Use of Soil Management Options in the Chinyanja Triangle of Southern Africa. *(2008) Ecology and Society 13: 1-9*

Njuki[1], J., Mapila[2], M., Zingore[1], S., and Delve[3], R.J.
[1]TSBF- CIAT, Malawi; [2]University of Pretoria, South Africa; [3]TSBF- CIAT, Zimbabwe

Abstract: Social capital has become a critical issue in agricultural development as it plays an important role in collective action, such as, management of common resources and collective marketing. Whilst literature exists on the role of social capital in the use and adoption of improved agricultural technology, such literature is fraught with issues of the measurement of social capital beyond membership of farmers in groups. We hypothesized that different types of social capital influence the adoption of soil management options differently. This study looked at the measurement of social capital, differentiating between the main types of social capital and employed factor analysis to aggregate indicators of social capital into bonding, bridging, and linking social capital. Using logit analysis, the role of these types of capitals on influencing use of different soil management options was analyzed. The study found that bonding, bridging, and linking social capital all influence the adoption and use of different soil management options differently, a trend that might be similar for other agricultural technologies as well. The study recommends more research investments in understanding the differentiated outcomes of these forms of social capital on use and adoption of technologies to further guide agricultural interventions.

Gender equity and social capital in smallholder farmer groups in central Mozambique. *(2008) Routledge Informa Ltd 18: 4, 650-657*

Gotschi[1], E., Njuki[2], J.M., and Delve[2], R.
[1]UNDP, Nicaragua; [2]TSBF- CIAT, Kenya

Abstract: This case study from Bu´zi district, Mozambique investigated whether gender equality, in terms of male and female participation in groups, leads to gender equity in sharing of benefits from the social capital created through the group. Exploring the complex connection between gender, groups, and social capital, we found that gender equity is not necessarily achieved by guaranteeing men and women equal rights through established by-laws, or dealing with groups as a collective entity. While there were no significant differences in the investment patterns of men and women in terms of participation in group activities and contribution of communal work, access to leadership positions and benefits from social capital were unequally distributed. Compared with men, women further found it difficult to transform social relations into improved access to information, access to markets, or help in case of need.

Gender Differences in Labor Allocation in West Africa: A Case Study of the Savannas of Northern Nigeria. *(2008) Humanity & Social Sciences Journal 2: 93 – 103*

Chianu[1], J.N., and Tsujii[2], H.
[1]TSBF- CIAT, Kenya; [2]Ishikwa Prefectural University, Japan

Abstract: Boserup's influential book 'Women's Role in Economic Development' generated debate on gender and development in Africa. Based on a survey of 322 households in northern Nigeria, this paper evaluates gender differences in labor allocation to eight enterprises (crop production, livestock production, processing, fuel wood activities, food gathering, trading, non-farm activities and salaried job) using weighted arithmetic mean. Results indicate that labor allocation to crop production and processing followed sex lines: men allocated most of their labor to crop production (71% by male children, 81% adult males). Women allocated most of their labor to processing (36% female children, 57% adult females). The high concentration of men's labor on crop production is strong evidence that men, not women alone (as earlier suggested) play important role in agricultural production. The study concluded with research and policy implications of the observed labor allocation patterns.

An integrated evaluation of strategies for enhancing productivity and profitability of resource-constrained smallholder farms in Zimbabwe, in press.

Zingore[1], S., González-Estrada[2], E., Delve[3], R.J., Herrero[4], M., Dimes[5], J.P., and Giller[6], K.E.
[1]TSBF- CIAT, Malawi; [2]Heifer-International, USA; [3]TSBF- CIAT, Zimbabwe; [4]ILRI, Kenya; [5]ICRISAT, Zimbabwe; [6]Wageningen University, the Netherlands

In African smallholder agriculture, improved farm scale understanding of the interaction between the household, crops, soils and livestock is required to develop appropriate strategies for improving productivity. A combination of models was used to analyze land-use and labour allocation strategies for optimizing income for wealthy (2.5 ha with 8 cattle) and poor (0.9 ha without cattle) farms in Murewa, Zimbabwe. Trade-offs between profitability, labour use and partial nutrient balances were also evaluated for alternative resource management strategies. Farm data were captured using the Integrated Modelling Platform for Mixed Animal-Crop Systems (IMPACT), which was directly linked to the Household Resource-use Optimization Model (HROM). HROM was applied to optimize net cash income within the constraints specific to the households. Effects of alternative nutrient resource management strategies in crop and milk production were simulated using the Agricultural Production Systems Simulator (APSIM) and RUMINANT models, respectively, and the output evaluated using HROM. The poor farm had a net income of US$ 1 yr^{-1} and the farmer relied on selling unskilled labour to supplement her income. The poor farm's income was marginally increased by US$18 yr^{-1} and the soil nitrogen (N) balance was increased from 6 to 9 kg ha^{-1} yr^{-1} by expanding groundnut production from the previous 5% to 25% of the land area. Further increases in area allocated to groundnut production were constrained by lack of labour. On the poor farm, maize production was

most profitable when cultivated on a reduced land area with optimal weeding. The wealthy farm had a maize-dominated cropping system that yielded a net cash balance of US$290 per annum, mainly from the sale of crop produce. Net income could be increased to US$1,175 yr^{-1}, by re-allocating the 240 hired labour-days more efficiently, although this reallocation substantially reduced partial soil N and phosphorus (P) balances by 74 kg N ha^{-1} and 11 kg P ha^{-1}, respectively, resulting in negative nutrient balances. Limited opportunities existed to increase productivity and income of the
Small holder farms without inducing negative nutrient balances. On the wealthy farm, groundnut was the least profitable crop; shifting its production to the most fertile field did not improve income, unless the groundnut residues were fed to lactating cows. The analysis carried out in this paper highlights the need to develop practical technological recommendations and developmental interventions that consider farm resource endowment (land, fertilizers, manure and labour), variability in soil fertility within farms and competing resource use options.

Livelihoods and rural wealth distribution among farm households in western Kenya: Implications for rural development, poverty alleviation interventions and peace. *(2008) African Journal of Agricultural Research 7: 455–464*

Justina[1] N.C., Ajani, O.I.Y[2]., and Chianu, Jonas N[1]
[1]TSBF– CIAT, Kenya; [2]University of Ibadan, Nigeria

Abstract: The study examined livelihoods and wealth distribution among farm households in western Kenya. Stratified random sampling was used to select 252 households from eight districts. Focus group discussions were used to collect complementary community-level data. Results indicate that average household size was seven persons. The cropping system was over 70% mixed. Agriculture was the main source of livelihoods. Labour was mainly allocated to crop enterprises, with household heads allocating > 50% of their labour to it. Maize (*Zea mays*) and common beans (*Phaseolus vulgaris*) were the most important staple/traded food crops. Poultry, followed by cattle dominated livestock enterprises. Few households diversified into small businesses, employment and artisan to enhance livelihoods. Despite this, 5–95% of people remained food insecure. Lack of cash and limited land access were the most important factors constraining agricultural development. Although, most households preferred selling produce in markets where prices were better, many not only sold produce but purchased inputs from nearest towns due to high costs of accessing better price markets. Wealth inequality among households was very high, with household wealth Gini-coefficient of 0.52 and per capita wealth Gini-coefficient of 0.55, calling for better interventions targeting to reach most vulnerable/marginal groups and create all-inclusive opportunities.

WORK IN PROGRESS

In the BGBD project we aim to do comparative analyses of the benchmark sites, in terms of socio-economic characteristics and in terms of the biophysical environment. We hope this will provide the relevant contextual information to look at land degradation and in this case

with particular emphasis on the biological component of land degradation. Work on the rural diagnostics will also be carried out in the AfSIS project and will build on the work done in the BGBD project.
Further a lot of work has been done in CIAT on participatory approached. In so far this is done in the context of ISFM this is reported in the annual report of the ISFM outcome line. We hope to draw on this experience to generate the output targets for 2009 that we consider to be very much a synthesis of the work done on enabling environment.

Environmental and Socio-economical comparison of benchmark areas of the CSM-BGBD project

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Introduction

The CSM-BGBD project is implemented in agro-ecological regions of global significance. This study aims to contrast the sites where the CSM-BGBD project operates in terms of ecological and environmental characteristics as well as in terms of socio-economic characteristics, including land use and agronomic characteristics. It will as such provide the context for the interpretation of difference we find in terms of BGBD as well as the context in which approaches and options for conservation of BGBD needs to be evaluated. I will help in determining the relevance of the findings of the project in assessing whether we find common trends in the loss of BGBD across agro-ecologies and social and economic environments.

Materials and Methods

It will require an analytical framework that is currently under discussion.
The analytical framework identifies the various indicators to be used to describe the bio-physical and socio-economic environment as well as land use and common agronomic practices. The biophysical attributes include the slope and relief intensity that are relevant attributes in assessing a range of characteristics like soil erosion, land suitability for cultivations etc. Rainfall and temperature will be used to describe climatic conditions and pH and soil organic carbon will be used as indicator of soil degradation. Socio-economic attributes include the size of the farm holdings, poverty levels and the farming systems. Lastly the agronomic attribute will include the crops grown, the fertilizer rates and general agronomic management.
This work is considered to be part of the synthesis reporting. Data and information for this study will be obtained from the papers and reports issued by the CPC on the inventory of BGBD and characterization of each of the benchmark areas, and additional data sources.

Expected results

Results will be presented in graphs (scatter plots, bar charts etc.) that will allow for easy assessment of the differences between benchmark areas in terms of the biophysical environment and socio-economic environment. We will also combine bio-physical and soieconomic characteristic in order to see whether there are logical grouping of the benchmark areas in both these terms. We know that the benchmark areas are often located in marginal areas. We see marked differences in terms of whether rural communities depend on agriculture for their livelihoods and in the importance of conservation measures and environmental concerns.

Determinants of Fertilizer Use in Southern Africa: The Role of Social and Human Capital, and Farmer Perceptions

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Fertilizer use in Southern Africa is some of the lowest in the world. The levels of use are far below that required to replace nutrients extracted or lost during crop production, the resulting effects on continued low yields, loss of organic mater and general soil health decline are well documented. Farm surveys in Malawi, Zambia and Mozambique show increased numbers of smallholder farmers using fertilizers between the 2005/6 and 2006/7 seasons. Although the intensity of use per ha did not significantly change between seasons. There are significant variations in fertilizer use, with Zambia having the highest amount of fertilizer used per unit of land in both seasons. Factor Analysis showed that fertilizer use was influenced by household and farm characteristics. More importantly it was also influenced by levels of social and human capital and farmers' perceptions of the effects of fertilizers on soil fertility. Farmers who perceived fertilizers as bad for their soil were less likely to adopt their use. This is a key result as the emerging discussion on a green revolution for Africa, as well as, the continued food crisis discussion is prompting increased fertilizer use as an immediate intervention for increasing nutrient inputs into developing world agriculture. Our results show that increased efforts need to be placed not only in increasing access to fertilizers but also on evolving farmer's perceptions and attitudes towards fertilizer use.

Assessment of factors affecting the use and management of organic resources for soil fertility management: Case of Meru South District, Kenya

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[1]University of Nairobi, Kenya; [2]TSBF-CIAT, Kenya

Introduction

The improvement of agricultural productivity is vital to achieving the Millennium Development Goals (Kimaru and Jama 2006). Kenya's economy relies on agricultural sector for export earnings and employment generation (Ministry of agriculture 2006). The sector provides employment to 70% of the Kenyan labor force, generates 60% of the foreign exchange, provides 75% of raw materials for industry, and provides 45% of total revenue (Central Bureau of Statistics 2005). The challenge lies with improving factor (labor, land, etc.) productivity in Kenyan agriculture, which has not reached optimal level (Nyangito and Odhiambo 2003, Ministry of Agriculture, 2006). Many factors are contributing to this, including soil fertility decline, poor infrastructure, inefficient marketing system, insecure land tenure, and unpredictable and erratic rainfall (Jayne and Nyoro, 2000). This means that year round household food security will increasingly depend on maximizing productivity and incomes from limited available land (Strasberg *et al.*, 1999). It is a key challenge to identify technologies that meet both agricultural productivity and sustainability goals. Presently, most smallholder farmers continuously plough small parcels of land with sub-optimal or without application of fertility replenishing inputs (Jayne *et al.*, 2005; Jayne and Nyoro 2000; Ministry of Agriculture 2004), leading to cycles of the mining of essential soil nutrients, with minimal replacement. A study on soil nutrient balance in Kenya indicates that nitrogen outputs exceeded inputs by 25 $kg^{-1}ha^{-1}yr^{-1}$, representing an annual depletion of 0.4 – 0.5% across farming systems (Jager *et al.*, 2001). Phosphorus depletion from the soils in Kenya has also been estimated at 3 kg^{-1} ha^{-1} yr^{-1} **(Table 4)**. The negative trend in fertility is aggravated by declining fallow periods due to population pressure, soil erosion, deforestation, and crop production on steep slopes with limited investments erosion control measures such as terraces. Poverty and other socioeconomic factors also constrain effective soil conservation practices (Ministry of Agriculture, 2004).

Table 4: Farm Level Soil Nutrient Balances in Kenya, 1996 (kg/ha/year)

Soil nutrient	Kisii district	Kakamega district	Embu district	All districts
Nitrogen (N)	**-112.0**	**-72.0**	**-55.0**	**-71.0**
Phosphorus (P)	**-2.5**	**-4.0**	**9.0**	**3.0**
Potassium (P)	**-70.0**	**18.0**	**-15.0**	**-9.0**

Source: Jager *et al.*, 2001, Smaling *et al.*, 1997

Organic resources which largely comprise of animal manures, green manures, crop residues and agro forestry and leguminous pruning play a pivotal role in improving and maintaining soil fertility across farming system in Africa (Kipsat 2001, Snapp *et al.*, 1998; Mucheru 2003; Lekasi *et al.*, 1998; Palm *et al.*, 2001). The key benefit is that they are reusable allowing farmers to rely upon them both in the short and the long term (Omare and Woomer 2002; Lekasi 2003). The strong correlation between agricultural productivity and soil fertility underlines the importance of utilizing organic inputs at the farm level. Research in Integrated Soil Fertility Management has promoted the concept of organic resources as complementary inputs in soil nutrient technologies across varying farming systems in the tropics. Positive results from farm trials using agroforestry pruning's in soil fertility technologies in Kenya have proven to be profitable, and farmers have the obligation of integrating them into their natural resource system (Jama et al., 2000, Kipsat 2001, Mucheru 2003, Macharia *et al.*, 2006). This study focuses on locally available organic resources and investigates their use in soil fertility management. The study also evaluates the factors that affect the use and management of organic resources by farm households. Related transactions are also being assessed, especially given that farmers in the study area have been noted to buy excess livestock manure, compost and crop residue from the other communities and vegetable vendors (Vanlauwe *et al.*, 2002). The specific objectives are: (i) to examine socio-economic factors influencing the use and management of organic resources; (ii) to investigate the institutional factors influencing the farm allocation of organic resources to varying uses; and (iii) to assess the effect of household and farmland variations on the organic resource practices and applications.

Materials and methods

Research Design

The research design will treat the farm household which is the decision making unit as the unit of analysis. Three groups of smallholder farmers will be considered: those that have adopted organic resources-based soil fertility management technologies for at least 2 years with minimal or no inorganic inputs (organic input group), a group that applies adequate quantities of inorganic inputs (inorganic group), and those that have neither adopted the organic technologies nor have the means to afford adequate quantities of inorganic fertilizers.

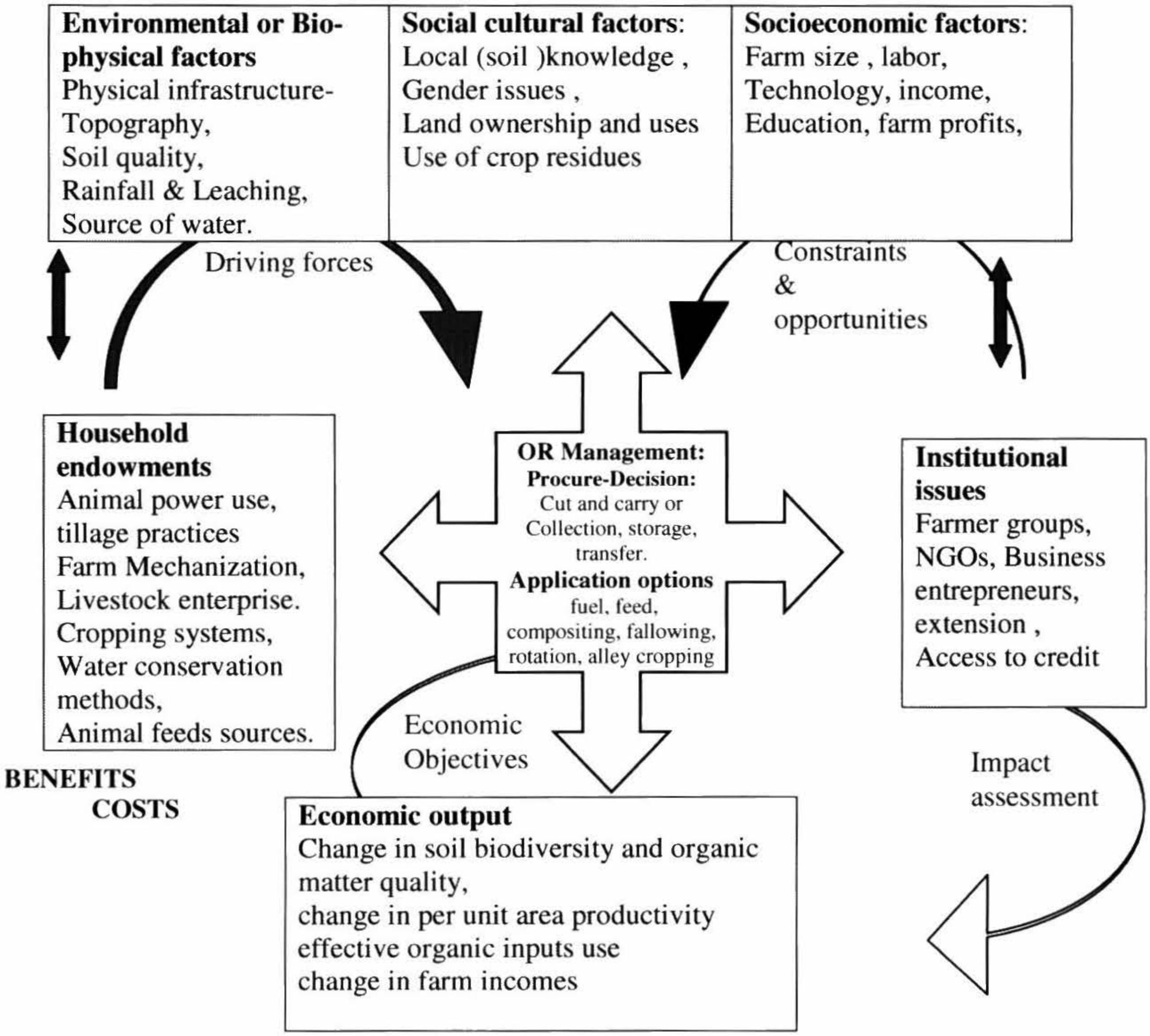
Study Area

This study will be conducted in Chuka division of South Meru district. According to Ministry of Agriculture (2006), Meru South District is an important smallholder agriculture district in Kenya's Eastern Province with a population of 205,451 and covers a total of 1,093 square kilometers. The District is characterized by a complex farming systems dominated by perennial cash crops, food crops and livestock. Tissue culture banana is also gaining popularity in this region (Micheni *et al.* 1999, Ministry of Agriculture (2006). Farm size averages 1.1 hectares for smallholders. Although people are moving to urban areas, absolute numbers of farmers in the rural areas are growing, putting pressure on the natural resources of the district (Mucheru 2003). The district is divided into five administrative divisions: Muthambi, Mugumoni, Mwimbi (Chogoria), Chuka and Igambang'ombe. Chuka division has a population of 53,517 and is in the one of the coffee/dairy/maize Land Use Systems (LUS) with an altitude of approximately 1500 m above sea level, annual mean temperature of 20^0celsius, and annual rainfall varying from 1200 to 1400 mm. The rainfall is bimodal, falling in two seasons. The long rains last from March through June and the short rains from October through December (Micheni *et al.* 1999). Use of mineral fertilizer in the district is limited except in irrigated areas and cash crops, manure use is also low and production per unit area has declined due to continuous ploughing with and sub-optimal use of farm inputs, and increased population (Mucheru 2003). Chuka Division was chosen because of previous research activities aimed at offering small-scale and resource poor farmers with feasible soil nutrient replenishment technologies and has a significant population pressure that has negatively impacted on the resource levels (Mucheru 2003). There is low usage of fertilizer except in contractual farms as tea and coffee farms. The landscape which is mostly hilly makes it susceptible to soil erosion. It has also been the focus of implementation of integrated soil fertility management program and representative of other South Meru divisions with similar kinds of constraints and opportunities. Furthermore, it has been identified on the basis of the institutional build up that has taken place over the past few years in the communities.

Sampling technique

The Sampling frame will be the list of farmers obtained from the chuka divisional Agriculture office. The sample size (n) will be 150 farmers considering gender parity in numbers if possible. The villages will be selected randomly and a separate list will be constructed of male-headed households and female-headed households. Effort will be made to classify the households into rich and poor. An equal number of male-headed households (internally also having equal number of rich and poor households) and female-headed households will be taken. Stratified random sampling will be applied where sample size will divided into disproportional strata according to those who use and do not apply organic inputs.

Data collection
Primary data will be collected through structured questionnaires. Secondary data will be collected from published sources where farmers' organic resources management has been documented. In order to administer the questionnaire effectively, the researcher will be actively involved in data collection.



Output 3. Socio-economic and cultural drivers
Output Target 2010: 30% of partner farmers in pilot sites use SLM options that arrested resource degradation and increased productivity in comparison with non-treated farms

We will look at the impact of the various activities employed especially in Southern Africa (Mozambique, Malawi and Zimbabwe, Zambia) in relation to investigating and promoting Conservation Agriculture in terms of adoption of CA by farmers. Please refer to the annual report of the ISFM outcome line for the progress of the current projects. For the AfSIS project we also aim that farmers will adopt conservation measures, but 2010 will be too soon to evaluate any possible impact in terms of adoption of alternative technologies.

Output 3. Socio-economic and cultural drivers	
Output Targets 2011	Scale-up research on soil fertility gradient to farm and landscape levels by conducting one or two carefully designed, integrated studies in collaboration with other CIAT scientists
	Landscape dynamics assessed, social and economic constraints to improved land and soil management assessed, application domains and options for improved soil and land management identified for the majority of the TSBF project sites

NO COMPLETED WORK

NO WORK IN PROGRESS

III.4. OUTPUT 4 - DECISION SUPPORT TOOLS FOR IMPROVED TARGETING OF RECOMMENDATION FOR SUSTAINABLE LAND MANAGEMENT AND NEGOTIATION SUPPORT; INSTITUTIONAL ENVIRONMENT AND SUPPORT SERVICES REQUIRED FOR SUSTAINABLE LAND MANAGEMENT IDENTIFIED AND POLICY RECOMMENDATIONS.

Outputs (Intended users)	**Outcome (Impact)**
Description: Decision support tools for improved targeting of recommendation for sustainable land management and negotiation support; Institutional environment and support services required for sustainable land management identified and policy recommendations. Intended users: Researchers from NARS, NGOs, Extensions services, policy makers, donor community	Outcome & Impacts: Principles of sustainable land management integrated in local and country policies and programs and investment plans; Strategy documents inform Donor community on possible investment options and ultimately reversed land degradation contributes to global SLM goals

Targeting of management interventions and policy recommendations

Outputs 1, 2 and 3 will provide input for the targeting of interventions. The targeting will build on the diagnoses to determine priority solutions for sustainable land management. The requirements for the successful implementation of recommended management interventions are matched with the locally prevailing conditions to identify a number of alternative solutions to land degradation. This process of matching results in some kind of suitability rating (aptitude) of proposed land uses and management regimes given the local conditions and circumstances. The targeting requires that possible impact of the interventions on the environment and livelihoods of the people are assessed and that trade-offs are analyzed, within the confines of the particular landscape. This output will conduct cases studies within each of the major agro-ecological zones (or impact zones) that will result in recommendations for targeted intervention to improve sustainable land management. Policy interventions are required to put the necessary support functions in place to establish and enabling environment. Insights in the constraints for the adoption of SLM practices by the various stakeholder groups, and policy recommendations will results from considering what actions are required to lift these constraints and to put the support functions in place. Policy recommendations will be elaborated for the selected landscapes within the impact zones for various scale levels or interventions domains, in deliberation with the various stakeholder groups within the area. Analyses of trade-offs will help in the negotiation of the preferred solution.

Output 4. Decision support tools
Output Targets 2008: Methods developed for socio-cultural and economic valuation of ecosystem services developed and applied for trade-off and policy analysis in at least in 1 humid and 1 sub-humid agroecological zones

COMPLETED WORK

Structural change in fertilizer procurement method: assessment of impact in sub-Saharan Africa. *(2008) African Journal of Business Management 3: 065 – 071*

Chianu[1], J. N., Adesina[2], A., Sanginga[3] P., Bationo[1] A., Justina[1] N.C., and Sanginga[1] N.
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Abstract: In June 2006, African Heads of State declared support for increase in quantity of fertilizers used by farmers from about 8 to about 50 kg ha-1. Following realization of the structural weaknesses in African fertilizer industry, regional joint procurement capable of reducing fertilizer farm gate price and increase demand has been noted as a potential route to attain this goal. Structural changes in fertilizer procurement in Africa can reduce farm gate price by 11–18%. This study compares the effect of fertilizer market structural changes on demand and farm income for 11 countries with base situation under three price elasticity of demand scenarios (-0.38, -1.43, and -2.24). Data analysis combined simulation techniques with regional farm enterprise analysis based on ex-ante information to assess the impact on farm income of alternative fertilizer pricing policies. Results showed that structural change in fertilizer procurement (reducing price by 15%) led to 6% additional income (US$ 125 million) under low elasticity (-0.38), 22% (US$ 472 million) under medium elasticity (-1.43), and 34% (US$ 730 million) under high elasticity (-2.24) compared with base. Switching from one scenario to another indicated the potential for 20–32% further increase in farm income. The paper concluded with a recommendation for increased support for structural interventions that reduce farm gate price of inputs because they increase production, productivity, and total income, leading to improved livelihoods.

Output 4. Decision support tools
Output Targets 2008: In at least four of the countries participating in the BGBD project policy stimulated to include matters related to BGBD management and sustainable utilization

COMPLETED WORK

Do forests preserve soil biodiversity

Okoth[1], P., Huising[1], J., Ichami[1], S., and Mung'atu[2], J.

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Poster presented at the SBSTTA 13, 18 - 22 February 2008Rome Rome, Italy,

Do forests preserve soil biodiversity?

The case of five soil organisms in seven tropical countries

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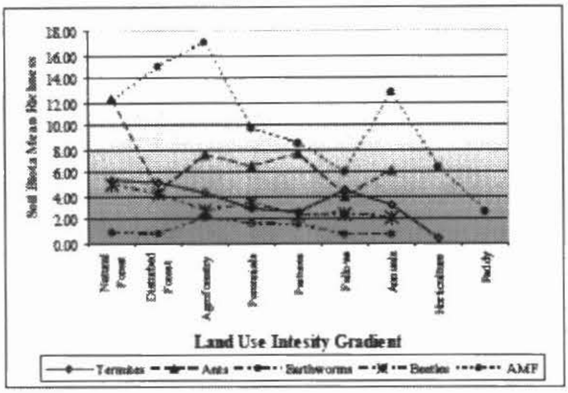
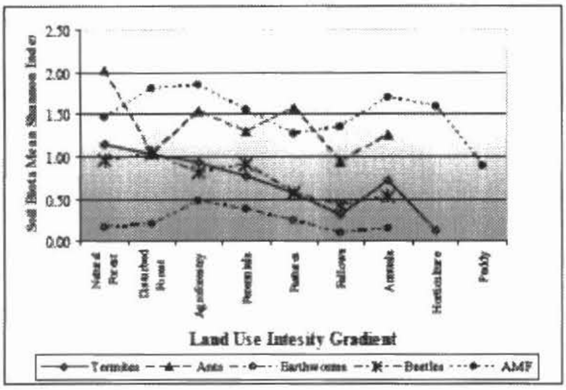
Results

- The highest mean species richness was in agroforestry systems which had 17 species of AMF.
- Though the forests recorded the highest number of species of ants (12), AMF (12) termites (5) and beetles (5).
- Whereas AMF showed the highest richness in all the land use kinds, earthworms had the lowest richness.
- Termites, ants and beetles showed highest species biological diversity (Shannon Index) in the forests.
- The richness gradually reduced in disturbed forests, in agroforestry systems, with lowest diversity occurring in the fallows.
- Annual crops though intensely used showed higher species diversity compared to agroforestry and perennial land use systems (i.e., coffee, tea, sugarcane, etc).



Distribution and trends of the mean species richness of termites, ants, earthworms' beetles and AMF in different land use kinds in the seven tropical countries.



Distribution and trends of the mean biological diversity of termites, ants, earthworms, beetles and AMF different land use kinds in the seven tropical countries.

The above poster was presented during the SBSTTA 13 of the CBD and also a presentation was given by the BGBD project during the side event that was organized and hosted by UNEP/DGEF. Its objective was to present the outcomes, information generated and technical assistance provided to developing countries by UNEP GEF projects on conservation and sustainable use of agricultural biodiversity.

The side event was addressed by UNEP's Executive Secretary of the CBD. About 40 people attended the meeting. The meeting included three presentations on: (i) Contribution to in-situ conservation of crop genetic diversity on farm and in the wild, (ii) Contribution to the International Pollinator Initiative, (iii) Contribution to the Soil Biodiversity Initiative through the conservation and sustainable management of below ground biodiversity (CSM- BGBD) project.

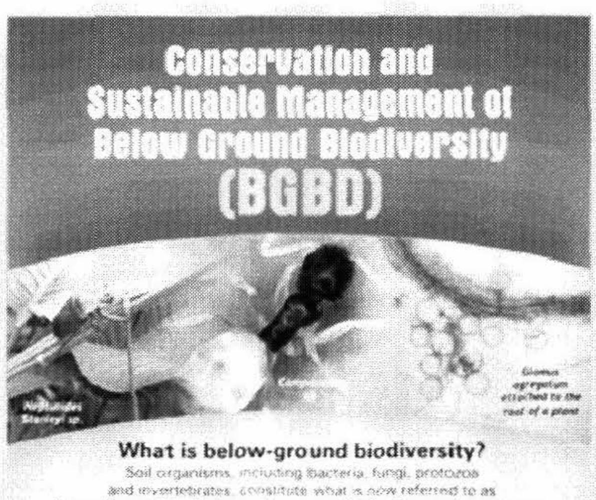
The main focus of the presentations was on the conservation impact of the projects, benefits to local communities and on the ways in which agricultural biodiversity can contribute to global challenges including climate change. The CSM- BGBD project highlighted specific issues requiring policy intervention in the seven countries participating in the Conservation and Sustainable Management of Below-ground Biodiversity project. These included: the due recognition of soil organisms and their importance in agriculture, ecosystem services, economy & culture and as a results cause them to be enshrined in individual country policy frameworks; that knowledge dissemination & infusion amongst all stakeholders be an important element of the respective governments; that soil biodiversity (BGBD) knowledge be integrated in schools & universities curriculum and to further identify who is responsible in each country, who regulates acquisition, exchange & transfer and how is benefits sharing addressed and who regulates?

International Biodiversity Day – 2008. "Biodiversity and agriculture"

The event was held on 22nd May 2008 at the National Museums of Kenya, Nairobi. The year's theme sought to highlight the importance of sustainable agriculture not only to preserve biodiversity, but also to ensure that we will be able to feed the world, maintain agricultural livelihoods, and enhance human well being into the 21st Century. Much of the campaign work in Kenya focused on the importance of agricultural biodiversity (BGBD inclusive), and especially traditional African leafy vegetables, in delivering dietary diversity and better nutrition and Health. School feeding programmes were a particular target.

TSBF was represented by in the meeting by Dr. Andre Bationo and Dr. Joyce Jefwa. The CSM-BGBD was represented by Mr. Stephen Ichami. The TSBF booth was shared by other soil laboratories including Real IPM Company Limited represented by Mr. Rikki Aguda and Crop Nutrition Laboratory Services represented by Mr. Jeremy.

The BGBD project prepared press releases in both English and Kiswahili on the general topic of the BGBD project as well as on the use of legumenosae nodulating bacteria, trichoderma and mycorrhiza as beneficial organisms. There was a media briefing organized as well that was attended by Dr. Peter Okoth, Prof. James Kahindi and Dr. Joyce Jefwa, that was aired by the local radio stations. The BGBD project also presented both the Kenyan BGBD project posters and GCO posters that interested many participants and the Kenyan assistant minister for Agriculture who was the Chief Guest during the occasion.



Biodiversidad del suelo y su manejo para la conservación de la fertilidad (Soil biodiversity and its management for the conservation of fertility)

III.5. OUTPUT 5 - STAKEHOLDER CAPACITY TO ADVANCE THE DEVELOPMENT AND ADAPTATION OF RECOMMENDATIONS FOR IMPROVED LAND MANAGEMENT ENHANCED; EFFECTIVE DISSEMINATION OF RESULTS AND ADVOCACY FOR SUSTAINABLE LAND MANAGEMENT

Outputs (Intended users)	**Outcome (Impact)**
Description: Stakeholder capacity to advance the development and adaptation of recommendations for improved land management enhanced; effective dissemination of results and advocacy for sustainable land management Intended users: C CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, young professionals, policy makers	Partners promoting resilient production systems with multiple benefits (food security, income, human health and environmental services) Improved resilience of production systems contribute to food security, income generation and health of farmers

Capacity building

Capacity building will be cross cutting through each of the outputs listed. Capacity building will done through graduate and post-graduate training, on the job-training of NARS and University staff that directly participate in the implementation of the projects, through short term training courses and stakeholder meetings and workshops. The graduate and post graduated training will be mostly associated with output 1, whereas on the job-training will be associated mainly with output 2 and output 3 to some extent. The training workshops and stakeholder meetings/workshop will be the main modus of capacity building for outputs 3 and 4. Most of the graduate and post-graduate training will be done through direct supervision of TSBF - CIAT staff though most of the training will be provide through the universities that participate in the TSBF - CIAT SLM research projects. Otherwise Afnet will play an important role in the provision of informal training. For stakeholder workshop and meetings we will increasingly try to involve and interest non-governmental organizations.

Output 5. Stakeholder capacity	
Output Targets 2009	Web content of the BGBD website enhanced to contain data and information on taxonomy and species identification, methods for inventory and characterization of BGBD, Synthesis reports on inventory, indicators of BGBD loss and soil biological quality indicators and management option and techniques for managing BGBD
	Documentation on integrated approach to the management of agricultural production landscapes with respect to soil health and conservation of the soil resource base

Completed Work

Catálogo ilustrado de hongos micorrizógenos arbusculares de la reserve de la Biosfera de Los Tuxtlas *(2008) (Illustrated catalogue of mycorrhizal fungi from the biosphere reserve of Los Tuxtlas), UNAM/SEMARNAT-CONACYT, CD (first digital edition)*

Varela[1], L., Estrada[1], A., Álvarez-Sánchezy[1], F. Sánchez- Gallen[1], I. and Hongosy Derivados, S.A.
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La manipulación del ambiente fisicoquímico (p.e. labranza mecánica y uso de fertilizantes inorgánicos) para incrementar o mantener la fertilidad de los suelos ha sido la estrategia más utilizada a nivel mundial, sin embargo, ante el deterioro que ella causa en los suelos, en particular los de ambientes tropicales, se ha tratado de implementar otros manejos del ambiente alternativos y menos dañinos.

En los últimos diez años una parte de los trabajos en ecología de comunidades se ha dedicado a tratar de entender la importancia que tiene la biodiversidad en la fertilidad y producción de biomasa de los diferentes ambientes, en particular, la biodiversidad del suelo puede ser fundamental, debido a que muchos de los microorganismos del suelo participan en procesos ecológicos muy relevantes para el mantenimiento y desarrollo de las comunidades vegetales, tales como la descomposición de todo el material biológico muerto, la captura de los nutrientes que están en el suelo y su transporte a las plantas, la captura de carbono, entre otros.

Precisamente en este marco, en diciembre de 2000, se aprobó por el Global Environment Facility un proyecto llamado Conservación y Manejo Sostenible de la Biodiversidad Bajo el Suelo, que empezó a desarrollarse en enero de 2002 en siete países en vías de desarrollo, Indonesia, India, Uganda, Kenia, Costa de Marfil, Brasil y México, bajo el auspicio del Tropical Soil Biology and Fertility (TSBF- CIAT), en Nairobi, Kenia. Su objetivo principal fue proporcionar los conocimientos y las técnicas para manejar y conservar la biodiversidad bajo el suelo (BGBD) en paisajes agrícolas tropicales, promoviendo la difusión del conocimiento y el entendimiento de la diversidad biológica bajo el suelo, en especial la más importante para la fertilidad y la producción agrícola sostenible de paisajes tropicales y generando y fomentando métodos que promuevan la conservación de la diversidad así como el uso sostenible del suelo y el mantenimiento de los servicios del ecosistema.

La hipótesis básica detrás de este estudio es que un manejo apropiado de la biota arriba y bajo el suelo logrará la conservación de la biodiversidad para beneficios nacionales y globales en mosaicos de uso de suelo con diferente intensidad de manejo y además resultará en beneficios para la producción agrícola sostenible.

Dentro de los organismos edáficos estudiados se encuentran las bacterias nitrificantes, lombrices, hormigas, hongos fitopatógenos, hongos micorrizógenos arbusculares, entre otros. En particular, el presente catálogo reúne los resultados sobre las especies de hongos micorrizógenos arbusculares encontradas en la Reserva de la Biosfera de Los Tuxtlas, Veracruz, México.

Los hongos micorrizógenos arbusculares (HMA) forman una asociación mutualista con las raíces de muchas angiospermas, gimnospermas y pteridofitas. Si bien su especificidad es muy baja, la asociación es obligada para los hongos y facultativa para las plantas. Estos HMA favorecen la absorción de nutrimentos (fundamentalmente P) y las plantas que los poseen en su sistema radical son más tolerantes a patógenos de las raíces y a condiciones ambientales adversas, como contaminación del suelo y estrés hídrico. Recientemente, se ha discutido su importancia en la composición y funcionamiento de ecosistemas naturales y constituyen además un recurso muy importante para el manejo sostenible de ecosistemas agrícolas. En la última década se han usado también como una herramienta complementaria en proyectos de restauración ecológica en sabanas de Venezuela, en matorrales áridos de México, en bosques tropicales estacionales de México y húmedos de Brasil y México, debido a que incrementan la supervivencia y crecimiento de plántulas de especies vegetales, aunque la respuesta depende de los rasgos de historias de vida de las especies.

Los HMA pertenecen al Phylum Glomeromycota y a la Clase Glomeromycetes del que se conocen aproximadamente en el mundo 200 especies. Se caracterizan por presentar micelio cenocítico y por carecer de reproducción sexual. Si bien en los últimos años se han empezado a realizar identificaciones moleculares a través de la generación de secuencias de ADN, la clasificación e identificación de los HMA están basadas principalmente en las características morfológicas de las esporas.

El objetivo de este catálogo ha sido poner a disposición de los interesados, fundamentalmente profesionales y expertos del área, información detallada de su descripción y distribución en tres localidades (ventanas) con diferentes usos del suelo en cada una (forestal, agroforestal, pastizal y milpa) en la Reserva de la Biósfera de Los Tuxtlas, Veracruz. Este catálogo es el primero en su tipo que para HMA se publica en México, y consideramos que será de gran utilidad por estar disponible en un formato electrónico diseñado de una manera versátil. Se describen entonces en este catálogo 12 géneros de HMA, se muestran fotos de 31 especies (o morfoespecies), y los datos de distribución de 60 especies.

El contenido está organizado con la siguiente información:
Introducción y método
Clasificación de los hongos micorrizógenos arbusculares (HMA)
Descripción de géneros:
Acaulospora

Ambispora
Archaeospora
Entrophospora
Diversispora
Gigaspora
Glomus
Intraspora
Kuklospora
Pacispora
Paraglomus
Scutellospora
Breve descripción de La Reserva de la Biósfera de Los Tuxtlas
Sitios de estudio
Lista de especies
Literatura citada

El catálogo forma parte de los resultados obtenidos a través del proyecto SEMARNAT-CONACYT-2002-c01-668 "Restauración ecológica en la zona intertropical: el uso de los hongos micorrízicos arbusculares", y complementariamente por el proyecto "Conservation and sustainable management of belowground Biodiversity", financiado por Global Environmental Facility (GEF), Programa Ambiental de las Naciones Unidas (UNEP), Tropical Soil Biology and Fertility (TSBF), Centro Internacional de Agricultura Tropical (CIAT) y el Instituto de Ecología, A.C.

This work is currently not available through the project WEB site, but it will be investigated whether this can be realized as yet.

WORK IN PROGRESS

The CSM-BGBD Project WEB sites

All the country project websites are up and running. Brazil, Cote d'Ivoire, India, Kenya, Mexico, Uganda, Indonesia and the global coordinating office have functional websites. You can visit the websites at the following URL addresses.

- http://www.bgbd.net
- http://www.biosbrasil.ufla.br/. http://www.unb.br/ib/zoo/bios/
- http://www.bgbdci.org
- http://lemlit.unila.ac.id/bgbd
- http://www.tsbfsarnet.org
- http://www.inecol.edu.mx/bgbd
- http://www.uonbi.ac.ke/research_projects/BGBD/
- http://www.bgbd.or.ug

In 2009 these WEB sites will be further enhanced and inventory data will be made available through the WEB sites as well.

Output 5. Stakeholder capacity	
Output Targets 2010	Validated intensive and profitable systems are being demonstrated, promoted by partners and adopted by farmers in 10 countries
	Products of the trade-off analysis are guiding the introduction and evaluation of alternative NRM options, better suited to the farmer production objectives and the environment of the actions sites
	Stakeholder workshops in selected productions landscapes involving national and local stakeholders, presenting recommendations for improved soil and land use management
	Stakeholders in target areas have an improved capacity for collective action and local policy negotiation and implementation of integrated land use practices using integrated agricultural research for development

Work on empowering farmer communities, establishment of innovation platforms for Conservation Agriculture etc. are being conducted in several projects of TSBF-CIAT. There are also project that aim to train Agro-dealers in ISFM practices so that they can better inform farmers on ISFM. See for reports on the progress of these activities the ISFM outcome line.

Part of the output targets refer to the AfSIS project where stakeholder workshops and training will take place as well. For most of these activities we do not expect the targets to be realized in 2010, but probably in the subsequent two years.

Output 5. Stakeholder capacity	
Output Targets 2011	Improve linkages with the private sector to improve access to fertilizer and develop recommendations for its use by farmers and other stakeholders involved.
	Demonstration and documentation of successful cases prove approach and methodology used and will generate additional funds for out scaling of the activities (donor buy-in) NGO adopt methodology and will lead to improved adoption and policy formulation.
	Degree training (BSc, MSc and PhD) on relevant topics
	Short term training courses (methods for inventory of BGBD, Decision support tools for recommendations on soil and land use management, Economic valuation and PES, etc.).

COMPLETED WORK

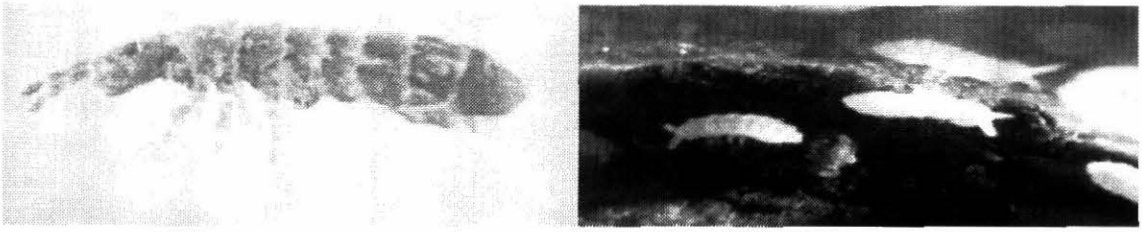
Global Analysis Workshop of data of the Below Ground Biodiversity project, IRD Center, Bondy, 28th September to 5th October 2008

The CSM- BGBD Project organized a training workshop on Multivariate Statistical Analysis (MSA) using BGBD Inventory Data for Global Statistical analysis and synthesis. The workshop was held at the institut de Recherché pour le Developpment (IRD), Bondy, Paris, France. There were 12 participants from 7 Countries including the Global Project Coordinator Dr. Jeroen Huising and Project Information manager Dr. Peter F. Okoth. Other participants included Professor Jerome Tondoh from Cote d'voire; Professor Kottapalli Sreenivasa Rao from India; Professor Fatima Moreira from Brazil; Professor Patrick Lavelle from France; Dr. Joyce Jefwa from Kenya; Dr. Elena Vasquez from Colombia; Dr. Isabelle Barois from Mexico; Dr. Argus Karyanto from Indonesia; Mr. Brian Isabirye from Uganda and Mr. Stephen Ichami from Kenya. The Participants received training on Multivariate Statistical analysis using ADE4 which enabled the participants to competently perform various multivariate analyses such as Principal Component analysis (PCA) and Co-Inertia analysis. The training was conducted by Professor Patrick Lavelle with handy assistance of Dr. Elena Velasquez and Ms. Nuria Ruiz. There was preliminary training on IndVal from Ms. Nuria. The attendees were awarded with certificates of participation at the end of the training.

CSM-BGBD Training Workshop on Collembola Ecology and Systematics,
24-28 November 2008, National Museums of Kenya, Nairobi.

From 24-28 November 2008 the International Collembolan Training Workshop was held at the National Museums of Kenya in Nairobi, organized by the GCO in collaboration with the BGBD Kenya team. The workshop was intended for participants from the BGBD African countries, *viz*. Ivory Coast, Uganda and Kenya. Two of the Kenyan students are involved in the Sida/Formas sponsored study on mesofauna and associated

trophic levels in the food web. We were able to get Dr. Arne Fjellberg, who is a world renowned expert on Collembola, from Norway, to teach the course.
The students were given an introduction to Collembola systematic by theoretical and practical approaches. Methods for making microscopic slides were demonstrated, using the glycerol/lactic acid medium ("Gisin") and hand made cavity slides. Students were making their own slides from material partly collected by themselves, partly by the instructor. Also fresh samples were collected from compost heaps in the garden of the Museum, and analyzed.
Handbooks for identification of African springtails are non-existent. Special publications - like a key to the Hypogastruridae of Kenya - were used. For general training in running identification keys students used a slide collection of European species and identification keys brought by the instructor.
The participants were very positive about the course as it provided them with practical training in the identification of collembolan species, where identification keys and expertise in Collembola are largely lacking in Africa. Collembolans are ubiquitous in all terrestrial biotopes and have an important ecological function. Participants have increased their ability to investigate the collembolan fauna in their respective projects and to include different aspects of collembolan diversity and function in their research, which was the aim of the training course.
Collembola are wingless, insect-like arthropods, ca. 0.5 to 5 mm long. Most species live in the soil or at the soil surface where they may reach densities of up to 100 000 individuals per m^2. Some species can also be found above-ground in the vegetation. World-wide, 7500 species are described and the estimated actual species number could be around 20000 (Bellinger et al. 1996-2000) while ca. 400 species are known from the Nordic countries (Fjellberg 2006). Collembola feed on dead organic matter and microorganisms associated with this substrate. They may also selectively feed on different microorganisms, for example plant parasitic fungi, and some species are known to feed on small soil animals, such as nematodes. They play a central role in the food web of the soil ecosystems since they contribute, directly and indirectly to decomposition and nutrient cycling (Filser, 2002). By feeding on plant pathogens collembolans can be of importance for regulation of plant diseases (Friberg et al. 2005). They can also be important alternative food for natural enemies of pest insects and thereby keep up the populations of these insect so they can be at hand at incidence of pest outbreaks (Settle et al. 1996, Bilde et al. 2000).
This was the last in a series of training workshop organized by the CSM-BGBD project, as part of its capacity building programme. All in all, the project has organized eight of these international training courses on the ecology and systematic of the various functional groups of soil organisms and in data analyses and inoculum production for example.



Degree training within the CSM-BGBD project

In 2008 there were in total 76 students involved in the CSM-BGBD project, excluding the students from Ivory Coast and Indonesia for which we do not have updated information. Of these, as far as we know, 8 completed their studies in 2008 and this can be considered completed work. However the majority is ongoing and is expected to finish in 2009 and 2010. For a complete list of students involved in the BGBD project and the research topics please see the annual report of the CSM-BGBD project for the year 2008.

						of degraded lands
India	Dangwal Divya	Doctorate		GBPHIED/ HNB Garhwal Univ.		Assessment of productivity, nutrient uptake and nitrogenase activity in three selected mountain legume crops under mix and monocropping
India	Chamoli K.P.	Post-doc		GBPHIED		*Documentation of indigenous knowledge* related sol fertility maintenance in Central Himalaya agroecosystem
India	Rawat L.S.	Post-doc		GBPHIED		Impact of Bio-compost and Vermicompost on yield of Rabi & Kharif season crops.
India	Kumar Lalit	Doctorate		GBPHIED/ HNB Garhwal Univ.		Productivity of agricultural crops and an alpine pasture in Garhwal Himalaya in relation to global environmental change.
India	Pant Santosh	Masters		GBPHIED/ HNB Garhwal Univ.		Studies on soil macrofauna of buffer zone agroecosystem of NDBR.
India	Misra Shalini	Doctorate		GBPHIED/ HNB Garhwal Univ.		Studies on forest disturbances in different management categories of Kedarnath Wildlife Sanctuary, Uttaranchal
India	Gupta Subho Das	Doctorate		GBPHIED		Soil fauna activity in pastures
India	Kundu Sumanta	Doctorate		GBPHIED		Soil fauna activity in a village landscape. Studies on village ecosystem function in Rawain valley of Central Himalaya: An ecological -economics approach.
India	Negi V.S.	Doctorate		GBPHIED/ HNB Garhwal Univ.		Survey and identification of soil macrofauna of NDBR
India	Singh Yudvir	Post-doc		GBPHIED		Survey and identification of soil macrofauna of NDBR

India	Sringeswara A.N.	Doctorate		Kuvenmpu Univ.	submitted	Analysis of the vegetation in the Kudremukh National Park region of the western ghats, India.
India	Pande Himanshu	Doctorate		Kumaon Univ.		Macrofauna diversity and abundance in Nanda Devi Biosphere Reserve
India	Rane Ajay	Doctorate		KFRI		Assessment of soil quality and management practices in different land use types in the Kerala part of Nilgiri Biosphere Reserve
India	Baiju E.C.	Doctorate		KFRI		Land use and landscape dynamics in a micro - watershed of Chaliyar River in Kerala part of Nilgiri Biosphere Reserve
India	Binu N.K.	Research fellow		KFRI		Distribution and diversity of arbuscular mycorrhizal fungi in different land use systems in the Kerala part of Nilgiri Biosphere Reserve.
India	Rahman P. Mujeeb	Research fellow		KFRI		Soil faunal diversity under different landuse systems in the Kerala part of Nilgiri Biosphere Reserve
India	Bineesha S.	Research fellow		KFRI		Diversity and dynamics of nitrogen fixing bacteria under different landuse systems in the Kerala part of Nilgiri Biosphere Reserve
India	Sahu Jithnedra Kumar	Research fellow		Sambalpur Univ.		Linkages between soil morphology and soil fauna in natural forests in Nilgiri Biosphere Reserve
India	Narhari	Research fellow		Sambalpur Univ.		Soil chemical characteristics in relation to soil macrofauna
India	Patra Debashish	Research fellow		Sambalpur Univ.		Soil ecological studies
India	P. Nirmala	Project fellow		University of Agricultural		Agricultural entomology

				Sciences, Bangalore		
India	M.S. Kitturmath	Project fellow		University of Agricultural Sciences, Bangalore		Agricultural entomology
India	M. Raghavendra Kumar	Ph.D. UAS		University of Agricultural Sciences, Bangalore		Agricultural microbiology
India	K.S. Usha	Project fellow		University of Agricultural Sciences, Bangalore		Agricultural microbiology
India	R. Sabu	Project Fellow		Kerala Forest Research Institute, Nilambur		Soil science
India	V. M. Nishad	Doctorate		Kerala Forest Research Institute, Nilambur		Microbiology
India	Rohit Kumar	Project Fellow		G.B. Pant Institute of Himalayan Environment and Development, Srinagar		Soil Zoology
India	Pradeep Kumar	Project fellow		G.B. Pant Institute of Himalayan Environment		Soil zoology

				and Development, Srinagar		
India	Joylata Laishram	M.Phil, JNU		JNU, New Delhi		Resource integration
India	Madhuri Dabral	Doctorate		G.K. University, Hardwar & G,.B. Pant Institute	Ph.D. Thesis submitted	Land use and Earthworms
Mexico	Hernández Lizbeth	Licenciatur a		Univ. Veracruzana	in progress	Efecto de diferentes usos del suelo sobre las comunidades de hormigas (Hymenoptera: Formicidea) en la Sierra de Santa Marta, Los Tuxtlas, Ver.
Mexico	Miranda Carlos A	Licenciatur a		Univ. Veracruzana	in progress	Manejo de palma camedor en dos ejidos de la región de Los Tuxtlas. Tesis de Licenciatura Facultad de Biología. Universidad Veracruzana, Xalapa, Ver.
Mexico	Mondragón Gómez Alberto	Licenciatur a		UNAM	in progress	Evaluación de la actividad enzimática en suelos bajo diferente uso en los Tuxtlas Veracruz
Mexico	Lloret Lourdes	Doctorate		UNAM	in progress	Diversidad de rizobios en Los Tuxtlas y en el Cañon del Sumidero en Chiapas
Mexico	Ormeño Orrillo Ernesto	Doctorate		UNAM	in progress	Diversidad de Bradyrhizobium de los Tuxtlas y de Phaseolus lunatus.
Kenya	Amek Tom	Masters		UON	Submitted	Ex-ante analysis of Technology adoption
	Achieng Celline Oduor	Masters		Kenyatta University	Submitted	Policy framework for utilization and conservation of below-ground biodiversity in Kenya

	Adama Moses	Masters		UON	writing	The Nexus Between Social And Economic Institutions, Intensive Farming And The Management Of Belowground Biodiversity: A Study Of Wundanyi Division, Taita-Taveta District.
	Mugambi Benson Rimbera	Masters		UON	writing	Impact of Land use changes on Nematode diversity and abundance in Taita and Embu
	Chirchir Joseph K.	Masters		UON	field work	Crop production practices and biodiversity conservation in Taita Taveta district
	Wanjiru Mwangi Margaret	Masters		Kenyatta University	Data analyses	Effect of *Trichoderma harzianum* and arbuscular mycorrhizal fungi on growth and diseases management in tea cuttings, tomato seedlings, and napier grass
	Maina Peter K.	Masters		Kenyatta University	Data analyses	The impact of land use on Distribution and Diversity of *Fusarium spp.* in Ngangao Forest and its adjacent farmlands
	Siameto Elizabeth	Masters		UON	Thesis writing	Molecular characterization and determination of biocontrol activity of *Trichoderma harzianum* (Green mould) isolates from Embu District, Kenya
	Mukundi David	Masters		UON	Thesis writing	Distribution and diversity of *Pythium* spp in Irangi and Ngangao forest, Embu, Kenya
	Muya Edward	Doctorate		UON	Proposal writing	Management practice for improved soil structure, nutrient availability and water use efficiency of degraded acid soils.
	Kibberenge Musobi	Doctorate		UON	Field work	
	Wachira Peter M.	Doctorate		UON	Field work	Enhancement of Nematophagous fungi on agricultural systems for biological control of nematodes
	Tepeny Taabu T.	Doctorate		UON	Field work	Effect of land use and soil management practices on the control of the

						Phytopathogenic Rhizoctonia species in Taita hills
	Nyaga John	Masters		JKUAT	Field work	Effect of Land Use Practices on Occurrence of Arbuscular Mycorrhizal Fungi (AMF) and Use of AMF Inoculum for Sustainable Crop Production in Taita Taveta and Embu Districts; Kenya
	Mwangi Ngare S.	Masters		JKUAT	Lab. analysis	Genetic diversity of leguminous nitrogen fixing bacteria and their symbiotic potential in Taita Taveta region, Kenya
	Mwenda George	Masters		JKUAT	Lab analysis	Genetic diversity and symbiotic efficiency of Rhizobia isolated from Embu, Kenya
	Wambugu Maribie C.	Masters		UON	Data analyses	Assessment of Acari diversity and densities in different land use types in Embu and Taita, Kenya
	Wephukulu Miriam	Masters		UON	Data analyses	Abundance of *Bacillus subtilis* and root –knot nematodes under different soil fertility management practices
	Otandoh Jane	Masters		UON	Field work	Efficacy trial on virulence of Trichoderma on the pathogenic fungi in Embu
	Kitivo Emily	Masters		UON	Data analyses	Investigation into the role of termite in soil structure and composition in relation to agricultural productivity.
	Sirengo Ann	Masters		UON	Data entry	Determinants of farmer use of agricultural management practices that enhance the population of beneficial soil organisms: The case of earthworm conservation in Kenya
	Muturi Jamleck	Doctorate		Kenyatta University	Field work	Influence of land use practices on the diversity and density of collembola in Embu and Taita, Kenya
Uganda	Lamtoo Geoffrey	Doctorate		Makerere Univ.	data analyses	

	Nkwiine Charles	Doctorate		Makerere Univ.	data analyses	
	Zawedde Justine	Masters		Makerere Univ.	Submitted	
CDI	Yannick Baidai	Bachelor				Role of the earthworm Dichogaster-terrae nigrae in soil compaction in agrosystems of *Centre-West Côte d'Ivoire*
	Serge Kassi	Master				Can earthworms from savanna grow and survive in soil from the forest?
	Amon Bosso	Master				Biological quality of soil in Centre-West Côte d'Ivoire: role of soil macro-invertebrate
	Cyrille B. Amani	Master				Economic value of agrosytems in Centre-West Côte d'Ivoire
	Blandine Sey	Master				Impact of land-use systems on floristic diversity in Centre-West Côte d'Ivoite
	Aurélie N'Dri	Master				*Impact of land*-use systems on enzyme activities in Centre-West Côte d'Ivoire: do earthworms play a role?
	Paul Assié	PhD				Pedo-morphological characterization of soils in agrosystems from Center-West Côte d'Ivoire
	Julien K. N'Dri	PhD				Acari as indicators of soil ecosystem disturbance in Côte d'Ivoire
	Arnault Guéi	PhD				Building a synthetic index of soil quality based on soil macroinvertebrates in Côte d'Ivoire
	Gérard K. N'Goran	PhD				Soil biodiversity and agricultural productivity: the perception of farmers from Centre-West Côte d'Ivoire

II.7. LIST OF PARTNERS

Partners per country

Austria: University of Natural Resources and Applied Life Sciences (BOKU)
Brazil: Universidade de Brasilia (UNB),Universida Regional de Blumenau (FURB) Universidade Federal de Lavras (UFLA),Insituto Nacional de Pesquisada Amazonia (INPA),Universidade Federal do Amazonas (UFAM),Centro de Energia Nuclear na Agricultura (CENA),EMBRAPA Solos,Centro de Ensino Luterano de Manaus (CEULM/ULBRA)
Cote d'Ivoire : Houphouët-Boigny National Polytechnic Institute (INP-HB/ESA),Université d'Adobo-Adjamé (UAA),Universite de Cocody (UC),Centre National de Recherche Agricole (CNRA),Ecole Supériere d'Agronomie du Bureau National d'Etudes et des Travaux (BNETD/CCT),Ivorian Center of Economic and Social Research (CIRES),National Agency for Rural Development (ANADER) S.O.S-Forêts (NGO), SODEFOR (State Forest Agency)
India: University of Agricultural Sciences (UAS), Kumaon University Kerala Forest Research Institute (KFRI),Sambalpur University,Jawaharlal Nehru University (JNU),Delhi University (DU), G.B. Plant Institute of Himalayan Environment Management (GBPIHEM).
Indonesia: Universitas Lampung, Brawijaya University, Gadjah Mada University, The Southeast Asian Regional Centre for Tropical Biology (BIOTROP),Research Institute for Agricultural Biotechnology and Genetic Resources (RIABGR),Forestry and Estate Research and Development Agency (FORDA),Biotechnology Research Institute for Estate Crops (BRIEC),Centre for Soil and Agroclimate Research, Bogor Agricultural University
Kenya: Kenya Agricultural Research Institute (KARI), Kenya Forestry Research Institute (KEFRI), University of Nairobi (UoN), National Museums of Kenya (NMK), Department of Resources Survey and Remote Sensing (DRSRS), United States International University (USIU), Methodist University
Malawi: Bunda College of Agriculture, Agricultural Research Station Chitedze
Mali: Institut d'Economie Rurale (IER), Mali
Mexico: Instituto de Ecologia A.C., Instituto Fitosanidad, Colegio de Posgraduados (IFCP), Universidade Autonoma de Mexico (UNAM), Universidade Veracruzana, Instituto Politécnico Nacional (IPN), National Institute of Forestry, Agricultural and Animal Research (INIFAP), Centro Experimental San Andres-Tuxtlas, Biosphere Reserve Los Tuxtlas, Group Vincemte Guerrero de Tlaxcala (NGO), Red A.C. (NGO) Dessarrolo Communitario de Los Tuxtlas (NGO)
Mozambique: Catholic University Mozambique (UCM), Mozambique, Instituto de Investigação Agrária de Moçambique (IIAM)
The Netherlands: Wageningen University and Research centre (WUR), The Netherlands
Republic of South Africa: University of Pretoria, RSA, University of KwaZulu Natal University of Free State, RSA

Tanzania: Selian Agricultural Research Institute (Tanzania), Agricultural Research Institute (ARI) Tanzania,
Uganda: Uganda Environmental Education Foundation (UEEF), Uganda
Africa 2000 Network (A2N), Uganda, Makerere University (MUK), Uganda, Appropriate Technology (AT), Uganda NARO, Uganda, National Forest Authority (NFA),National Environment Management Authority (NEA),Ministry of Agriculture (MOA)

Partners per type of institution

NARS: Bunda College of Agriculture, Malawi, Makerere University (MUK), Uganda University of Pretoria, RSA,NARO, Uganda,Catholic University Mozambique (UCM), Mozambique ,University of KwaZulu Natal, RSA, Instituto de Investigação Agrária de Moçambique (IIAM),University of Free State, RSA, Kenya Agricultural Research Institute (KARI). Kenya Forestry Research Institute (KEFRI),University of Nairobi (UON),National Museums of Kenya (NMK), Department of Resources Survey and Remote Sensing (DRSRS),United States International University (USIU, Methodist University, Instituto de Ecologia A.C., Mexico, Instituto Fitosanidad, Colegio de Posgraduados (IFCP), Mexico, Universidade Autonoma de Mexico (UNAM), Mexico Universidade Veracruzana (UV), Mexico Instituto Politécnico Nacional (IPN), Mexico National Institute of Forestry, Agricultural and Animal Research (INIFAP), Centro Experimental San Andres-Tuxtlas, Mexico, Biosphere Reserve Los Tuxtlas, Mexico Universitas Lampung, Indonesia, Brawijaya University, Indonesia, Gadjah Mada University, Indonesia, Research Institute for Agricultural Biotechnology and Genetic Resources (RIABGR), Indonesia, Forestry and Estate Research and Development Agency (FORDA), Indonesia, Biotechnology Research Institute for Estate Crops (BRIEC), Indonesia, Centre for Soil and Agroclimate Research, Indonesia, Bogor Agricultural University (IPB), Indonesia, National Forest Authority (NFA), Uganda, National Environment Management Authority (NEMA) , Uganda, Ministry of Agriculture (MOA), Uganda, Universidade de Brasilia (UNB), Brazil,Universida Regional de Blumenau (FURB) , Brazil,Universidade Federal de Lavras (UFLA) , Brazil,Insituto Nacional de Pesquisada Amazonia (INPA) , Brazil,Universidade Federal do Amazonas (UFAM) , Brazil,Centro de Energia Nuclear na Agricultura (CENA) , Brazil,EMBRAPA Solos, Brazil,Houphouët-Boigny National Polytechnic Institute (INP-HB/ESA), Cote d'Ivoire
Université d'Adobo-Adjamé (UAA), Cote d'Ivoire, Universite de Cocody (UC), Cote d'Ivoire, Centre National de Recherche Agricole (CNRA), Cote d'Ivoire, Ecole Supériere d'Agronomie du Bureau National d'Etudes et des Travaux (BNETD/CCT), Cote d'Ivoire Ivorian Center of Economic and Social Research (CIRES), Cote d'Ivoire, National Agency for Rural Development (ANADER), Cote d'Ivoire, SODEFOR (State Forest Agency), Cote d'Ivoire, University of Agricultural Sciences (UAS), India, Kumaon University, India, Kerala Forest Research Institute (KFRI), India, Sambalpur University, India, Jawaharlal Nehru University (JNU), India, Delhi University (DU), India, G.B. Plant Institute of Himalayan Environment Management (GBPIHEM), India, Agricultural Research Institute (ARI) Tanzania, Selian Agricultural Research Institute (Tanzania), Institut d'Economie Rurale (IER), Mali ,University of Zimbabwe, Zimbabwe

Advanced Research Institutes: Wageningen University and Research centre, The Netherlands, Swedish University of Agricultural Sciences (SLU), Uppsala, Sweden, University of Natural Resources and Applied Life Sciences (BOKU) ,Cornell University, USA, Institut de Recherche pour le Développement, France ,

International Agricultural Research Centers: IFDC, Togo, CIMMYT, Kenya & Zimbabwe, IITA, Uganda & Nigeria
ICRAF, Kenya, Indonesia,ICRISAT, Niger, Zimbabwe, Mali ,FAO. Italy
NGOs: Africare (Uganda), Uganda Environmental Education Foundation (UEEF), Uganda, Africa 2000 Network (A2N), Uganda, Appropriate Technology (AT), Uganda Group Vincente Guerrero de Tlaxcala, Mexico, Red A.C., Mexico, Dessarrolo Communitario de Los Tuxtlas, Mexico, Southeast Asian Regional Centre for Tropical Biology (SEAMEO BIOTROP), Indonesia,Centro de Ensino Luterano de Manaus (CEULM/ULBRA), Brazil,S.O.S-Forêts (NGO), Côte d'Ivoire,Catholic Relieve Service (CRS),