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Program ISFM-BASED CROP PRODUCTION SYSTEMS FOR MAJOR IMPACT ZONES IN THE TROPICS

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

PROGRAM

'ISFM-BASED CROP PRODUCTION SYSTEMS FOR MAJOR IMPACT ZONES IN THE TROPICS'

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TSBF Institute: Program: 'Integrated Soil Fertility Management-based crop production systems for major impact zones in the Tropics'

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I. PROJECT OVERVIEW

I.1. RATIONALE

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

To achieve sustainable investments in soil fertility rehabilitation, this Program, referred to as the ISFM Program, accepts the **INTEGRATED SOIL FERTILITY MANAGEMENT** paradigm. We define ISFM as *'The application of soil fertility management practices, and the knowledge to adapt these to local conditions, which optimize fertilizer and organic resource use efficiency and crop productivity. These practices necessarily include appropriate fertilizer and organic input management in combination with the utilization of improved germplasm'*. This definition is in line with the goals of the African Fertilizer Summit (AFS), recently held in Abuja, Nigeria, which aims at increasing fertilizer use from an average of 8 to 50 kg nutrients ha^{-1} by 2015. In the march to generate solutions to farmers' problems, research has generated a wide variety of technologies, such as fertilizer formulations, improved legume germplasm and crop rotations. ISFM arose because of the recognition that addressing the ***interactions*** between components (e.g., water, pests and soils) is as important as dealing with the components themselves. In this context, ISFM targets improved productivity, with fertilizer as en entry point, at the **PLOT AND FARM SCALE**.

Improving the natural resource base without addressing issues of **HEALTH AND NUTRITION AND INCOME GENERATION** (e.g. the resource-to-consumption logic) is often the reason for a lack of adoption of improved technologies and other farming practices. Maximum benefits from ISFM practices and technologies can only be obtained within an enabling context, where such factors as viable farm input supply and produce markets, improved health and nutrition, functional institutions, and good policy are in place.

The following target **CROPPING SYSTEMS** and **IMPACT ZONES** will form the focus of the Program: (i) millet and sorghum-based systems in dry-lands in Sahelian West-Africa, (ii) cereal-legume intercropping and rotations in moist-savannas of West, East and Southern Africa, (iii) cassava-based systems in humid lowland areas of West and Central Africa , (iv) upland rice-based systems in West and Central Africa, with a special focus on 'New Rice for Africa', (v) banana-based systems in East and Central African highlands, and (v) conservation agriculture in cereal croplands of West, East, and Southern Africa. The impact zones and cropping systems have been identified based on the large population depending on these systems for food and nutrition security and income (**Table 1**). Some ISFM-based technologies have shown a high potential for large-scale adoption and a relatively high increase in input use efficiency **(Quadrant A, Figure 1)** while further research for development investments are needed to fully assess the adoption potential of other technologies and their impact on resource use efficiencies **(Quadrant C, Figure 1)**.

These cropping systems and impact zones are partly based on the strategy of the **ALLIANCE FOR THE GREEN REVOLUTION IN AFRICA** (AGRA) that launched its Soil Health Program in 2008. This Program has adopted ISFM as a guiding framework for improving the soil health status of African soils and the Program is expected to backstop investments in this area.

Table 1: Selected characteristics of the impact zones addressed by the ISFM Outcome Line.

Impact zone	West African Sahel	West, East, and southern African moist savannas	West and Central African humid lowlands	East and Central African mid-altitude savannas
Major cropping systems; presence of legumes	Millet-sorghum based systems, cowpea, beans	Maize-legume intercrop/rotations; conservation agriculture; groundnut, beans, soybean	Cassava- and upland rice-based systems, groundnut, soybean, cowpea	Banana-based systems, beans, soybean, groundnut
Approximate land area under these cropping systems	23 million ha	32 million ha	18 million ha cassava; 1 million ha upland rice	6 million ha
People living from these cropping systems	38 million	157 million	163 million cassava; 2 million rice	30 million
Major constraints to increased productivity	Drought, low water use efficiency; low nutrient stocks; low crop-livestock integration; large distance to markets	Within-season drought (changing climate); small land size; lack of livestock; market volatility.	Chemically degraded soils; lack of improved production systems; poor infrastructure	Very small land holdings (highest population); lack of technologies; poor infrastructure and market access
Fertilizer use	Limited; good progress with micro-dosing	Moderate fertilizer use on maize	Virtually none on cassava; moderate levels on rice	Virtually none
Occurrence of poverty	Extensive and severe	Moderate incidence of chronic poverty	Limited to moderate	High poverty (in severity and numbers)
Potential for agricultural growth[a]	Modest; important challenges	Relatively good; high potential for poverty reduction	Moderate; good market potential for cassava and rice	Fairly low

[a] Farming systems and Poverty. Improving Farmers' Livelihoods in a Changing World. 2003. FAO, Rome, Italy.

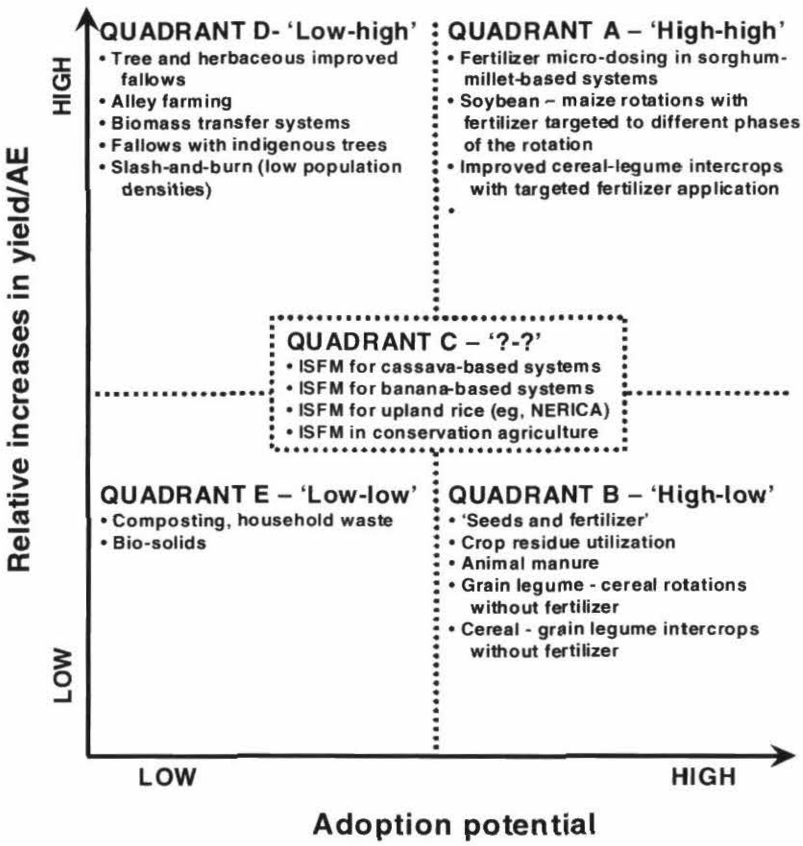

Figure 1: The relative adoption potential and contribution to soil fertility enhancement for various tested soil fertility management interventions.

The GOAL of the ISFM Program is to improve the livelihoods of people relying on agriculture in the impact zones by developing and creating an enabling environment for disseminating sustainable, profitable, socially just, nutrient-dense, and resilient agricultural production systems based on Integrated Soil Fertility Management (ISFM).

To achieve this Goal, a set of activities will be implemented of which the level and nature during the period 2010-2011 will vary according to progress made over the past years. For all systems, appropriate characterization and problem diagnosis has been achieved. **DESIRED OUTPUTS** related these activities are:

- **Output 1.** Processes and principles underlying the functioning of ISFM within the above cropping systems, with a special focus on fertilizer use and resilient germplasm.
- **Output 2.** Management practices adapted to the resource-base and socio-economic environment of smallholder farmers.
- **Output 3.** Enabling environments for dissemination of ISFM practices, focusing on viable input and output market linkages and appropriate nutritional knowledge and health.
- **Output 4.** Effective partnerships along each step of the value chain for innovative, effective and efficient dissemination and impact.
- **Output 5.** Stakeholder capacity to advance the development and adaptation of above outcomes.

The ISFM Program will require specific inputs from the **SLM PROGRAM** under CIAT-TSBF and various Programs from the two **OTHER RDCS**, in terms of access to improved germplasm, which forms an essential component of ISFM, and in terms of value addition opportunities and active partnerships to create an enabling environment for large-scale uptake of ISFM technologies **(Figure 2)**.

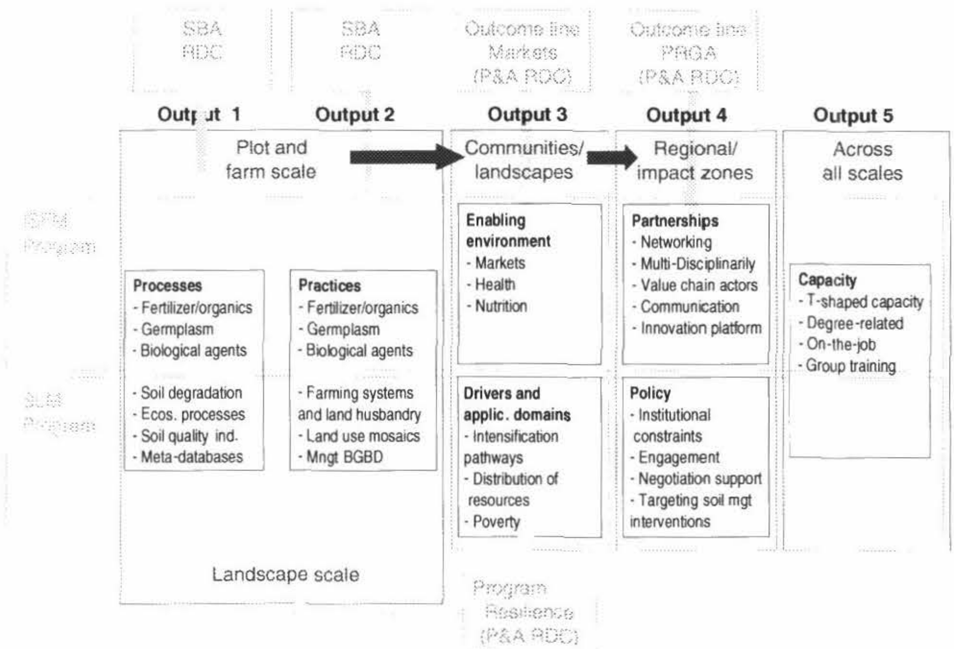

Figure 2: Specific focus areas of the ISFM and SLM Programs and potential linkages between these and the other CIAT Programs under the 'Sharing the Benefits of Agro-biodiversity' (SBA) the 'People and Agro ecosystems' (P&A) RDC.

I.2. ALIGNMENT TO CGIAR SYSTEM PRIORITIES

The ISFM Program housed mainly under CGIAR System **PRIORITY AREA 4D**: *Promoting sustainable agro-ecological intensification in low- and high-potential areas*. Most efforts are related to the following **SPECIFIC GOALS**:

- **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 4:** *Evaluate the production potential of high-productivity systems and their constraints and trends.*
- **Specific goal 5:** *To improve soil quality to sustain increases in productivity, stability, and environmental services through greater understanding of processes that governs soil quality and trends in soil quality in intensive system.*
- **Specific goal 6:** *To optimize productivity at high input use (e.g. labor, nutrients, pest control practices, water, seed, and feed) through understanding and managing spatial and temporal variation.*
- **Specific goal 7:** *Identify social, economic, policy, and institutional factors that determine decision-making about managing natural resources in intensive production systems and target interventions accordingly.*

The Program also contributes to the following Priority areas and Specific goals:

PRIORITY 2C: *Enhancing nutritional quality and safety.*

- **Specific goal 2:** *Evaluate biofortification strategies and introduce the best means to enhance the diets of nutritionally disadvantaged populations in developing countries.*

PRIORITY 4C: *Improving water productivity.*

- **Specific goal 1:** *Improve management practices that enhance the productivity of water.*

PRIORITY 5B: *Making international and domestic markets work for the poor.*

- **Specific goal 1:** *Enhance livelihoods and competitiveness for smallholder producers and food safety consumers influenced by changes in national and international markets.*

PRIORITY 5D: *Improving research and development options to reduce rural poverty and vulnerability.*

- **Specific goal:** *Identify agricultural research and development pathways, in order to implement options to reduce rural poverty at global and regional levels.*

I.3. IMPACT PATHWAYS

The impact of ISFM within the target cropping systems will be visible through improved production, income, human health and nutrition, soil fertility, and C sequestration and reduced nutrient mining and conversion of natural fallow to agriculture. If successful with the expected AGRA investments, projected impact figures are empowerment of 545,000 households (or approximately 3.8 million persons) to produce an additional 321,000 tons of additional food worth about $52 million per year. Similar improvement could be expected through year 5 as the number of cumulative participating households increases to 10.4 million. In this case, *agronomic efficiencies of mineral fertilizers are increased by 50%, organic inputs provide the fertilizer nutrient equivalent of 12.5 kg per ha, food supply in increased to 103 million tons per year and the net annual return of $495 million is realized from an annual investment of $33 million, resulting in a benefit to cost ratio of 15. Food supply among the eleven cooperating nations is increased by 72% through a 50kg/ha nutrient application target with 46% of the increase resulting from ISFM as a farmer-empowering, accompanying technology.*

As detailed above, the various Outputs are logically linked towards reaching impact through widespread adoption of ISFM practices. Each of the Outputs aims at reaching specific users who are then geared towards common outcomes and impact through effective partnerships.

The intended users of **OUTPUT 1** ***(PROCESSES AND PRINCIPLES)*** outcomes are mainly CGIAR, Advanced Research Institute (ARI), National Agricultural Research System (NARS), and Regional Consortia researchers who are envisaged to derive processes and principles based on applied research activities. The final impacts of this output are ISFM-based and sustainable production systems. Research activities from **OUTPUT 2** ***(MANAGEMENT PRACTICES)*** address the social, economic, and gendered dynamics of local knowledge generation and exchange, the nature of the interface between research-extension, local community institutions/social networks, and evaluate the economic and environmental impacts of current or proposed practices. The intended users of the outcomes of this output are development practitioners and farmers who are envisaged to apply the principles, concepts and methods to adapt and improve technologies to the prevailing production environments.

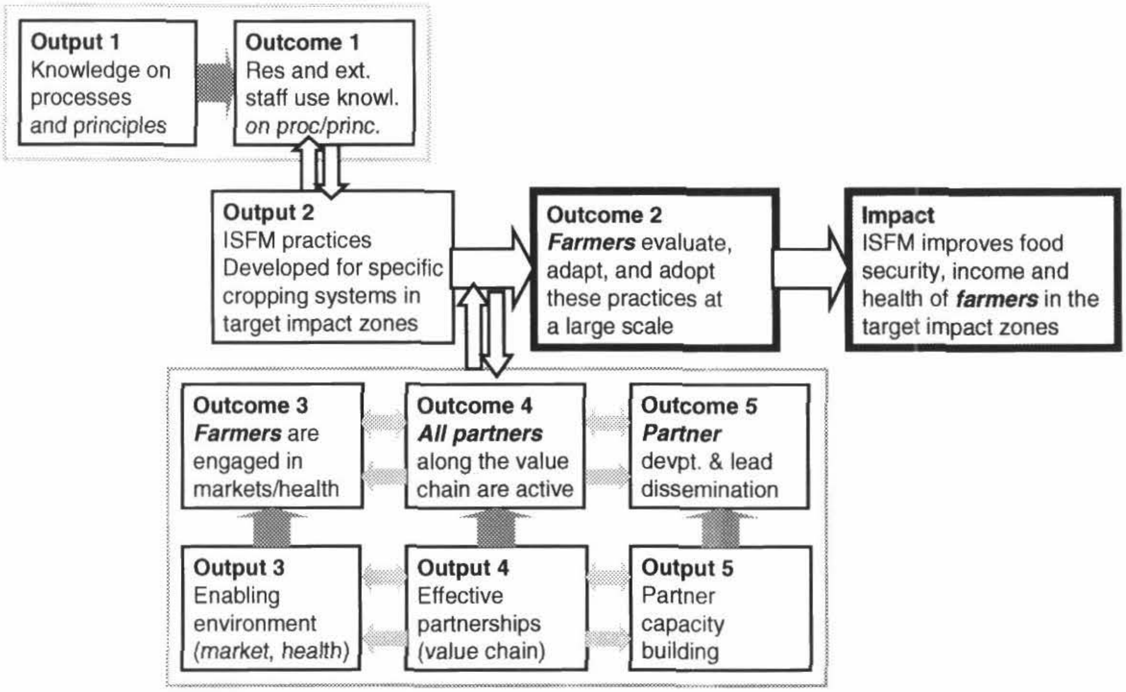

Figure 3: Linkages between the different Outputs, resulting in Outcomes and their relation to the overall goal of the ISFM Program. Light grey arrows show linkages between Outputs/Outcomes and dark grey arrows indicate the translation of Outputs into Outcomes.

An enabling environment for adoption of ISFM options is created in **OUTPUT 3** ***(ENABLING ENVIRONMENT)***, focusing on improved market access and knowledge on health and nutrition of farming communities. These interventions will not only create motivation for adoption of ISFM technologies but contribute directly to improved income and health and nutrition after adoption of such technologies. The intended users of the outcomes of this output are development partners and farming communities with specific attention given to enlightening the ISFM research community on these issues. The required networks for ensuring that outcomes generated in a specific output reach the intended users and logically linked to reach the ultimate Goal of this Program are addressed in **OUTPUT 4** ***(EFFECTIVE PARTNERSHIPS)***. As outcomes move from Output 1 to Output 3, networks of stakeholders become more and more complex and encompassing and ultimately, all value chain actors will be required to achieve the impact that this Outcome line is aiming at. At the center of the research-outcome-impact chain, **OUTPUT 5** ***(STAKEHOLDER CAPACITY)*** addresses the building of human and social capital of all CIAT-TSBF stakeholders for effective research and sustainable management of tropical soils. This is particularly necessary since managing soil fertility for improved livelihoods requires the integration of technical, social, economic and policy issues at multiple scales. To overcome this complexity, research and extension staff need the capacity to generate and share information that will be relevant to other stakeholders working at different scales (i.e., policy makers, farmers).

Since most operations in this Program are supported by specific projects, the operationalization of specific impact pathways will be dependent on the goals and objectives of these projects and will not necessarily cover the entire value chain within a specific project. The overall importance of this Program is then to oversee that the necessary **LINKS ARE CREATED BETWEEN VARIOUS INITIATIVES** operating in similar impact zones to ensure a continuity of partner networks to deliver the required impact. **VARIOUS STAKEHOLDERS** that are currently involved in this Program are detailed in Section 2.4.

The **KEY ASSUMPTIONS** for the 5 Outputs are: (i) security and political stability does not restrict access to target sites and continuation of on-going activities; (ii) Poverty reduction strategies remain central to human development support and funding; (iii) CIAT-TSBF stakeholders remain engaged and show limited staff turnover, (iv) CIAT-TSBF management continues to adapt and innovate in response to changing priorities, and (v) linkages remain maintained among research and development organizations. Other important assumptions are: (i) investments in various aspects of the outcome line are linked in time and space, (ii) large-scale capacity building initiatives are implemented sufficiently fast and in close relationship with development-related investments, and (iii) rural service providers are operational and rural infrastructure is sufficiently developed.

I.4. INTERNATIONAL PUBLIC GOODS

International and regional public goods (IPG) that will be generated through the ISFM Program include:

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

The Institute's comparative advantage is in conducting IPG research on ISFM in farming systems where soil degradation undermines local livelihoods and market opportunities. However, while CIAT-TSBF will focus primarily on strategic, applied, and adaptive research, it is also ready to support technology dissemination and development activities with partners via regional networks and global projects. Much of the research as well as NARES capacity building will be done via the Institute's regional partner network, the African Network for Soil Biology and Fertility (AfNet). Dissemination of findings will happen through effective partnerships with development partners.

II. ANNUAL REPORT 2009 SUMMARY

II.1. ISFM PROGRAM LOGFRAME

Targets	Outputs (Intended users)	Outcome (Impact)
Output 1	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 Targets 2009	Knowledge on **mechanisms** responsible for tolerance to drought and low soil P is available to guide breeding efforts in **legumes** rotated or intercropped with **cereals** in the moist savanna impact zone.	Legume breeders from international and national research systems involve soil scientists in the breeding program in SSA.
	The role of **organic matter** in regulating water, nutrient-limited and actual yield levels underlying **cereal and legume** production quantified in the Sahel and moist savanna impact zones.	Scientist from international and national research systems use information on appropriate organic matter management in their respective research activities.
	Direct inoculation with specific below ground biodiversity microorganisms, e.g., **rhizobia** in legumes systems and **arbuscular mycorrhizal fungi** in banana systems increasing crop productivity tested and demonstrated.	Private sector entrepreneurs avail to farmers micro-organisms that can be applied to crops at establishment.
	Mechanisms underlying the agronomic efficiency of applied **fertilizers** in the context of ISFM understood for **cereal-legume systems** in the Sahel and moist savanna impact zones and for **conservation agriculture** in the moist savanna zone, taking into account variability in soil fertility status at different scales.	Scientist from international and national research systems use information on appropriate fertilizer use for optimizing its agronomic use efficiency in their respective research activities.
	Relationships between soil fertility status and the **nutritional quality** of (bio-fortified) legumes quantified within the Sahel and moist savanna impact zones.	Partners in research for development focus on food quality in addition to production.
Output Targets 2010	**Modeling tools** (e.g., DSSAT, APSIM, NUANCES) for ISFM-based nutrient management used and adapted for **cereal-legume systems** in the Sahel and moist savanna impact zones.	Partners involved in research for development use modeling tools
	Mechanisms underlying the agronomic efficiency of applied fertilizers in the context of ISFM identified and understood for **cassava and rice-based systems** in the humid lowland impact zone and for **banana-based systems** in the mid-altitude impact zone, taking into account variability in soil fertility status at different scales.	Scientist from international and national research systems use information on appropriate fertilizer management for cassava-, rice- and banana-based systems in their respective research activities.
	A set of **mechanistic principles** underlying **ISFM** ***practices for Quesungual*** **agro-forestry systems** in the Central American hillside impact zone.	ISFM for conservation agriculture systems in Central America are assembled.

Targets	Outputs (Intended users)	Outcome (Impact)
	The role of **organic matter** in regulating water, nutrient-limited and actual yield levels underlying **cassava and rice-based systems** in the humid lowland impact zone and **banana-based systems** in the mid-altitude impact zone quantified.	Scientist from international and national research systems use information on appropriate organic matter management in their respective research activities.
	Relationships between **crop nutritional quality** and soil fertility status quantified for the major crops in the **different impact zones**.	Partners use information on the impact of soil fertility status on crop quality in their respective nutritional programs.
Output Targets 2011	The medium- to long term role of **soil organic matter** in regulating soil-based functions (e.g., acidity buffering, ECEC formation) underlying fertilizer use efficiency and crop production quantified for **cereal-legume systems** in the Sahel and moist savanna impact zones.	Partners adapt soil fertility management practices to support specific soil organic matter-related functions.
	Cassava, rice, and banana nutrient requirements and impacts on nutritional quality of respective food products quantified within the respective impact zones.	Stakeholders in research for development focus on food quality in addition to production.
	Modeling tools (e.g., DSSAT, APSIM, NUANCES) for ISFM-based nutrient management used and adapted for **cassava and rice-based** systems in the humid lowland impact zone *[2 yrs is not sufficient to get this output for banana-based systems]*	Partners involved in research for development are using the modeling tools
Output 2	<u>Description</u>: Management practices that are in resonance with the resource-base and socio-economic environment of smallholder farmers. <u>Intended users</u>: CGIAR, ARI, researchers from NARS and local universities, NGOs, farmer groups, private sector agents, extension services, and regional consortia.	<u>Outcome</u>: A large number of farmers in the target impact zones evaluate, adapt, and adopt improved technologies and systems. <u>Impact</u>: Improved technologies and systems, based on ISFM, improve food security, income and health of farmers in the target impact zones.
Output Targets 2009	**Local diagnosis** of soil fertility constraints and farmer understanding of important soil processes underlying ISFM for all impact zones	Scientists blend local and new scientific knowledge in the experimental design
	ISFM practices for **cereal-legume systems** tested, adapted, and validated to farmer conditions in the Sahel and moist savanna impact zones, including issues of **conservation agriculture**	Extension staff and farmers adapt cereal-legume systems and foster access to the inputs needed to improve their productivity
	Trade-off analysis is informing the identification of best ISFM practices for cereal-legume systems in the Sahel and moist savanna impact zones.	Scientists and extension staff use trade-off analysis tools to adapt and validate ISFM practices
Output Targets 2010	**Decision support systems** for locally adapted ISFM practices for **cereal-legume systems** in the Sahel and moist savanna impact zones	Extension service providers use decision support systems for ISFM for cereal-legume systems
	ISFM practices for **cassava and rice systems** tested, adapted, and validated to farmer conditions in the humid lowland impact zone	Extension staff and farmers adapt cassava and rice-based systems and foster access to the inputs needed to improve their productivity
	Trade-off analysis is informing the identification of best ISFM practices for cassava and rice-based systems in the humid lowland impact zone.	Scientists and extension staff use trade-off analysis tools to adapt and validate ISFM practices
Output Targets 2011	**Decision support systems** for locally adapted ISFM practices for **cassava and rice-based systems** in the humid lowland impact zone	Extension service providers use decision support systems for ISFM for cassava and rice-based systems
	ISFM practices for **banana-based systems** tested, adapted, and validated to farmer conditions in the humid lowland impact zone	Extension staff and farmers adapt banana-based systems and foster access to the inputs needed to improve their productivity

Targets	Outputs (Intended users)	Outcome (Impact)
Output 3	Description: Enabling environments for dissemination of ISFM practices, focusing on viable input and output market linkages and appropriate nutritional knowledge and health. Intended users: CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, extension services, policy makers.	Outcome: Farmers are generating more revenue and are knowledgeable about health and nutrition and using that income and knowledge to implement ISFM practices within their farms. Impact: Improved income and health and nutrition for the farmers in the target impact zones through adoption of ISFM-based production systems.
Output Targets 2009	Linkages with the **private sector** to improve access to fertilizer and develop recommendations for its use by farmers and other stakeholders involved in the **Sahel and moist savanna** impact zones.	Private sector partners are actively involved in linking farmers to input and output markets and providing information to farmers on ISFM in the Sahel and moist savanna impact zones.
	Knowledge of extension staff and farmers that are involved in adaptation and dissemination of ISFM practices on appropriate **nutrition and health practices** sufficiently developed in the **Sahel and moist savanna** impact zones.	Extension staff and development partners are disseminating information on appropriate nutrition and health practices in the Sahel and moist savanna impact zones.
Output Targets 2010	Linkages with the **private sector** to improve access to fertilizer and develop recommendations for its use by farmers and other stakeholders involved in the ***humid lowland*** *impact zone.*	Private sector partners are actively involved in linking farmers to input and output markets and providing information to farmers on ISFM in the humid lowland impact zone.
	Knowledge of extension staff and farmers that are involved in adaptation and dissemination of ISFM practices on appropriate **nutrition and health practices** sufficiently developed in the **humid lowland** impact zone.	Extension staff and development partners are disseminating information on appropriate health and nutritional practices in the humid lowland impact zone.
Output Targets 2011	Linkages with the **private sector** to improve access to fertilizer and develop recommendations for its use by farmers and other stakeholders involved in the **mid-altitude** impact zone.	Private sector partners are actively involved in linking farmers to input and output markets and providing information to farmers on ISFM in the humid lowland impact zone.
	Knowledge of extension staff and farmers that are involved in adaptation and dissemination of ISFM practices on appropriate **nutrition and health practices** sufficiently developed in the **mid-altitude** impact zone.	Extension staff and development partners are disseminating information on appropriate health and nutritional practices in the mid-altitude impact zone.
	The relative **role of access to markets** and access to knowledge on **health and nutrition** in adoption of ISFM practices evaluated for all impact zones.	Development partners are using information on the role of access to markets and access to knowledge on health and nutrition in the development of new initiatives aiming at disseminating ISFM.
Output 4	Description: Effective partnerships along each step of the value chain for innovative, effective and efficient dissemination and impact. Intended users: CGIAR, ARIs, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, private sector agents, extension services, policy makers.	Outcome: Partners are involved in addressing all components of the value chains related to the ISFM-based production systems. Impact: Improved ISFM-based production systems contribute to food and nutrition security and income and health of farmers in the target impact zones.
Output Targets 2009	**Strategic alliances** formed for disseminating ISFM practices within **cereal-legume systems** in the Sahel and moist savanna impact zones.	New institutional arrangements catalyze multidisciplinary work and enhance scaling up of ISFM practices in the Sahel and moist savanna impact zones.

Targets	Outputs (Intended users)	Outcome (Impact)
	Best **approaches developed** for disseminating ISFM practices within **cereal-legume systems** in the Sahel and moist savanna impact zones.	Development partners apply best approaches for dissemination of ISFM practices within cereal-legume systems in the Sahel and moist savanna impact zones.
Output Targets 2010	**Strategic alliances** formed for disseminating ISFM practices within **cassava- and rice-based systems** in the humid lowland impact zone.	New institutional arrangements catalyze multidisciplinary work and enhance scaling up of ISFM practices in the humid lowland impact zone.
	Best **approaches developed** for disseminating ISFM practices within **cassava- and rice-based systems** in the humid lowland impact zone	Development partners apply best approaches for dissemination of ISFM practices within cassava- and rice-based systems in the humid lowland impact zone.
Output Targets 2011	**Strategic alliances** formed for disseminating ISFM practices within **banana-based systems** in the mid-altitude impact zone.	New institutional arrangements catalyze multidisciplinary work and enhance scaling up of ISFM practices in the mid-altitude impact zone.
	Best **approaches developed** for disseminating ISFM practices within **banana-based systems** in the mid-altitude impact zone.	Development partners apply best approaches for dissemination of ISFM practices within banana-based systems in the mid-altitude impact zone.
Output 5	Description: Stakeholder capacity to advance the development and adaptation of above outcomes. Intended users: CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, private sector agents, policy makers.	Outcome: Stakeholders are leading the development and dissemination of ISFM practices in the context of initiatives lead by them. Impact: Large-scale impact of ISFM practices in the target impact zones.
Output Targets 2009	Capacity of **agro-input dealers** to support farming communities for implementing ISFM strengthened in all impact zones.	Agro-input dealers advice farming communities on ISFM-related issues.
	Farmer-to-farmer knowledge sharing and extension on ISFM through various facilitated activities in all impact zones	Farmers pay more attention to the sustainability of their farming system in addition to productivity
	Knowledge on principles and processes underlying ISFM practices embedded in soil fertility management **networks and regional consortia**	National system scientists contribute to the development of ISFM practices.
Output Targets 2010	**Curricula and technical manuals** for developing, adapting, evaluating, and disseminating ISFM practices, applicable to all impact zones.	Partners use technical information on ISFM in their specific activities.
	Extension materials for ISFM developed that are specific to the various aspect of drivers of ISFM and for the different impact zones	Farmers and extension staff are using extension materials for adaptation and dissemination of ISFM practices
	Group and degree-related training activities related to specific issues of ISFM development, evaluation, and dissemination for all impact zones.	National partners are actively engaged in the development, adaptation, evaluation, and dissemination of ISFM practices.
Output Targets 2011	**Institutionalization** of knowledge and approaches for developing, adapting, and evaluating ISFM practices within the **national research systems.**	Partners incorporating new knowledge and skills in new proposals and on-going research efforts.
	Institutionalization of knowledge and approaches for evaluating, and disseminating ISFM practices within the governmental and non-governmental **extension systems**.	Governmental and non-governmental extension partners are disseminating ISFM practices in the context of their own initiatives
	Local and national policy is informed about priorities for policy formulation that is required to facilitate the wide-spread adoption of ISFM practices.	ISFM issues are included in local and national policy strategies.

II.2. Output targets for 2009

II.2.1. Processes and principles underlying the functioning of ISFM within the above cropping systems, with a special focus on fertilizer use and resilient germplasm.

II.2.1.1. Knowledge on mechanisms responsible for tolerance to drought and low soil P is available to guide breeding efforts in legumes rotated or intercropped with cereals in the moist savanna impact zone.

Status: 75% Achieved.

Evidence:

→ CIAT-TSBF (2009) Evaluation and scaling up new chemical and biological commercial products for improving and sustaining crop yields in selected agro-ecological zones in sub-Saharan Africa. Progress Report 1 COMPRO, Jan-June 2009.

→ CIAT-TSBF (2009) Evaluation and scaling up new chemical and biological commercial products for improving and sustaining crop yields in selected agro-ecological zones in sub-Saharan Africa, Progress Report 2 COMPRO, July-December 2009.

II.2.1.2.The role of organic matter in regulating water, nutrient-limited and actual yield levels underlying cereal and legume production quantified in the Sahel and moist savanna impact zones.

Status: Fully Achieved.

Evidence:

→ Fonte, S.J., Yeboah, E., Ofori, P., Quansah, G.W., Vanlauwe, B., Six, J. (2009) Fertilizer and residue quality effects on organic matter stabilization in soil aggregates. Soil Science Society Journal of America 73, 961-966.

→ Gentile, R., Vanlauwe, B., van Kessel, C. and Six, J. (2009) Managing N availability and losses by combining fertilizer-N with different quality residues in Kenya. Agriculture, Ecosystems and Environment 131, 308–314.

II.2.1.3. Mechanisms underlying the agronomic efficiency of applied fertilizers in the context of ISFM understood for cereal-legume systems in the Sahel and moist savanna impact zones and for conservation agriculture in the moist savanna zone, taking into account variability in soil fertility status at different scales.

Status: Fully Achieved.

Evidence:

→ Kihara, J., Vanlauwe, B.Waswa, B., Kimetu, J.M., Chianu, J. and Bationo, A. (2010) Strategic phosphorus application in legume-cereal rotations increases land productivity and profitability in western Kenya. Experimental Agriculture 46, 35-52.

→ Chivenge, P., Vanlauwe, B., Gentile, R., Wangechi, H., Mugendi, D., van Kessel, C. and Six, J. (2009) Organic and mineral input management to enhance crop productivity in Central Kenya. Agronomy Journal 101, 1266-1275.

→ Chikowo, R., Corbeels, M., Mapfumo, P., Tittonell, P., Vanlauwe, B. andGiller, K.E. (2009) Nitrogen and phosphorus capture and recovery efficiencies, and crop responses to a range of soil fertility management strategies in sub-Saharan Africa. Nutrient Cycling in Agroecosystems (published online).

II.2.1.4. Relationships between soil fertility status and the nutritional quality of (bio-fortified) legumes quantified within the Sahel and moist savanna impact zones.

Status: >50% Achieved.

Evidence:
→ CIALCA (2009), Final Report of the first phase of the Consortium for Improving Agriculture-based Livelihoods in Central Africa (CIALCA), CIAT-TSBF, IITA, and Bioversity.

II.2.2. Management practices adapted to the resource-base and socio-economic environment of smallholder farmers.

II.2.2.1. Local diagnosis of soil fertility constraints and farmer understanding of important soil processes underlying ISFM for all impact zones.

Status: Fully Achieved.

Evidence:
→ Mairura, F.S., Mugendi, D.N., Mwanje, J.I., Ramisch, J.J., Mbugua, P.K., Chianu, J.N. (2007) Scientific evaluation of smallholder land use knowledge in Central Kenya. Land Degradation and Development.
→ Tittonell, P., Muriuki, A., Shepherd, K.D., Mugendi, D., Kaizzi, K.C., Okeyo, J., Verchot, L., Coe, R. and Vanlauwe, B. (2010) The diversity of rural livelihoods and their influence on soil fertility in agricultural systems of East Africa- A typology of smallholder farms. Agricultural Systems 103, 83-97.
→ Masvaya E.N., Nyamangara J., Nyawasha R.W., Zingore S., Delve R.J. and Giller, K.E. (2009) Effect of farmer management strategies on spatial variability of soil fertility and crop nutrient uptake in contrasting agro-ecological zones in Zimbabwe. Nutrient Cycling in Agroecosystems (published online).

II.2.2.2. ISFM practices for cereal-legume systems tested, adapted, and validated to farmer conditions in the Sahel and moist savanna impact zones, including issues of conservation agriculture.

Status: Fully Achieved.

Evidence:
→ Tabo, R., Bationo, A., Hassane, O., Amadou, B., Fosu, M., Kabore, S.S., Fatondji, D., Korodjouma, O., Abdou, A. and Koala, S. (2009) Fertilizer microdosing for the prosperity of resource poor farmers: a success story. Proceedings of the Workshop on Increasing the Productivity and Sustainability of Rainfed Cropping Systems of Poor, Smallholder Farmers, Tamale, Ghana, 22-25 September 2008.
→ Kiharą, J., Bationo, A., Waswa, B. and Okeyo, J. (2009) Tillage, residue management and fertilizer application effects on crop water productivity in western Kenya. Proceedings of the

Workshop on Increasing the Productivity and Sustainability of Rainfed Cropping Systems of Poor, Smallholder Farmers, Tamale, Ghana, 22-25 September 2008.

→ Mucheru-Muna, M., Pypers, P., Mugwe, J., Kung'u, J., Mugendi, D., Merckx, R. and Vanlauwe, B. (2010) A novel maize-legume-intercropping system increases crop yields and economic returns in the highlands of Central Kenya. *Field Crops Research 115: 132–139.*

→ Wasike, V.W., Lesueur, D., Wachira, F.N., Mungai, N.W., Mumera, L.M., Sanginga, N., Mburu, H.N., Mugadi, D., Wango, P. and Vanlauwe, B. (2009) Genetic diversity of indigenous Bradyrhizobium nodulating promiscuous soybean [Glycine max (L) Merr.] varieties in Kenya: Impact of phosphorus and lime fertilization in two contrasting sites. *Plant and soil 322: 151-163.*

→ Vandeplas, I., Vanlauwe, B., Driessens, L., Merckx, R. and Deckers, J. (2010) Reducing labour and input costs in soybean production by smallholder farmers in south-western Kenya. Field Crops Research 117, 70-80.

II.2.2.3. Trade-off analysis is informing the identification of best ISFM practices for cereal-legume systems in the Sahel and moist savanna impact zones.

Status: Fully Achieved.

Evidence:

→ Tittonell, P., Vanlauwe, B., Corbeels, M. and Giller, K.E. (2008) F Yield gaps, nutrient use efficiencies and response to fertilisers by maize across heterogeneous smallholder farms of western Kenya. Plant and Soil 313, 19-37.

→ Zingore, S., González-Estrada, E., Delve, R.J., Herrero, M., Dimes, J.P. and Giller, K.E. (2009) An integrated evaluation of strategies for enhancing productivity and profitability of resource-constrained smallholder farms in Zimbabwe. Agricultural Systems 101, 57–68.

→ Giller, K.E., Tittonell, P. , Rufino, M. , van Wijk, M.T. , Mapfumo, P. ,M. Herrero, Corbeels, M., Pacini, C., Smith, J. , Karanja, S. , Quiroz, C. , K'ungu, J. , Baijukya, F. , Kaizzi, C., Mwale, M., Sanogo, O.M., N. de Ridderl, S. Zingore and B. Vanlauwe. 2010. Communicating complexity: Integrated assessment of trade-offs within African farming systems to support development policy. Agricultural Systems (In press).

II.2.3. Enabling environments for dissemination of ISFM practices, focusing on viable input and output market linkages and appropriate nutritional knowledge and health.

II.2.3.1. Linkages with the private sector to improve access to fertilizer and develop recommendations for its use by farmers and other stakeholders involved in the Sahel and moist savanna impact zones.

Status: Fully Achieved.

Evidence:

→ Chianu, J. Ohiokpehai,O., Vanlauwe, B., Okoth, P., Roing, K., Adesina, A., Naidoo, P., Opondo, J. and Sanginga, N. (2007) A model for promoting a versatile crop that has remained minor: the case of soybean in Kenya, Poster rewarded at the GFAR meeting in India, 2007.

→ CIAT-TSBF, (2009) Final Project Report (Phase II) for Project on: Developing the multipurpose soybean value chain to increase income of smallholder farm families and other rural entrepreneurs in East Africa, supported by the Rockefeller Foundation.
→ Chianu, J. N., Ohiokpehai, O., Vanlauwe, B., Adesina, A., De Groote, H., and Sanginga, N. (2009) Promoting a Versatile but yet Minor Crop: Soybean in the Farming Systems of Kenya. Journal of Sustainable Development in Africa 10,324-344.
→ CIAT-TSBF, (2009) Strengthening Agro-dealer Technical Capacity in Integrated Soil Fertility Management in Western Kenya', Final project report - February 2008 – January 2009, Implemented by the Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture (CIAT-TSBF) with assistance of the Agricultural Market Development Trust (AGMARK).

II.2.3.2. Knowledge of extension staff and farmers that are involved in adaptation and dissemination of ISFM practices on appropriate nutrition and health practices sufficiently developed in the Sahel and moist savanna impact zones.

Status: Fully Achieved.

Evidence:
→ CIAT-TSBF, (2009) Final Project Report (Phase II) for Project on: Developing the multipurpose soybean value chain to increase income of smallholder farm families and other rural entrepreneurs in East Africa, supported by the Rockefeller Foundation.
→ CIALCA, (2009) Final Report of the first phase of the Consortium for Improving Agriculture-based Livelihoods in Central Africa (CIALCA), CIAT-TSBF, IITA, and Bioversity.
→ Chianu, J.N. (2009) 'Changing Lives through Soybean in Kenya'. Video produced by CIAT-TSBF.

II.2.4. Effective partnerships along each step of the value chain for innovative, effective and efficient dissemination and impact.

II.2.4.1. Strategic alliances formed for disseminating ISFM practices within cereal- legume systems in the Sahel and moist savanna impact zones.

Status: Fully Achieved.

Evidence:
→ Chianu, J. N., Ohiokpehai, O., Vanlauwe, B., Adesina, A., De Groote, H., and Sanginga, N. (2009) Promoting a Versatile but yet Minor Crop: Soybean in the Farming Systems of Kenya. Journal of Sustainable Development in Africa 10,324-344.
→ Crops Management Directorate, (2009) Strategy for Soyabean Production and Marketing in Kenya, Ministry of Agriculture Kenya.
→ CIAT-TSBF, (2009) Final Project Report (Phase II) for Project on: Developing the multipurpose soybean value chain to increase income of smallholder farm families and other rural entrepreneurs in East Africa, supported by the Rockefeller Foundation.
→ CIAT-TSBF, (2010) CSO Project Final Report South Kivu Province, DRC.

II.2.4.2. Best approaches developed for disseminating ISFM practices within cereal-legume systems in the Sahel and moist savanna impact zones.

Status: Fully Achieved.

Evidence:
→ Tabo, R., Bationo, A., Kabore, S.S., Hassane, O., Amadou, B., Siebou, P., Ouedraogo, S., Abdou, A., Fatondji, D., Sigue, H., Koala, S., Fosu, M. and Fredah, M. (2009) Institutional innovation: the potential of the warrantage system to underpin the green revolution in Africa Proceedings of the Workshop on Increasing the Productivity and Sustainability of Rainfed Cropping Systems of Poor, Smallholder Farmers, Tamale, Ghana, 22-25 September 2008.
→ Mugwe, J., Mucheru-Muna, M., Mugendi, D., Kung'u, J., J. Bationo, A. and Mairura, F. (2009) Adoption potential of selected organic resources for improving soil fertility in the central highlands of Kenya Agroforest Syst 76,467–485.

II.2.5. Stakeholder capacity to advance the development and adaptation of above outcomes.

II.2.5.1. Capacity of agro-input dealers to support farming communities for implementing ISFM strengthened in all impact zones.

Status: Fully Achieved.

Evidence:
→ CIAT-TSBF, (2008) Report of the Agro-dealer training workshop on Integrated Soil Fertility Management Kisumu, Western Kenya, 13–15 November 2008.
→ CIAT-TSBF and ARI, (2009) Report of the Agro-Input-Dealer training workshop on Integrated Soil Fertility Management, Morogoro, Tanzania, 5-6th March 2009 and Mikumi, Tanzania, 9-10th March 2009.
→ CIAT-TSBF, (2009) Strengthening Agro-dealer Technical Capacity in Integrated Soil Fertility Management in Western Kenya', Final project report - February 2008 – January 2009, Implemented by the Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture (CIAT-TSBF) with assistance of the Agricultural Market Development Trust (AGMARK).

II.2.5.2. Farmer-to-farmer knowledge sharing and extension on ISFM through various facilitated activities in all impact zones.

Status: Fully Achieved.

Evidence:
→ Donnelly, J. (2008) Soils – The magic of soybeans: Giving life back to depleted soils (Significant contribution of Chianu Jonas in pages 20–23). In: How farmers and researchers are finding solutions to Africa's Hunger 65 pp. CGIAR Secretariat, A Unit of the CGIAR System Office, 1818 H Street, NW Washington DC 20433, USA.

II.2.5.3. Knowledge on principles and processes underlying ISFM practices embedded in soil fertility management networks and regional consortia

Status: Fully Achieved.

Evidence:

→ Vanlauwe, B., .Bationo, A., Chianu,J., Giller, K.E., Merckx, R., Mokwunye, U., Ohiokpehai, O, Pypers, P., Tabo, R., Shepherd, K., Smaling, E Woomer, P.L. and Sanginga, N. (2010) Integrated soil fertility management: Operational definition and consequences for implementation and dissemination. Outlook on Agriculture (In press).

→ CIAT-TSBF, (2009) Integrated Soil Fertility Management in Africa: Principles, Practices and Developmental Process. Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture, Nairobi 252 pp.

→ Enhancing Networking in Soil and Water Management Side Event at the African Crop Science Society Conference 29th September, 2009, Southern Sun Hotel, Cape Town, South Africa CONVENORS: Sokoine University of Agriculture; University of Zambia, University of Malawi, RUFORUM, TSBF-AFNET and SADC; Supported by SADC ICART1 through the Networking Window.

II.3. PROJECT OUTCOME FOR 2009

CIAT-TSBF Integrated Soil Fertility Management Research Informs Africa Fertilizer Use Policy

Outcome statement

New institutional arrangements catalyze multidisciplinary work and enhance scaling up of technologies and best practices.

Research planning and documentation

Output target 2009: Strategies for institutionalizing of participatory NRM approaches and methodologies established. From Objective 3 of the 2007-2009, CIAT project PE-2: Integrated Soil Fertility Management in the Tropics (page. 125)

Adoption and use

In 2009, the International Fertilizer Industry Association (IFA) identified ISFM as part of their communication tool to disseminate knowledge and information to farmers, students, researchers, extension personnel, agribusiness representatives and policy makers. A publication, led by IFA and co-authored by TSBF, presents an overview of Integrated Plant Nutrient Management (IPNM) and Integrated Soil Fertility Management (ISFM). IPNM focuses on efficient use of all available sources of essential nutrients for crops. ISFM is the application of soil fertility management practices, and the knowledge to adapt these to local conditions, which optimize fertilizer and organic resource use efficiency and crop productivity. These practices necessarily include appropriate fertilizer and organic input management in combination with the utilization of improved germplasm. Combining these two concepts offers a holistic approach to providing plant nutrients and maintaining and/or enhancing soil productivity. Although the IFA report is targeted to non-experts, the IFA hopes that it will help scientists to explain key concepts to the general public and to future generations of students. Crop production is very complex. Good farmers are both artists and scientists, who must master a wide range of technical issues. Increasing nutrient use efficiency is just one element, but it lays the foundation for other aspects of good agricultural practices. The booklet focuses on how various nutrient sources can be used together. For example, organic sources of nutrients also add organic matter to the soil, which helps improve soil moisture retention and resistance to wind erosion, among other benefits. Other ISFM components, such as germplasm tolerant to adverse soil and/or climatic conditions, can increase the demand for nutrients and thus improve the efficiency of IPNM interventions. Over the past 20 years, TSBF has helped usher in the new ISFM paradigm. ISFM moves away from the earlier focus on inorganic fertilizers and puts greater emphasis on the role of organic matter and soil organisms in sustainable farming. CIAT-TSBF has made significant progress in both these areas of ISFM with partnered field research activities in numerous African countries. TSBF has advanced discussion of ISFM not only at numerous international scientific but also policy development meetings. In addition to IFA, the Alliance for a Green Revolution in Africa (AGRA) has also adopted the ISFM approach within its soil health program. ISFM has also guided numerous AGRA investments in Ghana, Kenya, Nigeria, Rwanda, etc.

Significance of outcome

The African Fertilizer Summit, held in 2006 in Abuja, and endorsed by the African Heads of State, resolved to increase fertilizer use in Sub-Saharan Africa from a current average of 8 kg fertilizer nutrients per hectare to 50 kg per hectare. A common misconception persists that supporting the use of manufactured fertilizers means opposing the use of organic sources of nutrients. Most agronomists, however, agree that optimal nutrient management entails starting with on-farm sources of nutrients and then supplementing them with manufactured fertilizers. The integration of organic and inorganic sources of nutrients should also be seen in the context of overall crop production, which includes the selection of crop varieties, pest control, efficient use of water and other aspects of integrated farm management. TSBF work with the IFA and AGRA expands the reach of ISFM. The IFA is a non-profit organization representing the global fertilizer industry. The over 500 members in about 85 countries serve farmers as they meet the world's growing food, feed, fiber and bioenergy needs. About half of members are based in developing countries. IFA addresses all activities related to the production, trade, transport and distribution of every type of fertilizer, their raw materials and intermediates. AGRA is a substantial network of national and international development partners.

Evidence:

Alley, M.M. and Vanlauwe, B.(2009) The Role of Fertilizers in Integrated Plant Nutrient Management, First edition, International Fertilizer Association, Paris, France, CIAT-TSBF, Nairobi, Kenya. 59p. http://www.fertilizer.org/ifa/Home- Page/LIBRARY/Publication-database.html/The-Role-of-Fertilizers-in-Integrated-Plant-Nutrient-Management.html

Vanlauwe et al. (forthcoming). Integrated soil fertility management: Operational definition and consequences for implementation and dissemination. Outlook on Agriculture, accepted for publication in March 2009. 30p.

AGRA, (2009) Strategy for an African Green Revolution. Nairobi. 20p. http://www.agra-alliance.org/section/about/agrastrategy

II.4. Publications for 2009

Refereed Journal Articles

Abdulai, A. and Birachi, E.A. (2009) Choice of Coordination Mechanism in the Kenyan Fresh Milk Supply Chain. Review of Agricultural Economics 31, 103–121.

Akinnifesi, F.L., Sileshi, G., Franzel,S., Ajayi, O.C., Harawa ,R., Makumba, A., Chakeredza, S., Mngomba, S., De Wolf J.J. and Chianu, J.N. (2009) On-farm assessment of legume fallows and other soil fertility management options used by smallholder farmers in southern Malawi. Agricultural Journal 4, 260–271.

Arango-Ulloa, J., Bohorquez, A., Duque, C. M. and Maass, B. L. (2009) Diversity of the calabash tree (Crescentia cujete L.) in Colombia. Agroforest Syst 76, 543–553.

Bediako, J. A., Chianu, J.N., Dadson, J. A. (2009) Crop storage efficiency and market competitiveness: Case of groundnut and cowpea in Ghana. African Journal of Marketing Management 13, 81–88.

Chianu, J.N., Ohiokpehai, O., Vanlauwe, B., Adesina, A., De Groote, H. and Sanginga, N. (2009) Promoting a Versatile but yet Minor Crop: Soybean in the Farming Systems of Kenya, Journal of Sustainable Development in Africa 10,324–344.

Chikowo, R., Corbeels, M., Mapfumo, P., Tittonell, P., Vanlauwe, B., Giller, KE. (2009) Nitrogen and phosphorus capture and recovery efficiencies and crop responses to a range of soil fertility management strategies in sub-Saharan Africa. Nutrient Cycling in Agroecosystems.

Chivenge, P., Vanlauwe, B., Gentile, R., Wangechi, H ., Mugendi, D., van Kessel, C. and Six, J. (2009) Organic and mineral input management to enhance crop productivity in Central Kenya Agronomy Journal 101, 1266-1275.

Fonte, S.J., Yeboah, E., Ofori, P., Quansah, G.W., Vanlauwe, B., Six, J. (2009) Fertilizer and residue quality effects on organic matter stabilization in soil aggregates. Soil Science Society Journal of America 73, 961-966.

Gentile, R., Vanlauwe, B., van Kessel, C., Six, J.(2009) Managing N availability and losses by combining fertilizer-N with different quality residues in Kenya Agriculture, Ecosystems and Environment 131, 308–314.

Jefwa , J., Mungatu, J., Okoth, P., Muya, E., Roimen, H., Njuguini, S. (2009) Influence of land use types on occurrence of Arbuscular mycorrhizal fungi in the high altitude regions of Mt Kenya. Journal of Tropical and sub-Tropical Agroecosystems 11, 277-290.

Kihara, J., Vanlauwe, B., Waswa, B., Kimetu, J.M., Chianu, J. and Bationo, A. (2009) Strategic phosphorus application in legume-cereal rotations increases land productivity and profitability in western Kenya. Experimental Agriculture 46, 35-52.

Lesueur, D., Founoune, H., Lebonvallet, S., Sarr, A. (2009) Effect of rhizobial inoculation on growth of Calliandra tree species under nursery conditions. New Forests 39, 129-137.

Masvaya, E.N., Nyamangara, J., Nyawasha, R.W., Zingore, S., Delve, R.J. and Giller, K.E. (2009) Effect of farmer management strategies on spatial variability of soil fertility and crop nutrient uptake in contrasting agro-ecological zones in Zimbabwe. Nutrient Cycling in Agroecosystems.

Mugwe, J., Mugendi, D., Mucheru-Muna, M., Merckx, R., Chianu, J. and Vanlauwe, B. (2009) "Determinants of the decision to adopt integrated soil fertility management practices by smallholder farmers in the central highlands of Kenya". Experimental Agriculture 45, 61 – 75.

Mugwe, J., Mucheru-Muna, M., Mugendi, D., Kung'u, J., Bationo, A., Mairura, F. (2009) Adoption potential of selected organic resources for improving soil fertility in the central highlands of Kenya. Agroforest Systems 76,467–485
Rivera, M., Amézquita Collazos, E., Rao, I., Menjivar Flores, J.C. (2009) Spatial and daily variability of soil moisture content in three agroforestry systems. Acta Agronómica, National University of Colombia 58, 75-83.
Sanchez, P.A., Ahamed, S., Carré, F., Hartemink, A.E., Hempel, J., Huising, J., Lagacherie, P., McBratney, A.B., McKenzie, N.J., Mendonça-Santos, L., Minasny, B., Montanarella, L., Okoth, P., Palm, C.A., Sachs, J.D., Shepherd, K.D., Vagen, T., Vanlauwe, B., Walsh, M.G., Winowiecki ,L.A., Zhang, G. (2009) Digital Soil Map of the World. Science 325, 680-681.
Wasike, V.W., Lesueur, D., Wachira, F.N., et al. (2009) Genetic diversity of indigenous *Bradyrhizobium nodulating* promiscuous soybean (Glycine max (L) Merr.) varieties in Kenya: Impact of phosphorus and lime fertilization in two contrasting sites. Plant and soil 322,151-163.
Zingore, S., Gonzalez-Estrada, E., Delve, R.J., Herrero, M., Dimes, J.P. and Giller, K.E. (2009) An integrated evaluation of strategies for enhancing productivity and profitability of resource-constrained smallholder farms in Zimbabwe. Agricultural Systems 101, 57-68.

Book chapters and workshop proceedings

Castro, A., Rivera, M., Ferreira, O., Pavón, J., García, E., Amézquita, E., Ayarza, M., Barrios, E., Rondón, M., Pauli, N., Baltodano, M.E., Mendoza, B., Wélchez, L.A., Cook, S., Rubiano, J., Johnson N. and I. Rao. (2009) Improving the efficiency of rain water use on hillsides in the sub-humid tropics: agricultural and environmental benefits of Quesungual system. In: Stockholm International Water Institute. Responding to global changes: accessing water for the common good. Proceedings of the SIWI World Water Week 2009, Stockholm, Sweden, 16-22 August 2009. pp 101-102.
Castro, A., Rivera, M., Ferreira, O., Pavón, J., García, E., Amézquita, E., Ayarza, M., Barrios, E., Rondón, M., Pauli, N., Baltodano, M.E., Mendoza, B., Wélchez, L.A., Cook, S., Rubiano, J., Johnson N. and I. Rao. (2009) Quesungual slash and mulch agroforestry system improves rain water productivity in hillside agroecosystems of the sub-humid tropics. In: Humphreys, E. and R.S. Bayot (eds.). Increasing the productivity and sustainability of rainfed cropping systems of poor smallholder farmers. Proceedings of the CGIAR Challenge Program on Water and Food International Workshop on Rainfed Cropping Systems, Tamale, Ghana, 22-25 September 2008. pp 89-97.
Chianu, J.N. (2009) 'Changing Lives through Soybean in Kenya'. Video produced by CIAT-TSBF. Crops Management Directorate, 2009, Strategy for Soyabean Production and Marketing in Kenya, Ministry of Agriculture Kenya. Enhancing Networking in Soil and Water Management Side Event at the African Crop Science Society Conference 29th September, 2009, Southern Sun Hotel, Cape Town, South Africa CONVENORS: Sokoine University of Agriculture; University of Zambia, University of Malawi, RUFORUM, TSBF-AFNET and SADC; Supported by SADC ICART1 through the Networking Window.
Chianu, J.N, Njuki, J., Birachi, E., Alonso, G., Lundy, M., Kirkby, R., Buruchara, R., Ohiokpehai, O., Vanlauwe, B. and Sanginga, N. (2009) Agricultural Market Development: A synthesis of CIAT's approach, priorities, experiences and case studies. Paper presented at conference on 'Towards Priority Actions for Market Development for

African Farmers' held at Safari Part Hotel, Thika Road, Nairobi, 13–15 May 2009, organized by ILRI/AGRA.

Chianu, J.N., Vanlauwe, B., Adesina, A., Chianu Justina, N., Sanginga, N. (2009) Model for agricultural market creation in Africa: soybean in Kenya. Paper presented at the World Soybean Research Conference VIII (Theme: "Developing a global soy blueprint for a safe, secure and sustainable supply") held in Beijing, China, 10–15 August 2009.

CIAT-TSBF and ARI, (2009) Report of the Agro-Input-Dealer training workshop on Integrated Soil Fertility Management, Morogoro, Tanzania, 5th-6th March 2009 and Mikumi, Tanzania, 9-10th March 2009.

Hallensleben, M.A., Polreich, S., Heller, J. and Maass, B.L. (2009) Assessment of the importance and utilization of cowpea (Vigna unguiculata L. Walp.) as leafy vegetable in small-scale farm households in Tanzania – East Africa. Paper presented at the Conference on International Research on Food Security, Natural Resource Management and Rural Development held at the University of Hamburg, October 6-8, 2009

Huising, J., Cares, J., Kimenju, J., Saxena, K.G., Gnonhouri, P., Navarro, F., Swibawa, G., Okoth, P., Mung'atu, J. (2009) Using nematode functional group abundance as soil quality indicators in tropical ecosystems. Diversitas Open Science Conference 2, Cape Town, 13-16 Oct. 2009. Book of Abstracts, p. 131

Jefwa, J.M., Sturmer, S., Balakrishna Serani, S., Varela, L., Huising, J., Okoth, P., Mung'atu, J., Ichami, S. (2009) Can arbuscular mycorrhizal fungi (AMF) be indicators of soil quality? Diversitas Open Science Conference 2, Cape Town, 13-16 Oct. 2009. Book of Abstracts, p. 148

Kihaṛa, J., Bationo, A., Waswa B. and Okeyo, J. (2009) Tillage, residue management and fertilizer application effects on crop water productivity in western Kenya. Proceedings of the Workshop on Increasing the Productivity and Sustainability of Rainfed Cropping Systems of Poor, Smallholder Farmers, Tamale, Ghana, 22-25 September 2008

Mugabo, R.J., Tollens, E., Chianu, J.N. and Vanlauwe, B. (2009) Farm-level incentives for the integration of soybean (Glycine Max) into cropping systems of Rwanda, Paper presented at a conference on Agriculture for Development in Sub-Saharan Africa, Nairobi, 27–28 May 2009

Ojo, O.D., Atobatele, J.T. and Chianu, J. N. (2009) Integrated harvesting techniques for African egg plant. Paper presented at the All Africa Horticultural Conference held from 31 August to 4 September 2009 at Safari Park hotel, Nairobi, Kenya.

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Rao, I.M. (2009) Essential plant nutrients and their functions. Centro Internacional de Agricultura Tropical (CIAT), Working Document No. 36. Cali, Colombia. 36 p.

Tabọ, R., Bationo, A., Hassane, O., Amadou, B., Fosu, M., Sawadogo Kabore, S., Fatondji, D., Korodjouma, O., Abdou, A., Koala, S. (2009) Fertilizer microdosing for the prosperity of resource poor farmers: a success story. Proceedings of the Workshop on Increasing the Productivity and Sustainability of Rainfed Cropping Systems of Poor, Smallholder Farmers, Tamale, Ghana, 22-25 September 2008

Tabọ, R., Bationo, A., Sawadogo K., S., Hassane, O., Amadou, B., Siebou, P., Ouedraogo, S., Abdou, A., Fatondji, D., Sigue, H., Koala, S., Fosu, M., Maina, F. (2009) Institutional innovation: the potential of the warrantage system to underpin the green revolution in Africa. Proceedings of the Workshop on Increasing the Productivity and Sustainability of Rainfed Cropping Systems of Poor, Smallholder Farmers, Tamale, Ghana, 22-25 September 2008

Other Publications (progress reports, posters and internal seminars)

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Okonya, J., Omadi, R., Polreich, S. and Maass, B.L. (2009) "How does traditional harvesting of young leaves for vegetable use affect seed yields of cowpea variety mixtures in Eastern Uganda?" Poster presented at the conference on Biophysical and socio-economic frame conditions for the sustainable management of natural resources at Tropentag, October 6-8, Hamburg, Germany.

Rivera, M., Amézquita, E., and I.M. Rao. (2009) Reducing erosion and improving crop water productivity: Quesungual slash and mulch agroforestry system (QSMAS). Poster paper presented at the 4th Scientific Posters Exhibit of CIAT, May 18-22, in Palmira, Colombia.

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II.5. PROJECTS OPERATIONAL IN 2009

ACTIVE TSBF BUDGET CODES – 2009

	Budget Code	Project title	Donor	Budget in 2008 (USD)
1	TS01	Integration CIAT-TSBF Holdback	CIAT	90,000
2	TS02	CIDA-Funds to Africa	CIDA	119,000
3	TS10	USAID's Funds to TSBF	USAID	18,719
4	TS15	Bridging funds	CIAT	29,500
5	TS25	France CIRAD Scientist	MOFA - France	5,000
6	TSA42	Scaling up livelihood impacts through farmer organization and access to market	KILIMO	227,329
7	TSA56	RF - Soybean Processing and Utilization for Improving the Health and Nutrition of Rural Households in HIV/AIDS affected areas of Kenya-PHASE 2	Rockefeller Foundation	375,104
8	TSA63	WOTRO-More Cropping Per Dropping: Optimizing the Water and Nitrogen use efficiency $ Crop Residue Management for Water Conservation Agriculture	WOTRO	12,116
9	TSA67	Increasing Total Farm Productivity in Vulnerable Production Systems in Mozambique through Improved Germplasm Water and Nutrient use efficiencies	AUSTRIA	177,707
10	TSA80	ICRISAT - Enhancing Rainwater and Nutrient Use Efficiency for Improved Crop Productivity, farm Income and Rural Livelihoods in the Volta Basin	Sub-contract from ICRISAT	52,425
11	TSA81	RF - Exploring the multiple potentials of soybeans in enhancing rural livelihoods and small Industry in East Africa	Rockefeller Foundation	226,243
12	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
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	TSB37	Breaking the unholy alliance of food insecurity, poverty and environmental degradation in Chitekwere EPA (Lilongwe ADD): Empowering farmers with soil, water and nutrient enhancing technologies for increased productivity	BIOFORSK	2,036
16	TSB41	Accelerated Uptake & Utilization of Soil Fertility Management Best-Bets Practices in eastern & Central Region.	ASARECA	99,858
17	TSB47	Promoting Conservation Agriculture to Improve Land Productivity and Profitability among Smallholder Farmers in Western Kenya	KILIMO TRUST	18,408

18	TSB51	A Globally Integrated African Soil Information Service (AFSIS)	AGRA	248,352
19	TSB57	Building Impact Pathways for Improving Livelihoods in Musa-based Systems in Central Africa	Sub-contract from Bioversity-International	203,000
20	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	39,875
21	TSB64	Facilitating the Adoption of Conservation Agriculture by Resource –Poor Smallholder Farmers in Southern Africa.	CIMMYT	8,022
22	TSB68	Kano-Katsina-Maradi Pilot Learning Site KKM PLS	Sub-contract from INRAN	20,000
23	TSB69	Sustaining Crop Yields In Selected Agro-Ecological Zones in Sub –Saharan Africa.	BMGF	1,842,999
24	TSB73	Improving Farms Livelihoods through Multi-stakeholder Innovation Platforms for linking smallholder farmers to research, Extension and Business Development Services.	ADA	138,412
25	TSB76	Tropical Soil Biology Fertility Institute-Operations	IDRC	23,938
26	TSB78	To Implement activities as task force lead Institution under the IITA as lead Institution (LI) at the Kano-Katsina Maradi Pilot Learning Site (KKM PLS) of the Sub Saharan Africa Challenge Programme (SSA CP)	Sub-contract from IFDC-	40,000
27	TSB82	Efficient water and nutrient use in cereal grains systems in market based conservation agriculture systems	Sub-contract from IITA SSA-CP	411,840
28	TSB84	Improving Agriculture –based Livelihoods in Central Africa through Sustainably Increased System Productivity to Enhance income, Nutrition Security and the environment -CIALCA II.	AGCD	678,956
29	TSB90	Enhancing Grain Legumes Productivity, and Production and the incomes of Poor Farmers in Drought-prone Areas of Sub-Saharan Africa and South Asia	Sub-contract from ICRISAT-	577,197
30	TSB92	Improving Farmers Livelihoods through the Adoption of Legume Based Soil Fertility Restoration Technologies in Kenya, Uganda and Tanzania	OPEC	28,899
31	TSB94	Improving and Strengthening Rural Community Access to Agricultural and Soil Fertility Information in Korogwe District, Tanzania	CTA	29,709
32	TSB96	Effects of Soil Fertility Interventions on Soil Aggregation and Organic Matter Incorporation and Stabilization: The Role of Soil Macrofauna	Sub-contract from UCLA	5,795
33	TSB98	Strengthening Agrodealers Technical Capacity in Integrated Soil Fertility Management (ISFM): A case of Kilosa and Morogoro Districts in Tanzania	Sub-contract from CNFA-	18,552
34	NSD32N / NSA03	Quesungual slash and mulch agroforestry system (QSMAS): Improving crop water productivity, food security and resource quality in the sub-humid tropics	CPWF	6,500
		TOTAL		**6,051,694**

II.6. STAFF LIST

TSBF Institute – Africa Staff

TSBF Institute - Director		
Sanginga, Nteranya	Soil Microbiologist	50%
Program Leader		
Vanlauwe, Bernard	Soil Scientist	75%
Senior Staff		
Birachi Eliud	Market Economist	50%
Chianu, Jonas	Socio Economist	75%
Corbeels, Marc	Soil scientist, modeler	75%
Hermann, Laetitia	Microbiology Engineer	100%
Huising, Jeroen	BGBD Coordinator (GIS Scientist))	25%
Jefwa, Joyce	Microbiologist	100%
Lesueur, Didier	Microbiologist	100%
Maass, Brigitte	Forage Agronomist	50%
Nyagaya, Martha	Nutritionist	25%
Ohiokpehai, Omo[1]	Food & Nutrition Scientist	100%
Pypers, Pieter	Soil scientist	100%
Roing, Kristina	Agronomist	50%
Saidou, Koala	African Network Coordinator	50%
Vanlauwe, Bernard	Soil Scientist	75%
Zingore Shamie	Soil Scientist	50%
Consultants		
Woomer, Paul	Soil Scientist, ISFM project	100%
Research Assistants		
Adolwa Ivan	Network Assistant	100%
Chirasha, Matthews	Soybean sector dev. officer	100%
Bontamba Thomas	Agronomist, DR Congo	100%
Gahigi Aimable	Research Asst, Kigali	100%
Ekofo Joseph	Collective Action Facilitator, DR Congo	100%
Kankwatsa, Peace	Research Asst, Kampala	100%
Kasereka, Bashikwabo	Research Asst, DR Congo	100%
Lodi-Lama, Jean-Paul	Research Asst, DR Congo	100%
Lunzihirwa, Julie	Agronomist, DR Congo	100%
Mairura, Franklin	Data Analyst	100%
Magreta, Ruth	Research Asst, Lilongwe	50%
Mapila, Mariam A.T.J.	Research Fellow, Lilongwe	100%
Mukalama, John	Research Asst, DR Congo	100%
Musyoki, Mary	Research Asst	100%
Okeyo, Jeremiah	Snr Scientific Assistant	100%
Sanginga, Jean-Marie	Research Asst., DR Congo	100%
Waswa, Boaz	Asst Scientific Officer	50%

[1] Left during the year

Technical Staff

Chibole, Livingstone	Field Technician	100%
Kimanthi, Martin	Greenhouse Assistant	100%
Kiongera,John	Lab Attendant	100%
Malala, Phillip	Greenhouse Technician	100%
Muema Esther	Technician – soil molecular biology	100%
Mburu, Harrison	Lab Assistant-Microbiology	100%
Muthoni, Margaret	Laboratory Assistant	75%
Mwangi, Elias	Laboratory Assistant	75%
Ngului, Wilson	Laboratory Technician	75%
Nyambega, Laban	Field Technician	100%
Njenga, Francis	Laboratory Assistant	75%
Administrative Staff		
Agallo, Henry	Driver / Field Assistant	50%
Akuro, Elly	Driver / Field Assistant	50%
Kareri, Alice	Administrator	50%
Kamau, Moses	Driver	50%
Kiragu, Wanjiku	Chief Operations Officer	50%
Kuya, Sebastien	Driver/Technician, DR Congo	100%
Mbui, Luke	Driver	50%
Meyo, Rosemary	Administrative Assistant	50%
Mulogoli, Caleb	Finance Officer	50%
Mutende, Oscar	Finance Assistant	50%
Mary Nderitu	Finance Assistant	50%
Mukankusi Teddy	Finance Assistant	50%
Ngwira, Evelyn	Accounts Asst, Lilongwe	50%
Nomsa Nhaoinesu	Admin Asst., Harare	50%
Odongo, Jacqueline	Administrative Asst.	50%
Ogola, Juliet	Snr Administrative Asst.	50%
Okoko, Stanley	Finance Assistant, Maseno	50%
Oruta, Annah	Project Administrator	50%
Sambo, Margaret	Admininistrative Asst	50%
Saddimbah George	Finance Assistant	50%
Zawadi Solange	Administrator , Kigali	100%

TSBF Institute – Latin America Staff

Visiting Researcher		
Castro, Aracely	ISFM	50%
Secretary		
Gómez, Julia	Secretary	12%

II.7. SUMMARY BUDGET

SOURCE	AMOUNT (US$)	PROPORTION (%)
TSBF		
Unrestricted Core	257,219	4%
Restricted Core	0	0%
Sub-total Core	**257,219**	**4%**
Restricted		
Special projects	1,930,281	32%
Sub Sahara Africa Challenge Program	413,876	7%
Water and Food Challenge Program	52,425	1%
Sub Total Restricted	**2,390,082**	40%
Direct Expenditures	**2,647,301**	44%
Non Research Cost	3,397,893	56%
Total Expenditures	**6,051,694**	**100%**

III. PROGRESS AGAINST OUTPUT TARGETS 2009 – 2011

III.1. OUTPUT 1 - 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.

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. Processes and principles: The adapted definition of ISFM is based on obtaining optimal use efficiencies of investments made in agricultural production and valorizing positive interactions between production factors. Processes and principles will look into (i) the supply side of nutrients through understanding interactions between fertilizers, organic inputs, and water management practices and (ii) the demand side of nutrients through understanding the functioning and mechanisms driving the potential of improved (legume) germplasm to thrive under unfavorable conditions (e.g., drought, low soil P, acidity). Substantial emphasis will be put on the diagnosis of site-specific soil constraints. Another major strategic research issue is related to the linkages between the soil fertility status and the nutritional quality of the produce. The major Outcome of Output 1 is related to the processes and principles being used in developing ISFM-based management practices in Output 2.

Output 1. Processes and principles
Output Targets 2009: Knowledge on mechanisms responsible for tolerance **to** drought and low soil P is available to guide breeding efforts in **legumes** rotated or intercropped with **cereals** in the moist savanna impact zone.

WORK IN PROGRESS

Unravelling mechanisms of efficient P acquisition in soybean and other crops, and benefits to cropping systems

E. Vandamme[1], K. Wairimu[1], A. Faye[1] and P. Pypers[1]
[1]*CIAT-TSBF, Kenya*

Introduction and justification

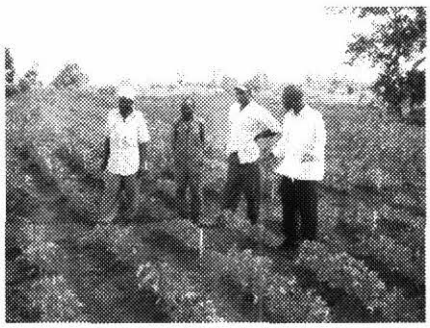
P deficiency is one of the major constraints for crop production in SSA soils. Specific legumes are capable of utilizing sparingly soluble P sources through specific root traits, but genotypes differ importantly in P efficiency. The use of P-efficient legume varieties can contribute to improved agronomic efficiency of P inputs, and not only improve production of the legume crop, but also productivity of the entire cropping system. Process work is conducted with the aim to unravel mechanisms of enhanced P use efficiency.

Materials and methods

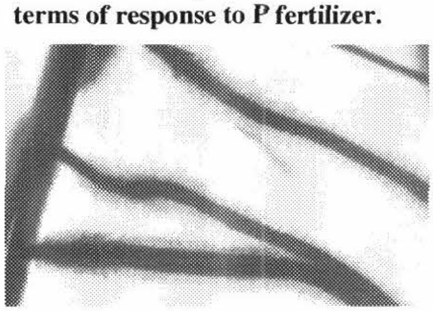
Multi-locational field trials have been conducted in Western Kenya to evaluate responses to P fertilizer and P use efficiency for 20 soybean varieties. Observations included shoot and root biomass production, root length and other morphological traits, nodule number and weight, mycorrhizal infection, grain yield and P uptake. Early root trait indicators for P-efficiency were assessed for 80 soybean varieties in pot experiments using iron-coated sand with different P application levels, and screening methods in double gel observation chambers following Bengough et al. (2004) are being developed. In addition, pot trials are conducted in low-P soils with contrasting P buffering capacity for a number of soybean varieties and reference cereal species. These trials aim at identifying the importance of specific root traits resulting in increased P efficiency. Observed data is correlated with field observations and combined with crop modelling to elucidate mechanisms of P uptake efficiency.

Preliminary results

In the field trials, clear differences in response to full and reduced doses of P fertilizer and efficient nodulation under low P conditions between soybean varieties were observed (**Photograph 1**). Observations will be evidenced by sample analysis (on-going). Farmer-managed field trials will be set up during the upcoming rainy season for in-depth screening of two contrasting varieties. In soybean screening trials in iron-coated sand, large variability was observed in growth under low-P conditions, as well as in response to applied P, indicating important genotypic variability in P efficiency. Two of the most efficient soybean varieties were TGx1835-10E and H11. Root morphological traits and root hair length and density are currently being assessed. Experimental screening methods and scanning root measurements are being fine-tuned. However, part of the variability observed in such short-term growth experiments was attributed to seed P reserves, which was is in turn related to grain size and cropping history. Efforts are on-going to exclude these seed influences for evaluation of early root traits. In a greenhouse experiment, differential response to P application was observed between different cereal species and different soybean



Photograph 1: Particpatory evaluation of soybean varieties in terms of response to P fertilizer.



Photograph 2: root hairs observed on a P-efficient soybean variety grown in a double gel chamber.

varieties (**Photograph 2**). Millet showed to be highly P-efficient relative to maize and sorghum: maximal shoot biomass yield was observed at soil P concentrations which were ten times lower than for the other two cereals. These differences are related to root traits. Millet produces more and finer roots than maize or sorghum. Similar differences were observed between soybean varieties: Nyala attained maximal shoot dry matter yields at a much lower P concentration in soil solution than TGx1740-2F ("SB19") and TGx1448-2E ("SB20").

Preliminary conclusions

Preliminary results indicate that wide variability in P uptake efficiency exists in soybean varieties evaluated, which is likely related to differences in root traits. Plant growth and root development during during early stages is strongly affected by the seed P reserve, and this needs to be taken into account in screening methods.

Arbuscular mycorrhizal fungi in East African Highland banana cropping systems as related to edapho-climatic conditions and management practices: case study of Rwanda

S. V. Gaidashova [1,2], P. J. A. Van Asten[3], J. Jefwa[4], B. Delvaux[2] and S. Declerck[5]
[1] Rwanda Agricultural Research Institute, Rwanda; [2] Unité des Sciences du sol, Université catholique de Louvain, Belgium [3] IITA, Nigeria; [4] CIAT-TSBF, Kenya; [5] Unité de microbiologie, Université catholique de Louvain, Belgium

Introduction and justification

Arbuscular mycorrhizal (AM) fungi form symbiosis with the roots of nearly 80% of plant species. The major functions are nutrient transfer from soil to plant, soil structure improvement through aggregation, and plant protection from drought stress and root pathogens. The combination of these attributes contributes to the long term stability of the ecosystems. Banana and plantains form associations with plants. Their presence, diversity and abundance are a function of climatic conditions, plant community composition and diversity, and soil disturbance.
East African highland (EAH) banana cropping systems provide food and income to over 30 million people. Decline in soil fertility and pests and diseases are major production constraints. Arbuscular mycorrhizae fungi have potential to alleviate the constraints. The diversity of 'indigenous' AM fungal species existing in different environments remains largely under-explored.

Materials and methods

A survey on AMF was undertaken in banana systems of five agro-ecological zones n Rwanda. Soil and root samples were collected and assessed for AMF species composition and colonization respectively. AMF were distinguished up to species morphotypes and some were not assigned names.

Preliminary results

The soil physco-chemical parameters differ amongst the agroecological zones: Acrisols (Butare-Gitarama), Ferrasols (Gashonga), Young alluvial (Bugarama), the Nitisol (Kibungo) and the Andisols (Ruhengeri). AMF Colonization was significantly ($p < .001$) variable between eco-regions. Colonization was least in Butare-Gitarama (17% and 16.5%) and highest in Gashonga 962.6% and 35.45) and the rest had intermediate colonization values (**Figure 4**). There is a negative correlation between colonization and coarse soil fraction (r = - 0.36 for frequency and r = - 0.28 for intensity, p <0.001) and soil P (r = -0.34, p<0.001 for frequency and r = -0.22, p 0.01). Tillage intensity rank was negatively correlated with colonization frequency (r = -0.30, p<0.001) and intensity (r = -0.20, p <.001); colonization was positively correlated with plant height (r =0.19, p < 0.01), girth (r = 0.14, p < 0.05), pseudostem volume (r = 0.15, p < 0.05) and root number (r = 0.22, p < 0.01). Fungal spore density was significantly higher (p < 0.05) in Gashonga and Ruhengeri (59.8 & 48.5 propagules per 100 g soil) than Butare-Gitarama and Kibungo (2.0 7 8.5 propagules per 100 g soil). Four genera (*Glomus, Acaulospora, Scutellospora* and *Gigaspora*) were identified from the site with the highest species isolated from Kibungo and the least in Butare-Gitarama, and the remaining intermediate.

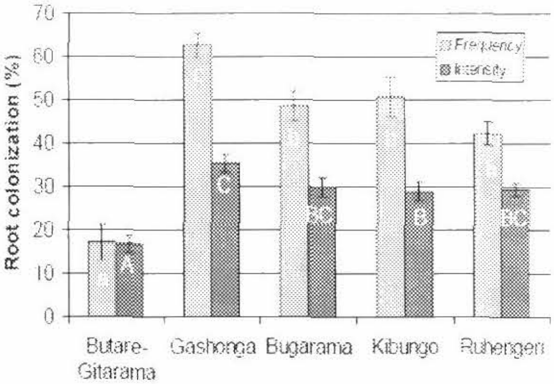


Figure 4: Mean colonization (frequency and intensity, %) of banana roots by the AM fungi in five eco-regions of Rwanda, 2006-2007. A, B, C-significant difference at p0.05 for intensity; a, b, c-significant differences at p 88 0.05 for frequency. Error bars indicate +SE.**

Preliminary conclusions

AM fungi in banana cropping systems in Rwanda were widespread but highly variable in different edapho-climatic conditions. These variations are most probably linked to rainfall management practices (tillage) and soil properties (texture and P content). These strains should be further isolated, identified and characterized for their beneficial effects on bananas under contrasted edapho-climatic and management practices in EAH banana cropping systems.

Benefits and potential use of Arbuscular mycorrhizal fungi (AMF) in banana and plantain systems in Africa

J. Jefwa[1], B. Vanlauwe[1], D. Coyne[2], P. van Asten[2], S. Gaidashova[3], E. Rurangwa[3], M. Mwashasha[4] and A. Elsen[5]
[1]CIAT-TSBF, Kenya; [2]IITA, Uganda; [3]Rwanda Agricultural Research Institute, Rwanda; [4]Kenya Agricultural Research Institute, Kenya; [5]Catholic University of Leuven, Belgium

Introduction and justification

Arbuscular mycorrhizae (AMF) form mutualistic or symbiotic relationships with plants. Over 90% of plant species associate with AMF, which are important for accessing and recycling nutrients. AMF can also increase plant access to water, play a role in the formation of soil aggregates, influence plant biodiversity, help protect against pests and diseases and improve fitness of plants in polluted environments. Banana and plantain (*Musa* spp.) are an important food crops across Africa. AMF occur naturally in the rhizosphere, and banana and plantain plants appear to be highly mycorrhizal. Much of the production areas are faced with poor soil fertility and significant pest and disease pressure. A number of studies reported on the protective effects of AMF on banana against nematodes. AMF offer significant promise to help address soil fertility and pests and disease constraints. Knowledge on the status of AMF in banana cropping systems is limited but increasing due to recent rising interest.

Materials and methods

This is a synthesis on AMF and banana research in Africa compiled by national institutions (ISAR-Rwanda, JKUAT-Kenya and NMK-Kenya) in collaboration with CGIAR centers (CIAT-TSBF, IITA and Bioversity) and advanced research institutes in Europe institutions (KUL-Belgium, UCL-Belgium) currently active in mycorrhizal research.

Preliminary results

AMF colonization of the cultivar Intutu in five agro-ecological zones of different available P vary with amount of available P with low P (< 20 mg kg^{-1}) was associated with high colonization rates, and high P (<40 mg kg^{-1}) low colonization, the effect being site specific. AMF colonization for different banana cultivars was similar for all cultivars within the same site in both banana systems in Kenya and Uganda with the exception of Kibuzi in Uganda. Banana systems still harbor high diversity of AMF species with up to 20 morphospecies identified. The distribution of AMF species is affected by Agroecological zonation. The most common AMF species in banana systems belong to the genera *Glomus* and family Acaulosporaceae (*Acaulospora* and *Entrophospora*). The benefits of AMF on growth, nutrient uptake and nematode management in banana has been demonstrated both under pot and field conditions, although not all species were effective in these functions (**Figure 5**). Studies undertaken in Africa are still few and mostly under greenhouse conditions.

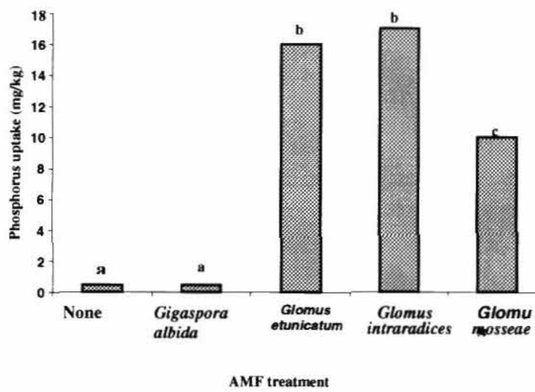


Figure 5: Phosphorus uptake in banana plantlets at potting phase, 22 weeks after inoculation with AMF averaged across nine banana cultivar in pot experiment.

Preliminary conclusions

The few studies undertaken on banana and AMF in Africa are good indications on the potential usefulness of AMF in banana systems. Banana systems are still conservatoire of high AMF species diversity. There is however need to screen for AMF efficiency on growth, nutrient uptake and suppression of pests and diseases. AMF interventions may benefit Africa which is characterized by low soil fertility and pests and diseases and unaffordable fertilizer and pesticides. More field evaluations should be undertaken.

Output 1. Processes and principles
Output Targets 2009: The role of **organic matter** in regulating water, nutrient-limited and actual yield levels underlying **cereal and legume** production quantified in the Sahel and moist savanna impact zones.

COMPLETED WORK

Fertilizer and residue quality effects on organic matter stabilization in soil aggregates. *(2009) Soil Biology & Biochemistry 73:961-966*

Fonte[1], S. J., Yeboah[2], E., Ofori[2], P., Quansah[2], G.W., Vanlauwe[3], B., Six[1], J.
[1]University of California, USA; [2]Soil Research Institute Academy-Kamasi, Ghana; [3]CIAT-TSBF, Kenya

Abstract: This study examined the influence of organic residue quality and N fertilizer on aggregate associated soil organic matter (SOM) in maize (*Zea mays* L.) cropping systems of southern Ghana. Six residue treatments of differing quality [*Crotalaria juncea* L., *Leucaena leucocephala* (Lam.) de Wit, maize stover, sawdust, cattle manure, and a control with no residues added] were applied at 4 Mg C ha−1 yr−1 both with and without fertilizer N additions (120 kg N ha−1 season−1). Soils (0–15 cm) were sampled 3 yr after study implementation and wet sieved into four aggregate size classes (8000–2000, 2000–250, 250–53, and <53 µm). Small macroaggregates (2000–250 µm) were further separated into coarse particulate organic matter (>250 µm), microaggregates within macroaggregates (53–250 µm), and macroaggregate-occluded silt and clay (<53 µm). Nitrogen fertilizer additions reduced aggregate stability, as was evident from a 40% increase in the weight of the silt and clay fraction ($P = 0.014$) as well as a decrease in microaggregates across all residue types ($P = 0.019$). Fertilizer similarly affected C and N storage within these aggregate fractions, while the effects of residue quality were largely insignificant cant. Our results suggest that fertilizer effects on soil aggregation may have important implications for long-term SOM dynamics.

Managing N availability and losses by combining fertilizer-N with different quality residues in Kenya. *(2009) Agriculture, Ecosystems and Environment 131:308-314*

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Abstract: The integrated soil fertility management paradigm, currently advocated in Sub-Saharan Africa for rehabilitating its soils, recognizes the possible interactive benefits of combining organic residues with mineral fertilizer inputs on agroecosystem functioning. Residue quality may be a controlling factor for any beneficial interactions. The objectives of this study were to determine the effect of different quality organic residues and mineral fertilizer on N cycling under field conditions in Embu, Kenya. We hypothesized that combining low quality residue with mineral N would reduce potential system losses of N by synchronizing N release with plant uptake. Residue treatments consisted of a control (no residue input), high quality tithonia (Tithonia diversifolia) residue (C to N ratio of 13:1) and low quality maize (Zea mays) stover residue (C to N ratio of 42:1) applied at a rate of 1.2 Mg C ha_{-1}. Subplots of each residue treatment received either 0 or 120 kg N ha_{-1} in a split-application, and maize was cultivated each season. During the 11th growing season of the trial (March–September 2007), we monitored soil mineral N, potential grossmineralization and nitrification rates, and plant N content. Extractable mineral N in the soil profile varied

with residue and fertilizer inputs throughout the growing season. The tithonia treatments showed early season N release of 22 kg N ha^{-1} in the upper 30 cm of the soil profile. The maize + fertilizer treatment displayed an immobilization of 34 kg N ha^{-1} after the application of N fertilizer. However, the lower mineral N of the maize + fertilizer treatment did not reduce crop N uptake, as mineral N in the other fertilizer treatments was leached from the upper soil (0–60 cm) at 57 d after planting. The interactive effect on crop yield and N uptake of combining residue with fertilizer-N changed from negative to positive as residue quality decreased. The benefit of combining low quality residue with N fertilizer in reducing N losses indicates that this soil fertility management strategy should be adopted in environments subject to high N leaching losses.

Biodiversity, carbon stocks and sequestration potential in aboveground biomass in smallholder farming systems of western Kenya. *(2009) Agriculture, Ecosystems and Environment 129: 238-252*

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Abstract: While Carbon (C) sequestration on farmlands may contribute to mitigate CO_2 concentrations in the atmosphere, greater agro-biodiversity may ensure longer term stability of C storage in fluctuating environments. This study was conducted in the highlands of western Kenya, a region with high potential for agroforestry, with the objectives of assessing current biodiversity and aboveground C stocks in perennial vegetation growing on farmland, and estimating C sequestration potential in aboveground C pools. Allometric models were developed to estimate aboveground biomass of trees and hedgerows, and an inventory of perennial vegetation was conducted in 35 farms in Vihiga and Siaya districts. Values of the Shannon index (H), used to evaluate biodiversity, ranged from 0.01 in woodlots through 0.4–0.6 in food crop plots, to 1.3–1.6 in home gardens. Eucalyptus saligna was the most frequent tree species found as individual trees (20%), in windrows (47%), and in woodlots (99%) in Vihiga and the most frequent in woodlots (96%) in Siaya. Trees represented the most important C pool in aboveground biomass of perennial plants growing on-farm, contributing to 81 and 55% of total aboveground farm C in Vihiga and Siaya, respectively, followed by hedgerows (13 and 39%, respectively) and permanent crop stands (5 and 6%, respectively). Most of the tree C was located in woodlots in Vihiga (61%) and in individual trees growing in or around food crop plots in Siaya (57%). The home gardens represented the second C pool in importance, with 25 and 33% of C stocks in Vihiga and Siaya, respectively. Considering the mean total aboveground C stocks observed, and taking the average farm sizes of Vihiga (0.6 ha) and Siaya (1.4 ha), an average farm would store 6.5 _ 0.1 Mg C $farm^{-1}$ in Vihiga and 12.4 _ 0.1 Mg C $farm^{-1}$ in Siaya. At both sites, the C sequestration potential in perennial aboveground biomass was estimated at ca. 16 Mg C ha^{-1}. With the current market price for carbon, the implementation of Clean Development Mechanism Afforestation/ Reforestation (CDM A/R) projects seems unfeasible, due to the large number of small farms (between 140 and 300) necessary to achieve a critical land area able to compensate the concomitant minimum transaction costs. Higher financial compensation for C sequestration projects that encourage biodiversity would allow clearer win–win scenarios for smallholder farmers. Thus, a better valuation of ecosystem services should encourage C sequestration together with on-farm biodiversity when promoting CDM A/R projects.

Long-term management of phosphorus, nitrogen, crop residue, soil tillage and crop rotation in the Sahel

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Introduction

In the Sudano-saherian zone of West Africa, several field trials have been going on to create a better understanding on how these fragile agro-ecosystems operate and the critical production levels. The objective of these network activities is to develop and implement such management options that mitigate soil degradation, deforestation and biological resources losses and enhance local economies while protecting the natural resource base. Soils in Niger are deficient in phosphorus (P); so to be efficient any soil fertility technology has to address this constraint before. On long term trials; continuous cropping over years has shown the limit of applying mineral P only and the use of alternative technologies are necessary. Among them, the use of inorganic fertilizer, crop rotation and better integrating mixtures of organic and inorganic sources of nutrients can contribute to increase crop production. Facing the problem of fertilizer affordability to smallholder farmers in Sub-Saharan Africa (SSA), the placement of small quantities (hill placement: HP) of NPK or other sources of phosphorus can be a best option. The use of Phosphate Rock (PR) is also recommended due to its cheaper cost. Manure also is not available for poor farmers, and then rotation and strip cropping systems is one of the best strategies to increase soil organic carbon and then food security and sustain rural livelihoods in sub-Saharan Africa. Combinations of these technologies can give very good results on crop production whenever possible.

Materials and methods

This factorial experiment started in 1993 was initiated at the research station of ICRISAT Sahelian Center at Sadore, Niger. The first factor was three levels of fertilizers (0, 4.4kg P + 15kg N/ha, 13kg P + 45kg N/ha), the second factor was crop residue applied at (300, 900 and 2700 kg/ha) and the third factor was manure applied at (300, 900 and 2700 kg/ha). The cropping systems are continuous pearl millet, pearl millet in rotation with cowpea and pearl millet in association with cowpea. The analysis of variance of the data indicated that fertilizer; crop residue and manure application resulted in a highly significant effect of both pearl millet grain and total dry matter yields.

Preliminary results

The data in **(Table 2)** indicate the comparative advantage to use P from both sources. Millet grain yield was increased from 495 kg/ha to 1375 kg/ha at Banizoumbou with the application of 13 kg P/ha. The data in **(Figure 6)** illustrate the response of pearl millet grain to the crop rotation and to the different input of organic and inorganic fertilizers. The farmer's practices yield 357 kg/ha of millet grain; the application of mineral fertilizer (13 kg P+45 kg N/ha) yielded 1037 kg/ha (625 kg/ha in 2008) but when these mineral fertilizers are combined with 2.7 t/ha of manure or crop residue in rotation with cowpea, yield of 1438 (1079 kg/ha in 2008) can be achieved.

Table 2: Optimum combination of plant nutrients for millet grain (kg/ha) at Karabedji, Banizoumbou and Sadore, Niger, 2009 cropping season

Treatments	Grain yield (kg/ha)		
	Karabedji	Banizoumbou	Sadore
1 Absolute Control	427	495	559
2 30 kg N ha^{-1}	526	552	712
3 12 kg P ha^{-1}	849	1375	1058
4 12 kg P ha^{-1} PR+ 30 kg N ha^{-1}	870	880	641
5 9 kg P ha^{-1} PR+ 3kg P + 30 kg N	990	1031	1178
6 6 kg P ha^{-1} PR + 6 kg P + 30 kg N	1089	1021	1178
7 3 kg P ha^{-1} PR + 8 kg P + 30 kg N	1307	1292	1289
8 12 kg P + 30 kg N	979	1260	1254
SE	42	149	116
CV	10%	30%	23%

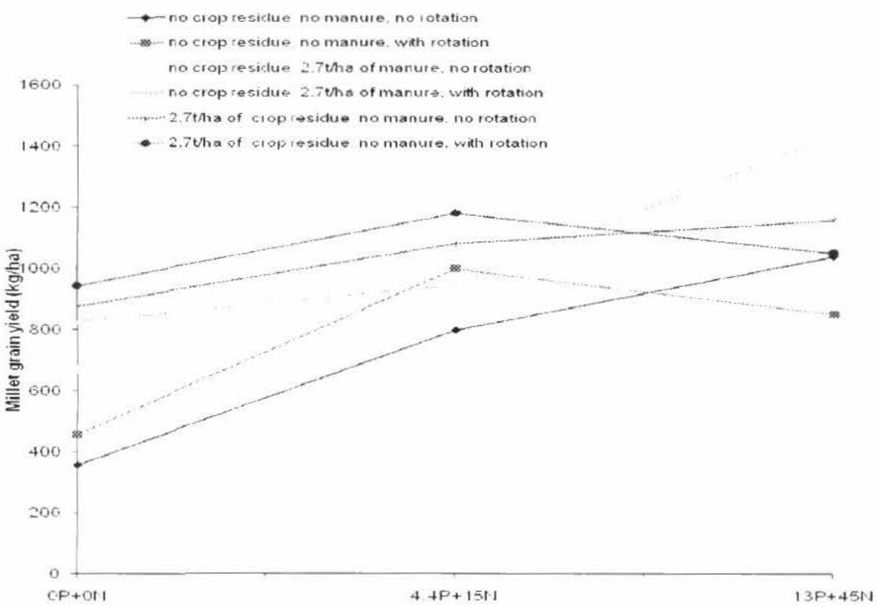

Figure 6: Effect of different N and P rates on pearl millet grain yield, Sadore, Niger, 2009 rainy season.

The data in **Figure 7** show that the application of P increased both millet grain and total dry matter yields significantly and this trend was more important in fertile soils.

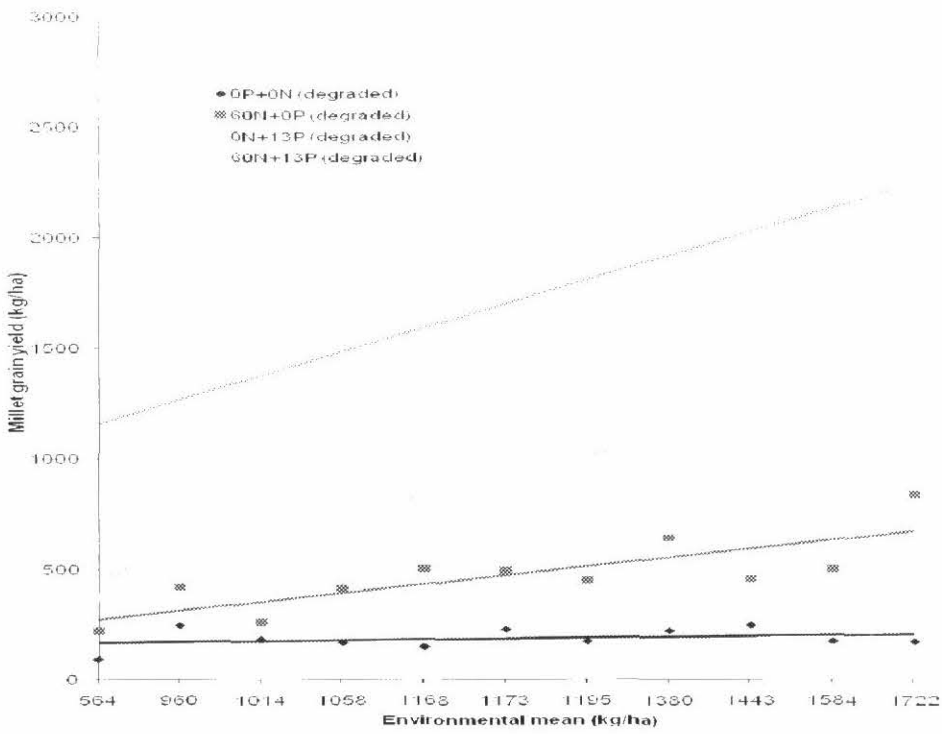

Figure 7: Effect of environmental mean on pearl millet grain yield, Karabedji, Niger, degraded lands, 1999-2009.

Field evaluation of commercial Rhizobium inoculants in Kenya

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Introduction and justification

Inoculation with Rhizobium can increase biological nitrogen fixation (BNF), growth and yield of legumes, and benefits of legumes to soil fertility. Therefore, it potentially constitutes an important component of ISFM options. This technology is however little used in Sub-Saharan Africa, either because it is not known by small-scale farmers and/or because it is not available. Nevertheless, a large number of commercial inoculants are produced worldwide by various companies, in different formulations. An evaluation of these products is required to evaluate the effectiveness of these products under conditions of African small-scale farmers.

Materials and methods

A set of field screening trials were conducted, parallel to the greenhouse evaluations, to evaluate the effectiveness of various soybean Rhizobium inoculants from a number of commercial companies (Becker Underwood, USA; Legume Network, UK; Mapleton Inc., Australia; and Soygro, South-Africa). Research *Bradyrhizobium japonicum* strains obtained from IITA (Nigeria), CIAT-TSBF (Kenya) and Marondera Soil Productivity Research Laboratory (Zimbabwe) were included for comparison **(Table 3)**. TwinN, although not a

Rhizobium inoculant, was included as the producer claims it enhances or induces N fixation in crops.
In April 2009, two researcher-managed trials were established in Chuka (Meru South District in Central Kenya) and Sidada (Siaya District in Western Kenya). The trial in Chuka was established on land belonging to a school, where no legumes had been cultivated for at least 3 years **(Photograph 3).** In Siaya, a site was chosen which was used for soybean seed production, and had been cultivated with a soybean monocrop during 5 seasons. The trials were laid out following a split-plot design with two factors: soybean variety (in the main plot) and application of Rhizobium inoculants (in the subplots). Three replicates were laid out in separate blocks. Plots contained 6 soybean lines of 3 m long, spaced at 0.75 m between lines and 5 cm within the line. Plots were separated by alleys of 1 m wide. In addition, only the inner 4 lines were inoculated; the outer lines were considered as borders to avoid contamination between plots. All measurements were taken on the inner two lines. Soybean varieties included Nyala, TGx1740-2F ("SB19") and TGx1835-10E ("SB3"). Nyala is an early-maturing variety that nodulates specifically and has been released in Kenya. SB19 and SB3 are both medium-maturing varieties that have been bred for promiscuous nodulation with indigenous Rhizobium, and produce relatively more biomass than Nyala, but have a similar or higher grain yield potential. Prior to inoculation, seeds were surface-sterilized by soaking in 5 % $Ca(ClO)_2$ during 5 minutes and rinsing thoroughly with distilled water. Inoculants were then applied at planting as seed treatments, following the rates and instructions supplied by the inoculant producers. A non-inoculated control was included as a negative control (further referred to as "control") as well as a non-inoculated control with mineral N addition as a positive control (further referred to as "reference"). In the reference treatment, urea was split-applied at 40 kg N ha^{-1} at planting and 40 kg N ha^{-1} topdress at 4-6 weeks after planting. In each main plot, two plots with maize (*Zea mays* L.) were grown as reference for biological N fixation using the natural abundance method. A blanket P application was done using *triple super phosphate* (TSP) fertilizer at 60 kg P ha^{-1} to eliminate P deficiency. Land preparation was done manually, and weeds were regularly controlled using a hand hoe. Care was taken to avoid contamination between plots by washing implements between plots. Legume biomass yield and nodlation was determined at 50% podding. All aboveground biomass was cut in a random 1 m section of the inner two lines. Subsequently, roots were carefully dug up and nodules were collected. Nodules were counted, washed using distilled water and fresh weights were determined. Collected biomass was oven-dried (60°C), weighed and ground prior to analysis. Nodules were surface-sterilized and stored in glycerol at -80°C. At maturity, grain and haulm yields were determined.

Photograph 3: Field screening of Rhizobium inoculants in Meru South, Central Kenya.

Table 3: Rhizobium inoculants evaluated in the field screening trials.

Product	Type	Producer	Active ingredients	Formulation
USDA-110	research strain	USDA (USA)	*Bradyrhizobium japonicum* (min. 10^8 CFU mL^{-1})	liquid
USDA4675	research strain	USDA (USA)	*Bradyrhizobium japonicum* (min. 10^8 CFU mL^{-1})	liquid
Inoculum 531	research strain	TSBF (Kenya)	*Bradyrhizobium japonicum* (min. 10^8 CFU mL^{-1})	liquid
Inoculum 442	research strain	TSBF (Kenya)	*Bradyrhizobium japonicum* (min. 10^8 CFU mL^{-1})	liquid
Inoculum 560	research strain	TSBF (Kenya)	*Bradyrhizobium japonicum* (min. 10^8 CFU mL^{-1})	liquid
Mix of inoculums 531, 442 and 560	research strain	TSBF (Kenya)	*Bradyrhizobium japonicum* (min. 10^8 CFU mL^{-1})	liquid
Soyflo®	commercial	Soygro (South Africa)	*Bradyrhizobium japonicum* strain WB74 (2.5 10^2 CFU mL^{-1})	liquid
Sojapak®50	commercial	Soygro (South Africa)	*Bradyrhizobium japonicum* strain WB74 (2.5 10^2 CFU mL^{-1}) and *Azospirilum* strain AND97 (10^9 CFU mL^{-1}), Mo, P_2O_5 and K_2O	liquid
Leguspirflo®	commercial	Soygro (South Africa)	*Azospirillum* strain AND97 (10^9 CFU mL^{-1}) and *Bradyrhizobium japonicum*	liquid
Legumefix	commercial	Legume Network (UK)	*Bradyrhizobium japonicum*	damp peat
HiStick	commercial	Becker Underwood (USA)	*Bradyrhizobium japonicum* (2 10^9 CFU g^{-1}) and *Bacillus subtilis* (2 10^8 CFU g^{-1})	damp peat
Vault LVL	commercial	Becker Underwood (USA)	*Bacillus subtilis* strain MBI 600 (Integral) (<1%) and *Bradyrhizobium japonicum*	liquid
Zim1 (1496MAR)	research strain	Marondera SPRL (Zimbabwe)	*Bradyrhizobium japonicum* (min. 10^8 CFU mL^{-1})	liquid
RACA6	research strain	IITA (Nigeria)	*Bradyrhizobium japonicum* (min. 10^8 CFU mL^{-1})	liquid
Sipeak	research strain	IITA (Nigeria)	*Bradyrhizobium japonicum* (min. 10^8 CFU mL^{-1})	liquid
TwinN	commercial	Mapleton Inc. (Australia)	various microbes	freeze-dried microbes

Preliminary results

In general, plant performance was poor in both sites due to low and poorly distributed rainfall. This affected seed germination, vegetative growth, podding and grain filling. In the site in Western Kenya, nodulation was high in all 3 soybean varieties, but higher in SB19 and SB3 than in Nyala (**Table 4**). Application of Rhizobium inoculants did not affect nodulation. In the site in Meru South, nodule numbers were significantly affected by the application of Rhizobium inoculants, and an interaction with soybean variety was observed (**Figure 8**). Commercial products HiStick and Legumefix, and strains RACA6 and Sipeak increased nodule numbers for all 3 varieties. Strains TSBF531 and the mixtures of the 3 TSBF strains only increased nodule numbers for Nyala and SB19.

Table 4: Nodulation for 3 soybean varieties observed in the site in Western Kenya.

Product	Number of nodules		Nodule fresh weight	
	LOG(nr m^{-2} + 1)	LOG(nr $plant^{-1}$+1)	(g m^{-2})	(g $plant^{-1}$)
Nyala	5.34	2.95	2.58	0.22
SB19	5.97	3.28	5.83	0.39
SB3	5.87	3.38	3.66	0.37
SED	0.16	0.14	0.71	0.07

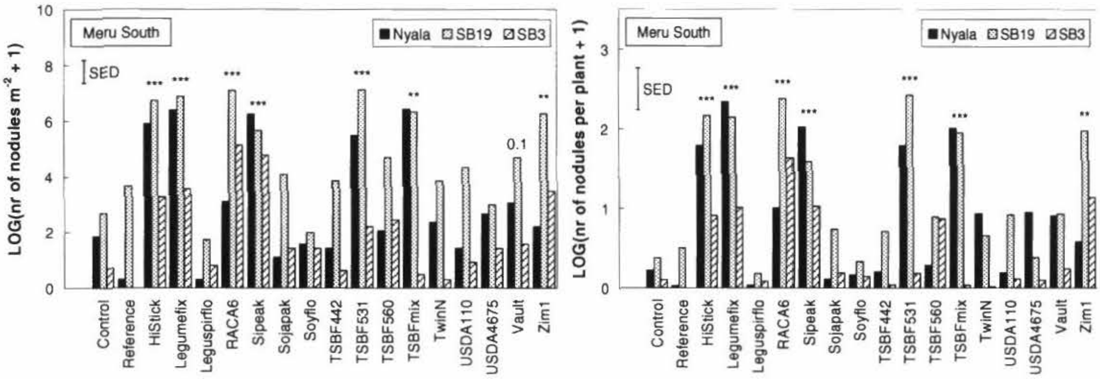

Figure 8: Log-transformed nodule numbers per m^{-2} (left) and per plant (right) as affected by the application of Rhizobium inoculants and soybean variety in the site in Meru South. The error bars represent the SED for the treatment × variety interaction. The significance level of difference with the control across the 3 varieties is indicated.

Strain Zim1 was only effective on SB19 and SB3. In the reference treatment with mineral N application, nodule numbers were lower (for Nyala and SB3) or similar (for SB19), relative to the control. Similar trends were observed when nodule fresh weights were compared, except that Legumefix only increased nodule fresh weights for Nyala and SB19 (**Figure 9**).

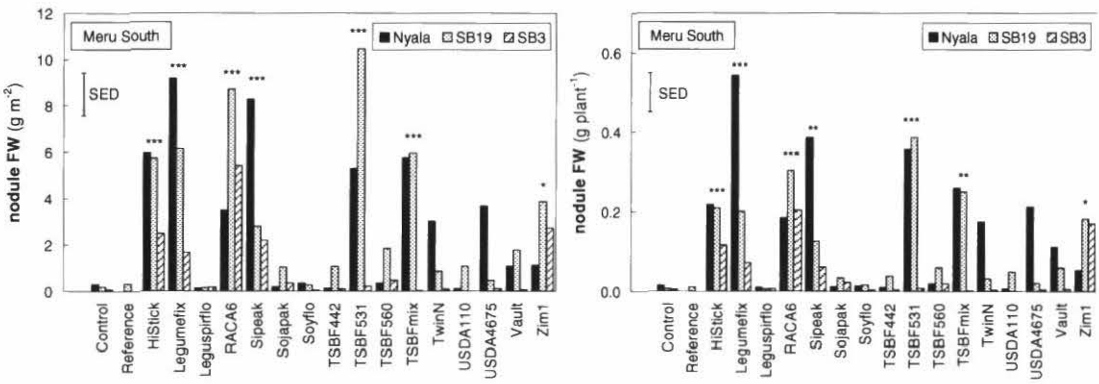

Figure 9: Nodule fresh weights (FW) per m^{-2} (left) and per plant (right) as affected by the application of Rhizobium inoculants and soybean variety in the site in Meru South. The error bars represent the SED for the treatment × variety interaction. The significance level of difference with the control across the 3 varieties is indicated.

Biomass yields were generally poor in both sites, due to unfavorable rainfall. In the site in Western Kenya, biomass yield differed significantly (P<0.01) between varieties: biomass yields were highest for SB19 (about 1250 kg ha^{-1}), followed by SB3 (about 1000 kg ha^{-1}) and lowest for Nyala (about 380 kg ha^{-1}). Application of Rhizobium inoculants did not affect biomass yields for any of the varieties (Fig. 4). A slight increase was observed in the treatment with addition of the mixture of TSBF strains, but this was only significant at $P<0.1$. In Meru South, no differences between varieties were observed (average biomass yield of 600 kg ha^{-1}). The application of the mixture of TSBF strains resulted in a significant ($P<0.01$) biomass yield increase (**Figure 10**). A slight increase was also observed for the treatment with Legumefix, but this was only significant at $P<0.1$. All varieties responded significantly ($P<0.05$) to N application in the reference treatment.

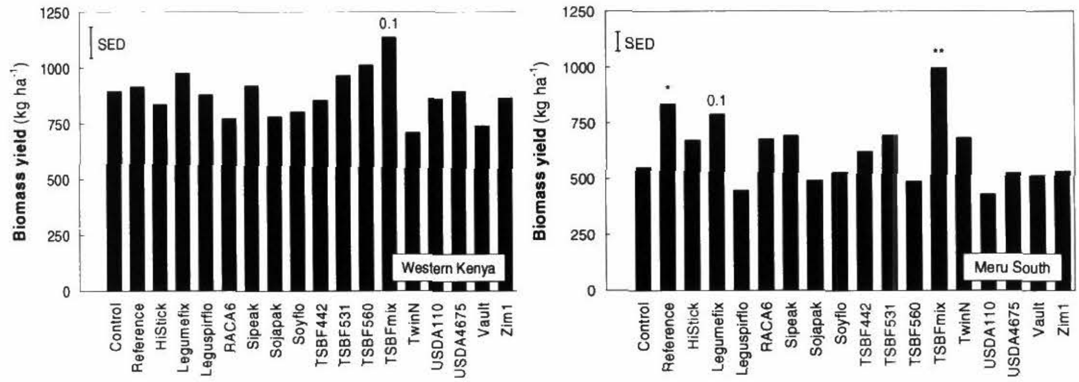

Figure 10: Biomass yield in the site in Western Kenya (left) and in Meru South (right) as affected by the application of Rhizobium inoculants. No interactions were observed with soybean variety. The error bars represent the SED for treatment effects. The significance level of difference with the control is indicated.

In the site in Meru South, a significant effect of inoculation on grain yield was observed, but this depended on the soybean variety grown (data not shown). Nyala and SB19 responded positively to application of Legumefix, the mixture of TSBF strains and Zim1, although the effect of the latter was only significant at $P<0.1$. In addition, positive yield responses were observed for SB19 in treatments with Histick and strain TSBF531. For variety SB3, Rhizobium inoculants did not affect grain yields. Highest yields were observed in the treatment with the mixture of TSBF strains, but this difference was only significant at $P=0.16$. Average grain yields for SB19 were almost twice as large as for Nyala and SB3. Nyala and SB3 responded to N application in the reference treatment, but SB19 did not. Based on these results, Legumefix, TSBF531, the mixture of TSBF strains and Zim1 can be considered as effective inoculants.

Greenhouse evaluation of commercial microbial inoculants and agrochemicals

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Introduction and justification

Various commercial microbial inoculants and agrochemicals are available on the market, claiming to enhance crop growth and production. While some of these products have clearly established modes of action (e.g., inoculation with Rhizobium for increased BNF, inoculation with mycorrhizae for enhanced P uptake, seed coating for alleviating deficiencies), others have not. Effective products can potentially improve agronomic efficiency of applied inputs, when integrated in ISFM technologies. Evaluation of such products is therefore useful, but due to the high number of products available, a rapid, low-cost and standardized screening procedure is required. This can be achieved in pot experiments under greenhouse conditions **(Photograph 4).**

Photograph 4: Greenhouse evaluation of commercial products.

Materials and methods

Commercial products were classified in four categories: Rhizobium inoculants (Cat. I), inoculants with free-living N-fixing microorganisms (e.g., *Azospirillum* spp.) (Cat. II-A), inoculants with other microorganisms (e.g., *Bacillus* or mycorrhizal inoculants) (Cat. II-B) and chemical products (leaf fertilizers, seed nutrient coatings, etc.). Products were collected or purchased from various commercial companies, and first evaluated in pot experiments. Two standard medium-fertility soils with differing texture (a sandy soil from the Coast, and a clay soil from the Central Province) were used. Cat. I products were evaluated in two soybean varieties (Nyala and TGx1740-2F), while the other products were evaluated in soybean (TGx1740-2F) and in maize (H513). Basal nutrients were applied with regard to the mode of action of the products. For products acting on N acquisition (Cat. I and II-A), all nutrients except for N were applied. Similarly, for products acting on P acquisition (P solubilizers, mycorrhizal, P seed coatings,), P was omitted or applied at a sub-optimal rate. For products supplying micronutrients, these nutrients were omitted from the nutrient solutions. Negative (without application of products) and positive controls (with application of additional nutrients) were included. Various parameters were determined, including growth, leaf chlorophyll content, nodulation (in soybean), pod load (in soybean), root biomass yield, and shoot biomass yield. Analyses included BNF (using the ^{15}N natural abundance method), mycorrhizal infection and nutrient uptake.

Preliminary results

The results presented below focus on shoot biomass yields as affected by the application of products from various products. Based on this and other parameters, 6 effective Cat. I products (Histick, Legumefix, Soyflo, TSBF442, Vault, 1495MAR = Zim1), 0 effective Cat. II-A products, 1 effective Cat. II-B product (Rhizatech), and 3 effective Cat. III products (Aton AZ, Teprosyn Zn/P and Turbotop) were found. These products have significant (P<0.05) positive effects on at least two relevant plant parameters.

1. Cat. I (Rhizobium inoculants)

The effect of the Cat. I products differed between both soybean varieties (**Figure 11**). In Nyala, none of the products resulted in shoot DM yield increases, relative to the control. Addition of Soyflo and TwinN significantly (*P*<0.05) reduced shoot yields. In TGx1740-2F, Histick, Soflo and Zim1 (1495MAR) increased shoot DM yields, but yield increases were small (13-20%). These products resulted in significant increases in nodulation (data not shown). Although Legumefix, Sojapak, TSBF442 and Vault also increased nodulation, no increased in biomass yield were observed. Effects of the products were independent of soil effects. Shoot DM yields of both varieties were about 30% higher in the Central Kenya soil than in the Coast soil. Biomass yield of TGx1740-2F were twice as large as of Nyala.

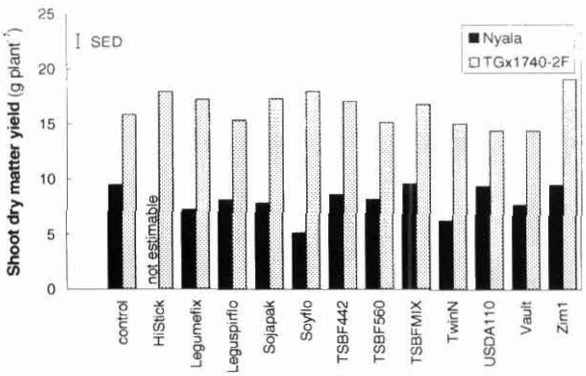

Figure 11: Soybean shoot DM yields, as affected by Cat. I products. Effects of products differed between both varieties. Error bars represent the SED for the variety × product interaction.

2. Cat. II-A (inoculants with free-living N-fixing microorganisms)

In maize, none of the products resulted in significant increases in shoot DM yield, independent of the soil (**Figure 12**). Application of mineral N in the reference treatment significantly increased maize as well as soybean DM yield. In soybean, only Integral slightly (*P*<0.1) increased shoot DM yield. For both crops, DM yields were significantly (*P*<0.01) larger in the soil from Central Kenya than in the Coast soil.

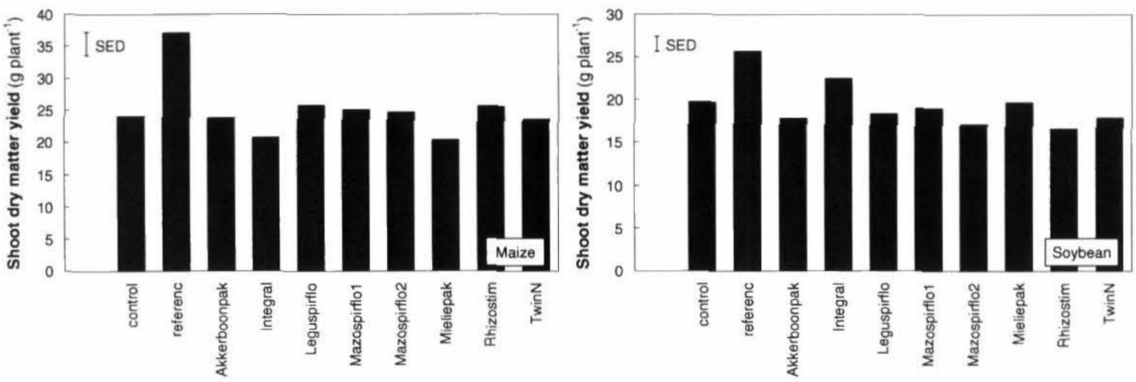

Figure 12: Maize and soybean shoot DM yields, as affected by application of various Cat. II-A products. Treatment effects did not interact with soil for both crops. Error bars represent SEDs for effect of product application.

3. Cat. II-B (other microbial inoculants)

In maize, only application of Rhizatech had a slight (*P*<0.1) positive effect on shoot DM yields, independent of the soil (**Figure 13**). Application of nutrients in the reference treatment significantly (*P*<0.01) increased shoot DM yield by about 50%, relative to the control. Shoot

DM yields differed significantly ($P<0.001$) between soils, and were just about twice as large in the soil from Central Kenya (on average 20 g DM), relative to the Coast soil (on average 11 g DM). In soybean, none of the products resulted in a significant increase in shoot DM yield. In the reference treatment, however, shoot DM yields were significantly lower relative to the control in the soil from Central Kenya soil, but significantly higher relative to the control in the Coast soil. This was related to the problems encountered with N application as NH_4NO_3.

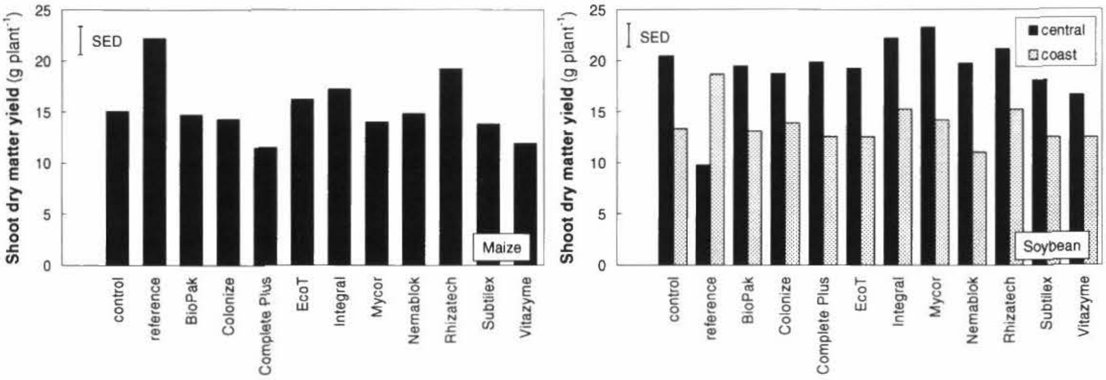

Figure 13: Maize and soybean shoot DM yields, as affected by application of various Cat. II-B products. In maize, treatment effects did not interact with soil, while in soybean, a significant soil × product interaction was found. Error bars represent SEDs for effect of product application, and soil × product interaction in maize and soybean, respectively.

4. Cat. III (chemical, non-microbial products)

In maize, none of the products had a positive effect on shoot DM yields (**Figure 14**). Application of nutrients in the reference treatment significantly ($P<0.001$) increased shoot DM yield by about 50%, relative to the control. In soybean, the effect of product application differed between both soils. In the Central Kenya soil, only the application of AtonAZ significantly ($P<0.05$) increased shoot DM yield. In the Coast soil, contrarily, a significant ($P<0.05$) increase in shoot DM was only observed after application of Turbotop. In the reference treatment, DM yields were significantly ($P<0.001$) higher than in the control in both soils.

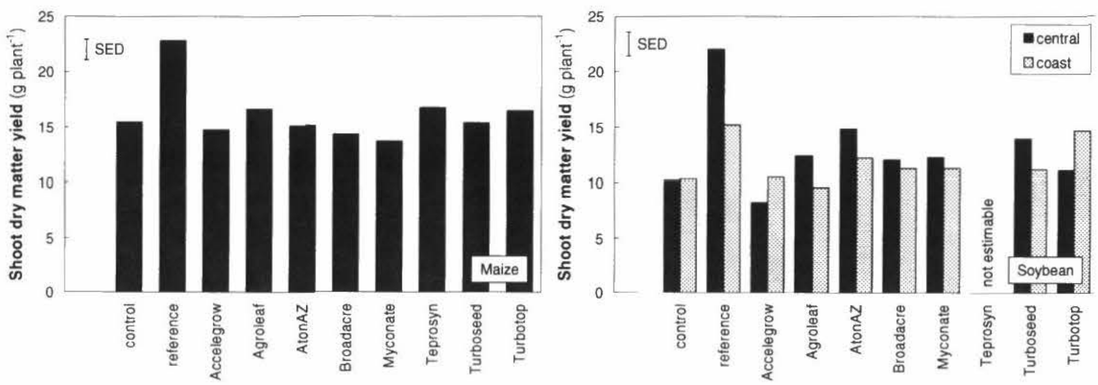

Figure 14: Maize and soybean shoot DM yields, as affected by application of various Cat. III products. In maize, no differences between soils were observed, while in soybean, a significant soil × product interaction was found. Error bars represent SEDs for effect of product application, and soil × product interaction in maize and soybean, respectively.

Evaluation and scaling up new chemical and biological commercial products for improving and sustaining crop yields in selected agro-ecological zones in sub-Saharan Africa

Evaluation of Biological and Chemical products on Banana and Plantains

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Introduction and justification

The use of commercial products on banana is against a background of constraints known to hinder success of Tissue Culture (TC) banana plantlets, with the aim of alleviating the constraints following application. The plantlets offer an excellent means of providing pest and disease-free planting material to farmers. They are, however, devoid of microbes and hence delicate and prone to stress and pests and diseases. Microbial commercial products may have 'positive impact' on their post-planting performance.
Tissue Culture banana plants are delicate and devoid of food reserves. They are also more prone to shock, pests and diseases and may not establish under low soil fertility environments. Biological hardening is therefore recommended before transplanting. Microbial commercial products that enhance plant growth and production exist in the markets and the conditions of effective functioning of the products not known.

Materials and methods

Greenhouse experiments are being conducted to evaluate the effects of commercial products on the growth of banana under different agro ecological zones. The commercial products comprising of bacterial and fungal organisms have different modes of action. The evaluation is undertaken through hardening and potting stages under greenhouse conditions and subsequently under natural field conditions.

Preliminary results

The effects of products (fungal and bacterial) are dependent on soil conditions with effect more evident in Vertisols (Dark Montimorillonite 2:1 clay mineral-rich and poorly-drained cracking- Vertisols, also referred to as black cotton soils), and Eutric Nitosols (high in Aluminum and Iron-low P soils) than the Rhodic Ferrasols. The main effect of products, disregarding soil types, had significant effect ($p = 0.013$) on shoot dry weight of TC banana plantlets **(Figure 15)**, height and leaf surface area.

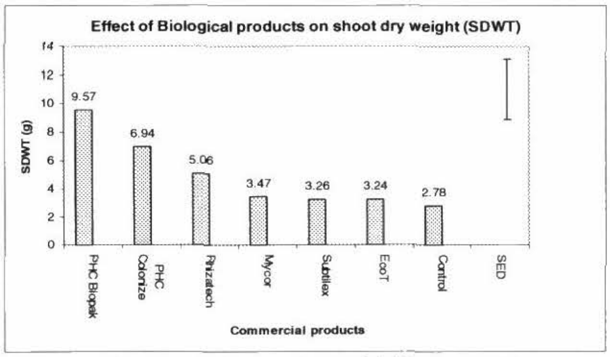

Figure 15: Shoot dry weight (SDWT) of TC banana plantlets with and without (control) commercial products.

Preliminary conclusions

Microbial commercial products have potential to alleviate stress and improve growth of TC bananas. However, this will depend on the soil conditions. Investigations are still in progress to establish optimum conditions under which products can function.

Biological nitrogen fixation by rhizobia and mineral fertilizer savings: implications for green revolution in Africa

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Introduction and justification

Although it is common knowledge that soil microorganisms form an important component of below ground biodiversity, providing important ecosystem services that may sustain and enhance agricultural production, few policies have been formulated that deliberately seek to benefit from the services provided. Applying the knowledge gained from on-station and on-farm trials in Africa, complemented with necessary assumptions on FAO-sourced soybean data, this study contributes to awareness on the importance of these microorganisms by estimating the financial value of N-fixation (which helps to cut down the N-fertilizer needs of soybean and the subsequent maize) of legume nodulating bacteria (LNB) associated with promiscuous soybean varieties.

Materials and methods

This study was carried out using FAO data from 19 African countries. Evaluation of the financial value was based on the method of cost savings in terms of mineral N fertilizer that would have been required to attain the same level of N fixed biologically.

Preliminary results

Results show that the financial value of the N-fixing attribute of soybean in Africa, especially the promiscuous varieties, annually amounts to ~US$ 200 million across the 19 countries. With the fertilizer price of~US$795 t^{-1} (June 2008), this would amount to US$ 375 million. Given these huge benefits from soybean BNF, and the potential to further expand it, this paper outlined four strategies (expansion of the area under soybean cultivation, soybean yield increase through an increase in the N-fixed per hectare, use of P fertilizer to increase the yield of soybean, and inoculation of promiscuous soybean varieties with Bradyrhizobium) for increasing the appropriation of the benefits from BNF for improved welfare of farm families in Africa.

Preliminary conclusions

Given the current prevailing circumstances in Africa, expansion of the area under soybean cultivation could be argued to be the most promising strategy. However, the sustainability of this strategy will depend on the extent of market and infrastructural development. Next is the use of P fertilizer to increase the yield of soybean. Use of P fertilizer can easily lead to the doubling of soybean yield as has been demonstrated both on-station and on-farm under farmer management. The remaining two strategies (soybean yield increase through an increase in the N-fixed per hectare and inoculation of promiscuous soybean varieties with Bradyrhizobium), require investments in the areas of plant breeding, market stimulation, and infrastructural development to mention but a few. In other words, a strong policy and political support is essential.

Output 1. Processes and principles
Output Targets 2009: Mechanisms underlying the agronomic efficiency of applied **fertilizers** in the context of ISFM understood for **cereal-legume** systems in the Sahel and moist savanna impact zones and for **conservation agriculture** in the moist savanna zone, taking into account variability in soil fertility status at different scales.

COMPLETED WORK

Organic and Mineral Input Management to Enhance Crop Productivity in Central Kenya. *(2009) Agronomy Journal 101:1266-1275*

Chivenge[1], P., Vanlauwe[2], B., Gentile[1], R., Wangechi[2], H., Mugendi[3], D., Van Kessel[1], C.and Six[1], J.
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Abstract: Organic resources (ORs) are important nutrient inputs in tropical agriculture. Combined with mineral fertilizers, they form the backbone of integrated soil fertility management. This study was conducted to determine the medium- to long-term influence of OR quality and quantity on maize productivity and to evaluate the occurrence of additive benefits in terms of extra grain yield produced by the combined application of ORs and N fertilizers. Farmyard manure, high quality Mexican sunflower [*Tithonia diversifolia* (Hemsl.) A. Gray], intermediate quality calliandra (*Calliandra calothyrsus* Meisn.) and maize (*Zea mays* L.), and low quality silky-oak (*Grevillea robusta* A. Cunn. ex R. Br.) sawdust were incorporated into the soil at equivalent rates of 1.2 and 4 Mg C ha^{-1} yr^{-1} in Embu (clayey) and Machanga (sandy soil), together with a control to which no OR was added. All plots were split, with one half receiving 120 kg N ha^{-1} $season^{-1}$ as $CaNH_4NO_3$. The ORs, except sawdust and maize, improved maize grain yields compared with the control at both sites. Greatest mean maize yields (i.e., 4.9 and 2.3 Mg ha^{-1} $season^{-1}$, in Embu and Machanga, respectively) over 10 seasons were observed with the high rate of Mexican sunflower, but was not significantly different from calliandra and manure. Generally, maize yields were greater with higher than lower OR rates, except for maize and sawdust. Although N fertilizer additions to the ORs improved grain yields in Embu, the increase was marginal; resulting in negative interactive effects of applying ORs with N fertilizers, especially with high-N ORs. Thus high-N ORs should not be applied in combination with N fertilizers, especially at such high fertilizer N rates.

Nitrogen and phosphorus capture and recovery efficiencies and crop responses to a range of soil fertility management strategies in sub-Saharan Africa. *(2009) Nutrient Cycling in Agroecosystems: Published online*

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Abstract: This paper examines a number of agronomic field experiments in different regions of sub- Saharan Africa to assess the associated variability in the efficiencies with which applied and available nutrients are taken up by crops under a wide range of management and environmental conditions. We consider N and P capture efficiencies (NCE and PCE, kg uptake kg-1 nutrient availability), and N and P recovery efficiencies (NRE and PRE, kg uptake kg-1 nutrient added). The analyzed cropping systems employed different soil fertility management practices that included (1) N and P mineral fertilizers (as sole or their combinations) (2) cattle manure composted then applied or applied directly to fields through animal corralling, and legume based systems separated into (3) improved fallows/cover crops cereal sequences, and (4) grain legume-cereal rotations. Crop responses to added nutrients varied widely, which is a logical consequence of the wide diversity in the balance of production resources across regions from arid through wet tropics, coupled with an equally large array of management practices and inter-season variability. The NCE ranged from 0.05 to 0.98 kg kg-1 for the different systems (NP fertilizers, 0.16–0.98; fallow/cover crops, 0.05–0.75; animal manure, 0.10–0.74 kg kg-1), while PCE ranged from 0.09 to 0.71 kg kg-1, depending on soil conditions. The respective NREs averaged 0.38, 0.23 and 0.25 kg kg-1. Cases were found where NREs were [1 for mineral fertilizers or negative when poor quality manure immobilized soil N, while response to P was in many cases poor due to P fixation by soils. Other than good agronomy, it was apparent that flexible systems of fertilization that vary N input according to the current seasonal rainfall pattern offer opportunities for high resource capture and recovery efficiencies in semi-arid areas. We suggest the use of cropping systems modeling approaches to hasten the understanding of Africa's complex cropping systems.

Strategic phosphorous application in legume-cereal rotations increases land productivity and profitability in Western Kenya. *(2009) Experimental Agriculture 46:35-42*

Kihara[1], J., Vanlauwe[2], B., Waswa[2], B., Kimetu[3], J.M., Chianu[2], J. and Bationo[2], A.
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Abstract: Many food production systems in sub-Saharan Africa are constrained by phosphorus (P).We hypothesized that within legume-cereal rotation systems: targeting P to the legume phase leads to higher system productivity, and that use of grain legumes leads to better economic returns than use of herbaceous legumes. Four P application regimes: (i) no P, (ii) P applied every season, (iii) P applied in season 1 only and (iv) P applied in season 2 only were tested for four seasons in three cropping systems (continuous maize, mucuna-maize rotation and soybean-maize rotation) in a split plot experiment set up in Nyabeda, western Kenya. Treatments where P was applied were better than no P treatments. While continuous cereal systems showed the need for application of P every second season, rotation systems involving mucuna and soybean indicated that application in one out of three seasons could be sufficient. Nitrogen fertilizer equivalence was 52 to >90 kg N ha−1 for soyabean and 37 to >90 kg N ha−1 for mucuna, depending on P fertilization and season. Analysis of marginal rates of return (MRR) showed that soybean-maize rotation with one application of P was the

most economically viable option, with an MRR of at least 147% compared to other non-dominated options.

WORK IN PROGRESS

The impact of the various components underlying Conservation Agriculture on crop yield in Kenya

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Introduction

Experiences from past research have shown that for any meaningful adoption, conservation agriculture (CA) research process must be farmer-led or farmer-pulled and there is therefore need to raise farmer awareness of its benefits. Constraints to adoption must be removed to enhance the adoption of CA practices. There is need also for training, especially of farmers and technicians on the various components, practices and principles of CA. Access to markets and credit are essential to ensure incremental investment in CA. Further, to encourage massive adoption of CA and hence reverse the land, and environmental, degradation there is need to provide an incentive to smallholder farmers, who form the majority of land users, to enable them adopt and adapt sustainable agricultural practices. The goal should be to bring the farmers out of poverty with no further impoverishment of soils and other natural resources.

Materials and methods

Project activities are being implemented in two contrasting catchments in Siaya district (**Photograph 5**). At each of the benchmark site, the mother trials were distributed across the catchments so as to reach most farmers as possible within the region. All the mother trials are acting as replicates distributed within the catchment. The main mother trials are centrally located and will be used mainly for learning purposes and training farmers and other stakeholders on the concepts of CA using the FFS approach. In each of the 2 catchments, 30 more farmers will be selected representative of catchment conditions to lay out baby trials for the different CA practices to account for the biophysical and socio-economic conditions in the catchment. Baby trials will be started in subsequent seasons whereby farmers will pick out particular treatments to try them out on their individual farms. The Mother trials have the following treatments: (i) absolute Control - Farmers' practice (cereal/legume intercrop (maize/beans); no input application), (ii) no Till -cereal/legume

Photograph 5: Farmers in N. Alego listening to a point from the field officer.

rotation (maize/soybean) (*current season crop - soybean*) (rip and subsoil, mulch, fertilizer), (iii) no Till -maize/desmodium-intercrop (rip and subsoil, fertilizer; push-pull approach), and (iv) conventional Tillage -Maize/bean intercrop (fertilizer). Plot size was adjusted to 10m x 10m from 15m by 15m due to difficulty in fitting the bigger plots in most farmers' fields. Soil moisture measurements will be done using gravimetric tests. The soil moisture measurements will be taken at a minimum of three sample locations at each catchment monitoring site. Rainfall data will be collected at each Mother trial site for the entire period of experimentation. In addition composite soil samples will be collected from all the plots before planting in each season for further analysis.

In addition to what is called Farmers practice/experimentation, two additional plots of the actual farmers practice (1-homestead field and 1-bush field) from two farmers adjacent to either the mother trial or its replicates or the baby trials will be monitored and yield measurements collected as control plots, and the farmers interviewed on their management interventions of these fields. A field technician will be based at each catchment to collect both socio-economic and bio-physical data.

Preliminary results

One of the main principles underlying the practice of conservation agriculture is to provide sufficient soil surface cover to influence soil properties and smother weeds. In treatment 3 (T3) for all the mother and baby trials, desmodium was established under maize as a cover crop (**Figure 16**). In several of the trials, desmodium established well providing a good ground cover during the 2nd and 3rd seasons. It's anticipated that desmodium will provide sufficient soil cover especially over the dry season.

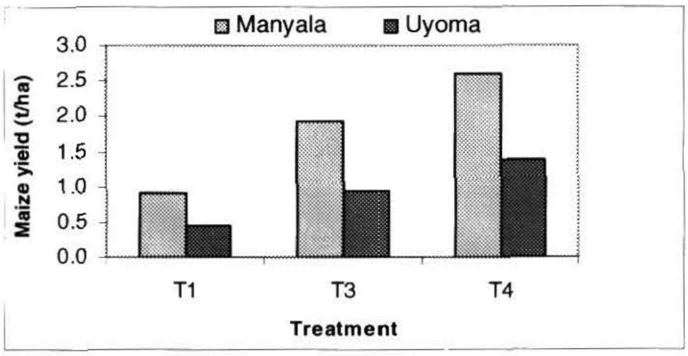

Figure 16: T1: Control – Conventional tillage (*maize/beans intercrop*); T3: Reduced Tillage - Cereal/cover crop *(maize/desmodium)*; T4: Conventional tillage (*maize/beans intercrop*).

Legume cover crops will supply nitrogen through biological fixation. In the first years of CA, the organic matter content also needs to be increased and the cover crops will supply this demand of biomass. In the first years of CA, the demand for nitrogen is high and therefore it is important to use legumes as the most rational source to supply this initial demand. Another important aspect is that the legumes are a protein source to feed the local people. It will not work where crop productivity is too low to achieve appreciable levels of ground cover. And as rather a daunting challenge, farmers, extension workers and researchers have to look at the whole issue of tillage differently if the concept of CA has to be embraced. This calls for a change of farmers' attitudes, because of the often deeply engraved traditional practice (mindsets) that they have had over the years. As long as the mind stays conventional it will be difficult to implement successful no tillage in practical farming. Hence "*a farmer has to first change his mind before changing his planter*" in the start of a journey into conservation agriculture. Entry points into the journey require a carefully defined "roadmap" that is locality, if not agro-ecological or farm specific. CA road map must take into consideration ongoing farmer organizational systems including capacity to venture into farming as a business. Thus this project seeks crystallize some of these issues and come up with concrete results and pathways on promoting CA among smallholder farmers in western Kenya.

Empowering farmers with soil, water and nutrient enhancing technologies for increased productivity in Southern Africa

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Introduction

In southern Africa, AfNet in collabollation with the Bioforsk Soil and Environment of Norway and the Department of Agricultural Research Services (DARS, Chitedze) are implementing an integrated soil fertility management project in Malawi. The project addresses key constraints to agricultural production and soil productivity in Chitekwere, located in a relatively dry region of Malawi. The project laid strong emphasis on participatory approaches to technology development and adoption. At the Extension Planning Area (EPA) level interaction between farmers, researchers and extension resulted in the choice of 5 technologies which were to be on-station and on-farm tested. One hundred farmers were involved, each picking up a technology or two of her/his choice. Plots of 10 X 10 m were used for the trials, which were conducted during the rainy season. Yield data of Year 1 have shown promise for some of the technologies, but were not enough to draw conclusions. The trials are being repeated in Year 2. The project ends in September 2010.

Materials and methods

The choice of the technologies aimed to minimize nutrient mining and improve water use efficiency (WUE) - some of the key components of increasing productivity. Water use efficiency can be improved agronomically by e.g. increasing the crop canopy, which in turn will maximize interception of radiation and reduce evaporation. Increased productivity can also be obtained through the combination of organic and small amounts of mineral fertilizer and by intercropping the main crop with legumes. The following 5 technologies have been identified and tested in this project: (i) maize intercropping with a legume (cowpea / common beans), (ii) maize intercropping with *mucuna*, (iii) conservation agriculture, minimum tillage with use of herbicides, (iv) conservation agriculture, minimum tillage with *mucuna* as a cover crop, no herbicides applied, and (v) maize intercropped with *Tephrosia candida* (Agroforestry) A basal dressing all participating farmers were supplied with an NPS fertilizer (23:21:0+4S). In all the trials, maize (ZM 621) was used as the test crop. The conventional practice (farmer's practices) constituted the CONTOL treatments. "Mother trials" were researcher-managed and located at the EPA. Planning and outlaying of the trials was done with the participation of farmers, extension and researchers. From the "Mother trials", the farmers were free to choose the technologies they wanted to try on their farms, so-called "Baby trials". The sections' extension agents assisted the farmers in setting up and managing the "Baby trials". It was, however necessary to encourage farmers to choose technologies that they otherwise would not have chosen voluntarily to avoid bias.

Preliminary results

The maize yield in different treatments ranged between 4.2 and 5.6 tons/ha which is far beyond the national average maize yield of 1.2 tons/ha (**Table 5**). The farmers perceived this dramatic yield increase compared to their traditional practices as very positive. Most of them had very good stands of maize, on their trial plots, with big cob sizes as depicted in the photo below. The increase in yields can be associated with enhanced use of inputs (fertilizer & seed), enough rainfall and appropriate management practices. Although, these results are from trials of only 1 year, the table above shows that, yields from some of the technologies introduced were statistically comparable to the conventional mineral fertilizer application. This is particularly true of conservation agriculture, minimum tillage with use of herbicides and maize intercropping with *Tephrosia candida*. A combination of mineral fertilizer with any of the technologies is expected to result in even higher yields.

Table 5: The aggregated maize yields of the first year are tabulated below.

Technology option	Maize grain yield (kg/ha)
Maize production with inorganic fertilizer	5615
Maize intercropping with a legume crop (cowpeas)	4242
Conservation agriculture, minimum tillage with use of herbicides	5372
Conservation agriculture, minimum tillage with crop cover (Mucuna)	4239
Maize intercropping with *Tephrosia candida (Agroforestry)*	5240
S.E.	673
CV%	23

Preliminary conclusions

Preliminary results obtained from the on-farm trials so far indicate that all the technologies being promoted show great promise in enhancing maize yields, consequently alleviating hunger and poverty in target areas through increased food security. Which of the options is more cost effective requires a more in-depth analysis of all the factors involved in production. Part of this work will be carried in the second year of the project.

Development and validation of the crop-stage based irrigation scheduling and fertilization techniques for irrigated maize in semi-arid zones of Malawi

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Introduction and justification

Crop productivity in the Shire Valley region in southern Malawi is adversely affected by low (<600 mm yr^{-1}) and unreliable rainfall, and extended dry spells during the rainfall season. In addition, repeated cultivation under smallholder management with little fertilizer inputs has led to soil fertility depletion, with nitrogen and phosphorus commonly deficient in most fields. Maize water requirement for four different irrigation scheduling scenarios (Daily Water Budget and three fixed scenarios of 40 mm every 3-4 days, 7 days and 14 days) studied at Kasinthula Research Station with different fertilizer and manure management.

Materials and methods

Water was used most efficiently under Daily Water Budget Irrigation scheduling (DSWBIS), but was difficult to use considering lack of weather data, calculation complexity and illiteracy levels among farmers. It was then modelled into a simple Crop Staged Based Irrigation Scheduling Technique (CSBIST) which predicted application of 20 mm every 7-8 day from planting to day 51, 20-30 mm every 3-4 day from day 51-125, and Water application depth of 30 mm every 6 days from day 125 up to physiological maturity for dry season maize production. The Crop stage based irrigation scheduling was field validated with Daily Water budget irrigation scheduling and irrigation of 40 mm every 3-4 days in 2007 and 2008. It was a split-plot design replicated three times. The three irrigation scheduling scenarios were main plots and three Nitrogen sources: Urea and Urea mixture with compost and FYM in 2:1 ratio at 120 N kg/ha.

Preliminary results

The results (**Table 6**) showed that maize yield was not significantly different between crop stage-based irrigation scheduling (8.88 and 9.14 t ha^{-1}) and daily water budget irrigation scheduling (9.61 and 9.35 t ha^{-1}) in respective years. Both scheduling scenarios significantly differed ($P<0.05$ and $P<0.01$) with the fixed scenario of 40 mm every 3-4 days. Nitrogen sources had no effect on maize yield in all irrigation scheduling scenarios ($P>0.05$). Water use efficiency (WUE) was highest under daily water budget scenarios (1.42 and 1.38 kg ha^{-1} m^3) and Crop-stage based scheduling technique (1.31 and 1.36 kg ha^{-1} m^3), and lowest under application of 40 mm every 3-4 days (0.63 and 0.62 kg ha^{-1} m^3).

Table 6: Crop stage based irrigation scheduling

Irrigation Scheduling Scenarios		**Nitrogen Sources**		**Mean**	**Irrigation (m^{-3} ha^{-1})**	**WUE (kg ha^{-1} m^3)**
	Urea	2/3Urea + 1/3FYM	2/3Urea+ 1/3Compost			
DSWBIS	9.22[a]	9.30[a]	9.54[a]	9.35[a]	6790	1.38
CSBIST	9.20[a]	9.37[a]	9.19[a]	9.14[a]	6700	1.36
Every 3-4 Days Irrigation Scheduling Scenario	8.13[a]	7.39[b]	7.56[b]	7.67[b]	12400	0.620
Mean	9.26[a]	8.97[a]	8.82[a]			

*Values followed by the same letter are not significantly different ($P<0.05$)

Preliminary conclusion

Preliminary results obtained showed that more water is lost at 40 mm every 3-4 days schedule. The Crop-stage based scheduling technique outperformed farmers' preferred irrigation scheduling scenario, and would be an attractive option to use scarce water resources efficiently.

Performance of bucket drip irrigation powered by treadle pump on tomato and maize-bean production

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[1]CIAT-TSBF, Malawi

Introduction and justification

Performance of bucket drip irrigation (BDI) powered by treadle was evaluated on tomato and intercropped maize-bean crops from 2005-2007at Kasinthula Research Station, Malawi.

Materials and methods

The experiment was laid out in Randomised Complete Block Design (RCBD) with three replicates. The BDI system consisted of 1300 litre-tank mounted at 1.5 m above ground, connected with a 32 mm mainline and 15 mm lateral lines spaced at 1 m by 0.6 m. A treadle pump was used to lift water to the tank. Tomato and intercropped maize-bean were irrigated every 4 days. Analysis was made on labour, irrigation uniformity, yield and profitability.

Preliminary results

The system reduced labour and water by >25% and showed high uniform application depth (80-95%) and wetted diameter (84-100 %,). Yields were significantly different ($P<0.05$) between tomato varieties. Maize-bean yields were highly significantly different ($P<0.001$) between monoculture, intercropping system and bean varieties. Monocropped maize and monocropped beans outweighed intercropped maize-bean yields. Intercropped maize-beanfaced interspecific competition though their combined yield value was significantly high compared to monocropping system. It was therefore recommended to intercrop maize-bean under drip irrigation. Consequent economic analysis showed that there was a significant difference in terms of net income between the crop enterprises. Tomato was more valuable for drip irrigation as compared to maize and beans.

Preliminary conclusion

It can be concluded that BDI powered by treadle pump saves labour, time and provides uniform irrigation for crop production. Tomato is recommended for the system as compared to maize and beans.

Evaluation of nitrogen fixation and transfer in a maize-Desmodium intercropping system

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Introduction and justification

Most legumes contribute nitrogen (N) through excess N fixed after decomposition of the residues but some Desmodium spp seems to have some direct benefits on intercropped maize. The objective of this study was to get an insight on i) the best time of intercropping maize and Desmodium, (ii) soil volume that would allow optimal growth of maize and Desmodium and (iii) isotope and natural abundance method of quantifying N fixation.

Materials and methods

The study was conducted in a greenhouse located at Moi University using soil collected from Siaya district. The treatments were as shown in (**Table 7**). Before sowing, all macro and micro nutrients (P, K, Ca, Mg, S, Zn, Cu, Mn and B) in form of salts were applied. Collected data included maize heights, Desmodium canopy height, color and biomass.

Table 7: Treatments combinations for preliminary pot trial

Treat-ment	Cropping system	Maize planting time (Weeks after planting Desmodium (WAPD))				Soil weights		Repli-cates	Total No. of pots
		0	6	8	10	10kg	20kg		
1	D. *uncinatum* + maize	√	√	√	√	√	√	3 (for all WAPD)6 (for 10 WAPD)	**36**
2	Sole maize	√	√	√	√	√	√	3	**24**
3	Sole D uncinatum	√				√	√	3	**6**
4	Sole maize with 15N	√				√	√	3	**6**
5	Sole D uncinatum with 15N	√				√	√	3	**6**
	Total No. of pots								**78**

Preliminary Results

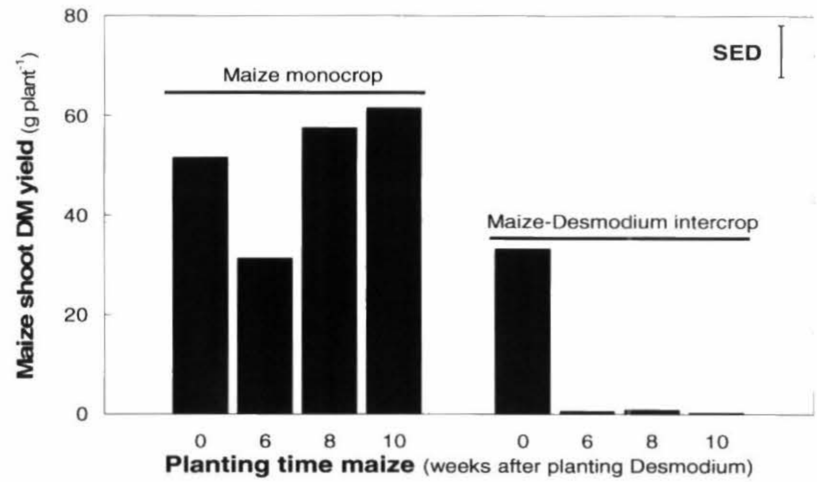

Figure 17: Effect of mono and inter cropping system on maize shoots (g/plant) yield.

Soil used in the study was acidic (4.89), had low N (0.091%), very low available P (2.35 mg P/kg) and moderate organic carbon (2.42%) according to interpretation given by Okalebo *et al.* (2002). Mono maize grew normally but maize planted inside Desmodium had a stunted growth . Mono maize shoots increased from 52g/pot to 62 g/pot in maize planted at 0 and 10 weeks after planting Desmodium (**Figure 17**). However, maize shoots yield of the intercrop decreased from 33g/pot in maize planted at the same time with Desmodium (0) to 0.3 g/pot in maize planted inside Desmodium at 10 weeks after planting Desmodium. 24 and 35 g/pot maize shoots were obtained in 10 and 20 kg soil weights respectively. Similar trend occurred with maize roots. Desmodium shoots yield increased with time from 21 g/pot to 74 g/pot in treatments with maize planted at 0 and 10 weeks after planting Desmodium respectively. Increase in soil weight resulted to significant increase in Desmodium shoot yields. Mean Desmodium shoot yields for 10 and 20 kg soil weights were 34g/pot and 70g/pot respectively.

Preliminary conclusions

Preliminary greenhouse results showed that planting maize inside Desmodium at a later date after planting Desmodium is not a viable option. Better growth of maize is achieved when maize is planted at the same time with Desmodium or after pruning Desmodium. Chemical analysis of the plant samples is ongoing to quantify biological nitrogen fixation and nitrogen transfer.

Soil and crop performance in conventional and conservation tillage systems in Western Kenya; the role of termites

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Introduction and justification

Conservation Agriculture, based on minimum soil tillage, crop residue retention and crop rotation, is being promoted to revaengineers, especially termites, to improved soil performance and crop growth under different tillage and residue management systems is not clear. We studied the effects of tillage and residue management on termite abundance and diversity in an agronomic field experiment in Western Kenya. A macrofauna exclusion experiment (using selective insecticides) was established within the field trial in 2005, to study the role of soil macrofauna. Our objectives were (i) to quantify the effects of different tillage and residue management on the abundance and diversity of termites, soil properties and crop performance, (ii) to see how these termites, soil and crop performance parameters are affected by soil macrofauna exclusion, and (iii) to compare different methods to quantify termite abundance and diversity in agricultural field experiments.

Materials and methods

Termite abundance was measured by monolith and soil core sampling and the diversity of termites was measured by combining those two methods with a transect sampling. Crop residue cover, soil moisture, and soil compaction were measured several times during one cropping season. Soil chemical properties were measured at different depths. Long-term yield data are available.

Preliminary results

Tillage and residue management did not significantly affect on termite abundance and diversity. Total soil carbon at 0-5cm, and to a lesser extent, at 5-15cm depth, was increased by residue retention, especially under no-till. The effect of tillage and residue management on soil moisture was not clear, whereas soil compaction was increased under no-till, especially when residues were removed. Macrofauna exclusion significantly reduced termite abundance, but not diversity, and resulted in a slower decrease in residue cover over the cropping season. Four years (8 cropping seasons) of macrofauna exclusion had also resulted in a significant increase in soil C (by 7-10%) and N content (by 4-15%) in the top 5 cm of the soil in the treatments that received crop residues. The latter may be explained by a direct effect of termites which remove crop residues to their nests, although possible indirect effects through a higher biomass production in the treatments which received insecticides still needs to be looked into. Macrofauna exclusion did not result in significant changes in soil moisture content and no consistent effects on soil compaction were found.

Apparent termite induced pest damage to soybean and maize at 18 weeks after planting was significantly reduced by macrofauna exclusion. However termite pest damage may have been overestimated because it is difficult to distinguish between real damage due to termites and other causes such as other (less visible) organisms or wind. The quantification of termite abundance and diversity in small agricultural plots, especially under no-till, has several complications. Further improvement of termite assessment methods is therefore recommended.

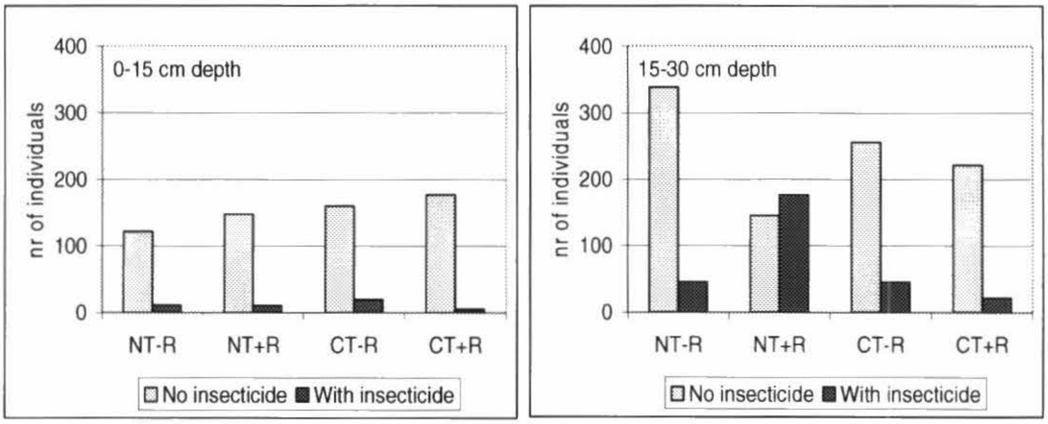

Figure 18: Termite abundance in the 4 different management treatments, No-till without crop residues (NT-R), No-till with crop residues (NT+R), Conventional till without crop residues (CT-R) and Conventional till with crop residues (CT+R), all under maize-soybean rotation.

Preliminary conclusion

We conclude that Conservation Agriculture did not lead to a change in termite abundance and diversity as compared to conventional tillage and did not find proof for a positive impact of termites on soil and crop performance, at least not during the first 8 seasons. Further research should elucidate to what extent positive effects of macrofauna exclusion on soil and crop parameters are directly related to termite activities.

Evaluation of agronomic efficiency of sole and combined fertilizer and organic input application assessed in farmer adaptation trials in the Eastern Province of Rwanda

P. Pypers[1], N. Tenge[1], A. Gahigi[1], C. Ndayisaba[1] and B. Vanlauwe[1]
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Introduction and justification

Fertilizer use efficiency is strongly affected by soil fertility and can be improved through combined application with organic inputs at moderate rates. Understanding how agronomic efficiency (AE) is affected by these factors can allow local adaptation and targeting of fertilizer to the most responsive fields. In the Eastern province of Rwanda, previous demonstration trials showed strong responses to fertilizer in both beans and soybean. Through farmer-managed, multi-locational adaptation trials, this response can be better understood, and aid in developing site-specific fertilizer recommendations.

Materials and methods

Farmer adaptation trials were conducted in the Eastern Province of Rwanda during 3 consecutive cropping seasons. Trials were conducted in four sites in Umutara (Nyakigando, Kabarore, Rugarama and Murambi), two sites in Kibungo (Gatore and Kabare), and two sites in Bug sera (Musenyi and Murama). During each season and in each site, 10 participating farmers received planting material and fertilizer and were trained to install and manage an adaptive trial with four treatments: (i) a control without inputs, (ii) sole DAP fertilizer application at a rate of 200 kg ha^{-1}, (iii) organic matter (OM) applied at 5 t ha^{-1}, (iv) combined application of DAP fertilizer (100 kg ha^{-1}) and OM (2.5 t ha^{-1}). Farmers were given the choice between soybean, beans and maize. The farmers described the field chosen for the trial in terms of soil fertility level, local soil name, landscape position and cultivation history. Following data was collected: planting, weeding and harvest dates, emergence rates, weed cover, plant stand at harvest and grain yield. At harvest, farmers scored each plot in terms of labour demand, vegetative growth, disease prevalence, yield and produce quality. AE of the fertilizer applied was calculated as follows:

$$AE_F = (GY_F - GY_{CON}) / F_F$$
$$AE_{FOM} = (GY_{FOM} - ½\, GY_{CON} - ½\, GY_{OM}) / F_{FOM}$$

with AE_F = AE of fertilizer applied solely (kg kg^{-1}), GY_F = yield obtained with sole application of fertilizer (kg ha^{-1}), GY_{CON} = yield obtained in the control without inputs (kg ha^{-1}), F_F = fertilizer quantity applied in the sole fertilizer treatment (200 kg ha^{-1}), AE_{FOM} = AE of fertilizer applied in the treatment with combined fertilizer and OM application (kg kg^{-1}), GY_{FOM} = yield obtained with combined application of fertilizer and OM (kg ha^{-1}), GY_{OM} = yield obtained with sole application of OM (kg ha^{-1}), and F_{FOM} = fertilizer quantity applied in the treatment with combined fertilizer and OM application (200 kg ha^{-1})

Preliminary results

Control bean grain yields were on average 740 kg ha^{-1}, but varied between 0 and 2000 kg ha^{-1} **(Figure 19)**. Application of fertilizer significantly increased the average grain yield by 48%. Responses to fertilizer varied largely, between -500 and +2000 kg ha^{-1}. Combined application of fertilizer and organic matter resulted in significant, but smaller yield increases (on average 35%). However, the variability in response (-400 - +1000 kg ha^{-1}) was relatively smaller than in the sole fertilizer treatment. Yield responses were generally larger in Umutara than in Kibungo and Bugesera, probably due to more favorable rainfall. Average AE of the fertilizer applied was comparable in the sole fertilizer treatment (1.8 kg kg^{-1}) than in the combined fertilizer and OM treatment (1.7 kg kg^{-1}) **(Figure 20).** Generally, AE values were highly variable. When control yields were smaller than 200 kg ha^{-1}, AE values were smaller than 1 kg kg^{-1}. For increasing control yields, increasingly larger maximal AE values were observed. Largest AE values (5-7 kg kg^{-1}) were observed for control yields of about 1000 kg ha^{-1}. For larger control yields, maximal AE values decreased. No response was observed for control yields exceeding 2000 kg ha^{-1}. Similar results were obtained in soybean and maize (data not presented). The variability in response to fertilizer is a result of soil fertility, organic matter quality, management (timely planting and weed control) and environmental factors (rainfall). Investigations will be conducted to evaluate to what extent the variability observed can be attributed to these factors. The farmer adaptation trials also included packages for evaluation of rotational benefits of soybean and beans, and improved intercropping arrangements in legume-cereal systems (data not presented).

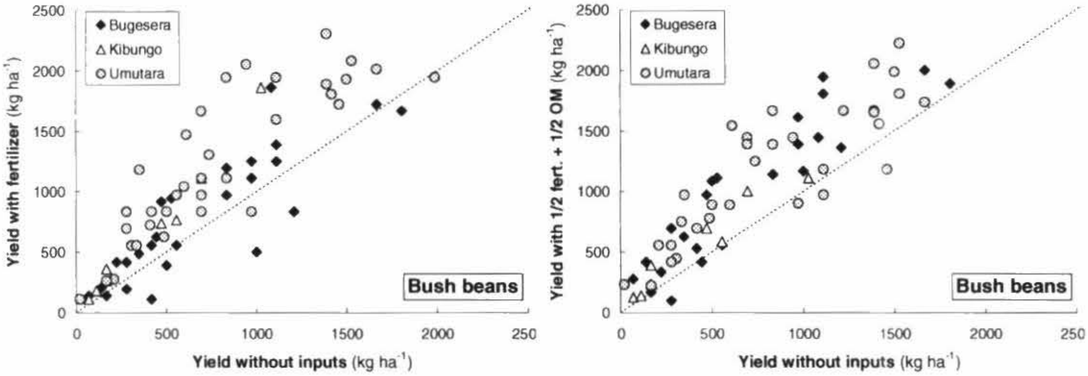

Figure 19: Bean grain yield in a treatment with sole fertilizer application (left) or combined fertilizer and organic matter yield (right) in function of the yield obtained in the control without inputs, in 3 regions in the Eastern Province of Rwanda.

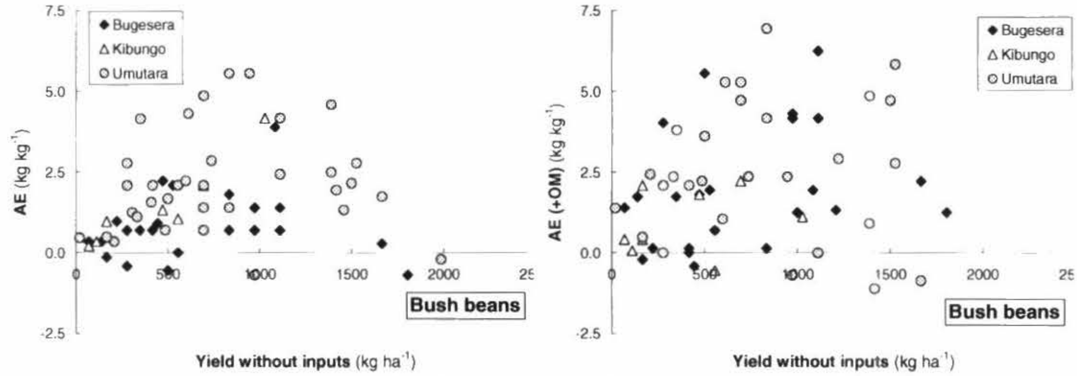

Figure 20: Agronomic efficiency (AE) of fertilizer applied in a treatment with sole fertilizer application (left) or combined fertilizer and organic matter yield (right) in function of the yield obtained in the control without inputs in 3 regions in the Eastern Province of Rwanda.

Output 1. Processes and principles
Output Targets 2009: Relationships between soil fertility status and the nutritional quality of (bio-fortified) legumes quantified within the Sahel and moist savanna impact zones.

WORK IN PROGRESS

Bio-fortified beans: interactions between soil fertility and nutritional quality of produce

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Introduction and justification

The magnitude of micronutrient malnutrition is increasingly taking centre stage in policy discussions on food and nutrition security. It is recognized that food security needs to refer not merely adequate energy intakes, but also to ensuring sufficient intakes of essential micronutrients (Meenakshi et al., 2007). Beans are important sources of Fe and Zn. The Harvest Plus initiative of CGIAR aims at increasing the Fe content in beans by 40 – 60 ppm, which will result in important increases in Fe intake, particularly in areas such as Sud-Kivu and Rwanda, where beans are a major staple crop.

Materials and methods

During the legume evaluation trials, a number of these so-called bio-fortified beans were tested in farmers' environment; grain samples were collected and analyzed for Fe and Zn content.

Preliminary results

We found that several varieties were indeed bio-fortified, characterized by Fe contents above 70 mg Fe kg^{-1}. However, for several of these varieties significant interactions with the environment were observed. The variety BRB194, for example, one of the most preferred varieties in the Eastern Province of Rwanda, contained on average 76 mg Fe kg^{-1}, but this concentration varied between 67 and 88 mg Fe kg^{-1}. Moreover, these interactions with the environment appear to be correlated with soil properties, particularly with soil organic matter contents, and different varieties appear to have contrasting interactions with soil properties **(Figure 21)**.

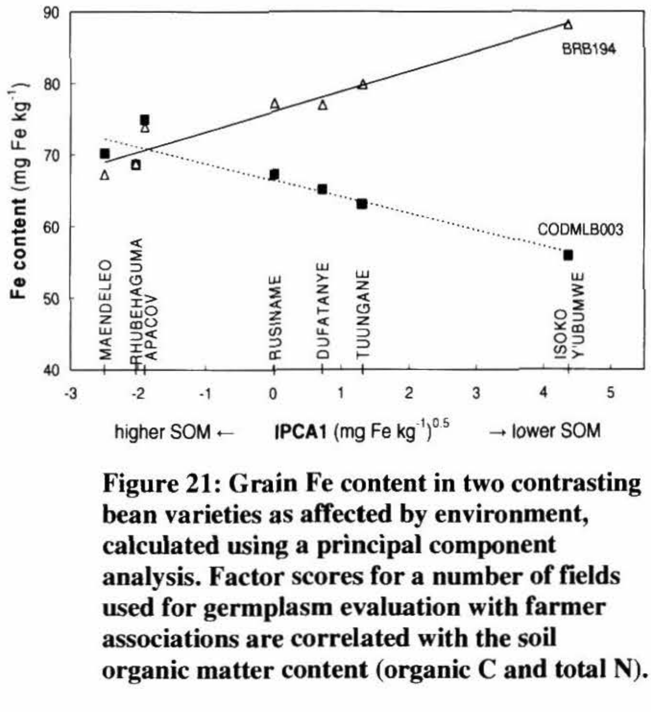

Figure 21: Grain Fe content in two contrasting bean varieties as affected by environment, calculated using a principal component analysis. Factor scores for a number of fields used for germplasm evaluation with farmer associations are correlated with the soil organic matter content (organic C and total N).

Preliminary conclusions

The observed trends are not easily understood, but crucial to value the ability of bio-fortified varieties to improve micronutrient nutrition in a specific region. More sampling and measurements are currently on-going to fully apprehend the genotype × environment interactions for a selected number of farmer-preferred bio-fortified bean varieties.

Output 1. Processes and principles
Output Targets 2010: Modeling tools (e.g. DSSAT, APSIM, NUANCES) for **ISFM**-based nutrient management used and adapted for **cereal-legume systems** in the Sahel and moist savanna impact zones.

WORK IN PROGRESS

Managing soil fertility diversity to enhance resource use efficiencies in smallholder farming systems: a case from Murewa District, Zimbabwe

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In sub-Saharan Africa smallholder farming systems, soil fertility and crop productivity vary substantially on different plots within and across farms. Therefore, nutrient resource allocation strategies appropriate for plots differing in fertility are required to increase overall crop production and resource use efficiency at farm and village scale. We applied a dynamic model (FIELD) to explore short- and long-term consequences of various strategies for use of limited nutrient resources (mineral N and P fertilizers and cattle manure) available to farmers on crop productivity and soil organic carbon (SOC) in a case study village in Murewa District, Zimbabwe. Simulations were done for four types of farms with different access to resources on each of two main soil types found in the area: an infertile granitic sandy soil and a more fertile dolerite-derived red clay soil. FIELD simulated a rapid decline in SOC and maize yields when native woodlands (FZ1) were cleared for maize cultivation without fertilizer inputs coupled with removal of crop residues. This is typical management on plots belonging to poor farmers and plots distant from homesteads on wealthy farms, resulting in a zone of depleted soils (FZ4) characterized by poor crop response to fertilizer application. Applications of at least 10 t manure ha^{-1} yr^{-1} for about 10 years were required to restore maize productivity to the yields attainable under FZ1. Long-term (>30 years) application of manure at 5 and 3 t ha^{-1} resulted in SOC levels comparable to zones of high (FZ2) and medium (FZ3) soil fertility observed on farms of cattle owners. Targeting manure application to restore SOC to about 60% and 50% of contents under native woodlands was sufficient to increase productivity to 90% of attainable yields on the sandy and clay soils respectively. On the sandy soil, nutrient resources on farms of cattle owners were used most efficiently in the short-term when manure was applied to FZ3 plots and mineral fertilizers to FZ2 plots. There is scope to improve productivity of smallholder farms by targeted application of limited mineral and organic nutrient resources to fields varying in soil fertility, although this has greater impact on wealthier farmers who have more fertile soils and greater access to fertilizer and manure. Short-term increases in crop productivity achieved by reallocating the same amount of limited manure to less fertile fields were short-lived on the sandy soil, and increased investment in organic nutrient resources is necessary to sustainably increase crop productivity. Preventing degrading systems under cultivation is difficult, particularly in low input farming systems, and attention should be paid to judicious use of the limited nutrient resources to maintain levels of soil fertility that support good crop response to fertilizer application.

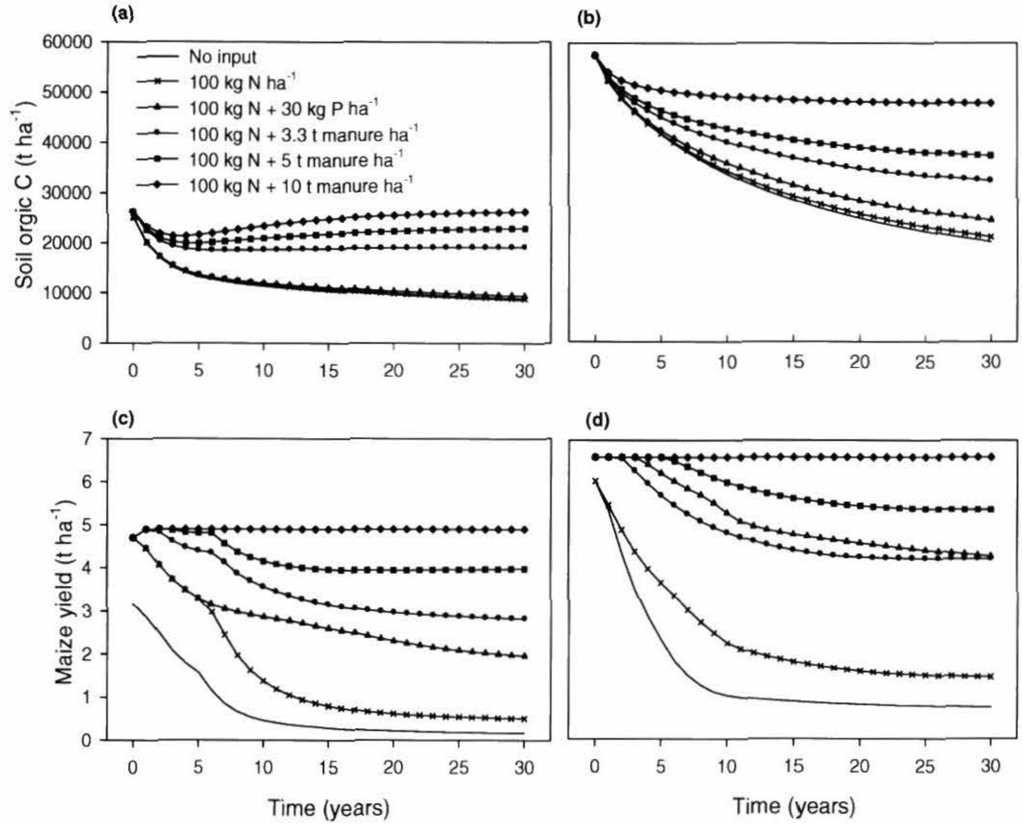

Figure 22: Simulated effects of resource management options on long-term dynamics of soil organic C on the sandy (a) and clay soils (b), and maize grain yields on the sandy (c) and clay (d) soils.

Output 1. Processes and principles
Output Targets 2010: Mechanisms underlying the agronomic efficiency of applied fertilizers in the context of ISFM identified and understood for **cassava and rice-based systems** in the humid lowland impact zone and for **banana-based systems** in the mid-altitude impact zone, taking into account variability in soil fertility status at different scales.

WORK IN PROGRESS

Alternatives to slash-and-burn for soil fertility management in lowland cassava production systems in Bas-Congo, DR Congo

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Introduction and justification

In Bas-Congo, cassava is the main staple crop grown by virtually all farmer households. The low population density and consequent low land pressure allows farmers to practice agriculture by 'slash-and-burn' and relatively long fallow-periods, typically 2-4 years.

Farmers commonly do not apply any fertilizer, manure or other nutrient inputs, but invest large amounts of labour for land preparation and weed control. Cassava yields obtained by farmers are low (around 10-15 t ha^{-1}). ISFM options can increase yields using improved germplasm in combination with judicious addition of fertilizer and organic inputs, but should increase in larger returns to investment relative to the traditional 'slash-and-burn' system.

Materials and methods

Researcher-managed trials were installed in two sites in Bas-Congo (Mbuela and Kiduma) following a randomized complete block design with three replicates and thirteen treatments. The first treatment was an absolute control whereby the natural vegetation was slashed and removed from the plot. In the second treatment, the natural vegetation was slashed, chopped, piled up in strips, and buried in the planting beds. In the third treatment, the natural vegetation was similarly slashed and piled up in strips, but was burnt prior to establishing the planting beds ('slash-and-burn' farmers' common practice). The following 3 treatments consist of a response to fertilizer applied at rates of 40, 120 and 200 kg K ha^{-1}, with the natural vegetation slashed and removed from the plot. Fertilizer was spot-applied as compound NPK (17:17:17) fertilizer. In the seventh treatment, the natural vegetation was managed as in the second treatment (buried under the planting beds), and additional fertilizer was spot-applied at planting at a rate of 40 kg K ha^{-1}. In the following two treatments, *Tithonia* and *Chromolaena* green manure were added at a rate of 2.5 t DM ha^{-1}. In the final four treatments, these green manure applications at the same rate of 2.5 t DM ha^{-1} were combined with fertilizer applications at 40 and 120 kg K ha^{-1}. Observations included cassava growth and storage root yield, produce quality, and residual effects of the amendments during the subsequent season (replanted with cassava). Detailed labour measurements were taken for all operations, and input and output prices were collected regularly during the trial period for economic analysis.

Preliminary results

In none of the two sites, the slash-and-burn treatment resulted in increased storage root yields, relative to the treatment where the natural vegetation was slashed and buried in the planting beds (**Figure 23**). Both treatments resulted in a significant (P<0.05) increase in storage root yields of about 6 t ha^{-1}, relative to the control, where the natural vegetation was cleared and removed from the plots. Control yields were relatively low (about 12 t ha^{-1}) and no significant differences were observed between the two experimental sites. Response to fertilizer differed significantly (P<0.05) between sites. While in Kiduma, cassava responded to fertilizer application up to a rate of 200 kg K ha^{-1}, no response beyond 120 kg K ha^{-1} was observed in Mbuela. Maximal yields were twice as large in Kiduma (40 t ha^{-1}) than in Mbuela (20 t ha^{-1}). Application of *Chromolaena* green manure did not result in larger storage root yields than slashing and burying the natural vegetation. Application of *Tithonia* increased yields by 13 t ha^{-1} relative to the treatment with the natural vegetation buried in Kiduma, but not in Mbuela. In Mbuela, no response to additional fertilizer application was observed. In Kiduma, however, response to additional fertilizer application was only observed in combination with *Chromolaena* green manure. Combined application of *Chromolaena* green manure and fertilizer 120 kg K ha^{-1} resulted in storage root yields of 35 t ha^{-1}, which was comparable with yields obtained with *Tithonia* green manure.

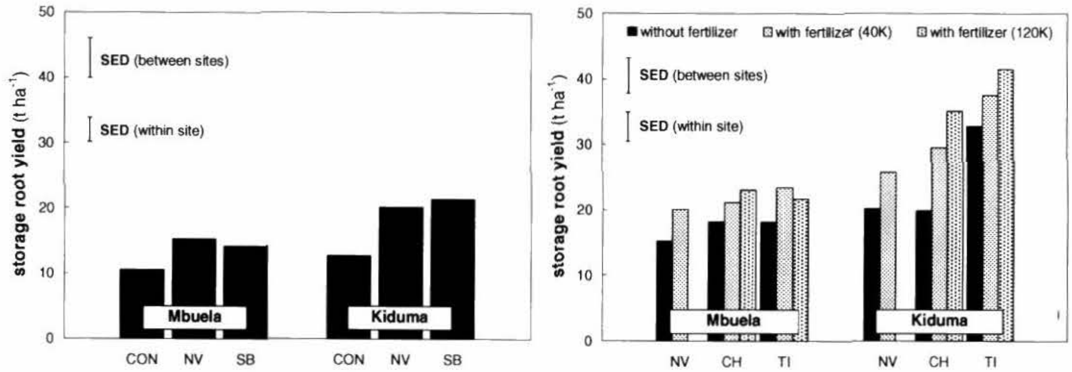

Figure 23: Cassava storage root yield as affected by burying the natural vegetation (NV) in the planting beds, and 'slash-and-burn' (SB) relative to a control (CON) with the vegetation removed from the plot prior to planting (CON) (left), and by application of *Chromolaena* (CH) or *Tithonia* (TI) green manure solely or in combination with fertilizer at 40 or 120 kg K ha^{-1} (right).

Little formation of secondary storage roots occurred. In weight, secondary storage roots comprised less that 4 % of the total storage root yield. No differences between sites or treatments were observed (data not shown). The proportion of tradable primary storage roots was larger in Kiduma (86 %) than in Mbuela (56 %), but was unaffected by the application of fertilizer or green manures. The proportion of tradable primary roots was not correlated with the total storage root yield. Most storage roots classified as non-tradable were of inferior size (or unit weight). Only a minor proportion of the primary harvest roots (2 %) were considered non-tradable because of high fibre content or due to damage or decay. Non-tradable roots weighed on average 0.2 kg per storage root, independent of site or treatment. The size of the tradable primary roots was affected by treatments, although only significant at $P<0.1$. Storage root sizes were largest (0.7 kg per storage root) in the treatments with combined green manure and fertilizer application, and smallest (0.4 - 0.5 kg) in the control and treatments with natural vegetation slashed and buried, or slashed and burned. In the other treatments, intermediate storage root sizes (0.60 kg) were observed. The flesh content (fresh matter) was slightly but significantly ($P<0.001$) larger for tradable (78 %) than for non-tradable storage roots (74 %). The DM content of the cassava storage root flesh equaled 39 %.

Preliminary conclusions

An economic analysis shows that the use of *Tithonia* or *Chromolaena* green manure is most profitable under current conditions (benefit-cost ratio = 5 – 6), followed by fertilizer application (benefit – cost ration = 3 – 5). Both options result in highly profitable yield increases, and are viable alternatives for the common slash-and-burn practice. The use of green manure and fertilizer will depend on the relative price and availability of both inputs.

Output 1. Processes and principles
Output Targets 2010: A set of mechanistic principles underlying ISFM practices for Quensungal agro-forestry systems in the Central American hillside impact zone.

COMPLETED WORK

Quesungual slash and mulch agroforestry system improves rain water productivity in hillside agroecosystems of the sub-humid tropics.

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[1]CIAT; [2]ESNACIFOR, Honduras; [3]INTA, Nicaragua; [4]CORPOICA, Colombia; [5]Harvard University, USA; [6]IDRC, Canada; [7]UWA, Australia; [8]UNA, Nicaragua; [9]FAO, Honduras; [10]CPWF-CGIAR

Abstract: The Quesungual Slash and Mulch Agroforestry System (QSMAS) is a smallholder production system with a group of technologies for the sustainable management of water, soil and nutrient resources in drought-prone areas of hillside agroecosystems of the sub-humid tropics. QSMAS integrates local and technical knowledge and provides resource-poor farmers with an alternative to the environmentally unfriendly slash and burn (SB) traditional production system. The main objective of this study was to determine the key principles behind the biophysical resilience of QSMAS and its capacity to sustain crop production and alleviate water deficits on steeper slopes with risk of soil erosion. Activities included the evaluation of QSMAS performance compared to the traditional SB system in terms of water dynamics (including crop water productivity), nutrient dynamics, and greenhouse gas fluxes (including global warming potential). Results indicate that the application of the four principles behind QSMAS productivity and sustainability (no slash-and-burn, permanent soil cover, minimal disturbance of soil, and improved fertilizer practice), has positive effects on the soil-plant-atmosphere relationships, soil quality, and on landscapes and the environment. Validation in Nicaragua and Colombia underpin the potential of QSMAS to enhance support for livelihoods in vulnerable rural areas in sub-humid tropics.

WORK IN PROGRESS

Dynamics of nitrogen and phosphorus in Quesungual Slash and Mulch Agroforestry System

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[1]CIAT, Colombia; [2]National University of Colombia – Palmira; [3]Harvard University, USA; [4]CORPOICA, Colombia; [5] CIAT-Honduras

Introduction and justification

The Quesungual Slash and Mulch Agroforestry System (QSMAS) is a smallholder production system with a group of technologies for the sustainable management of soil, water and nutrients in drought-prone areas in hillsides of the sub-humid tropics. QSMAS is practiced in southwest Honduras (Central America), where it has successfully replaced the non-sustainable, environmentally unfriendly slash-and-burn (SB) traditional system. The main objective of this study was to determine the effect of the components of QSMAS and the principles (*no SB, permanent soil cover, minimal disturbance of soil and efficient use of fertilizer*) that define its management on the dynamics of nitrogen (N) and phosphorus (P), and the impact of these dynamics on the productivity and sustainability of the system in Honduras.

Materials and methods

Research was conducted to compare 5 land use systems: (1) Slash-and-burn (traditional production system); (2, 3 and 4) QSMAS of <2 years, 5-7 years and >10 years old, respectively; and (5) Secondary forest (reference land use system). SB and QSMAS were managed applying local practices to produce maize (*Z. mays*) and common bean (*P. vulgaris*). QSMAS also included the addition of fertilizers with the application of 49 kg N + 55 kg P ha^{-1} 8-10 days after planting (DAP) and 52 kg N ha^{-1} ~30 DAP for maize; and 46 kg N + 51 kg P ha^{-1} 8-10 DAP for common bean.

Measurements included: (1) *in situ* determination of decomposition and nutrient release from biomass of trees, shrubs and annual crops (Wieder and Lang,1982), using the litterbag technique (Bocock and Gilbert, 1957); (2) *ex situ* N aerobic mineralization to measure the potential conversion of organic N into inorganic forms available for plant uptake (Anderson and Ingram, 1993); (3) *ex situ* partition of soil total P to measure the size of different pools with varying levels of availability, following a sequential fractionation (Tiessen and Moir, 1993; (4) *ex situ* size-density fractionation of soil organic matter (SOM) as indicator of potential functional activity of SOM (Meijboom et al., 1995; Barrios et al., 1996); (5) *ex situ* nutrient partitioning of crop biomass, to measure the contribution of annual crops in the reference site to N and P cycling and balance; and (6) *in situ* determination of crop yield in the different land use systems.

Preliminary results

Research results comparing the performance of the traditional land use systems (i.e. the traditional SB no fertilized, QSMAS fertilized and secondary forest), indicate that in terms of biomass mineralization, the decomposition and release of N and P from a mixture of vegetative materials of different quality (good, intermediate and poor) according to the C:N ratio, were similar among systems (**Figure 24**). For QSMAS, this suggests an effective biological activity and nutrient cycling over time. Total soil organic matter (SOM) content in QSMAS increased over time. However, the biologically active fraction of SOM (light fraction, LL) was reduced in both production systems, compared with the secondary forest. Total N content in soil was similar among the production systems evaluated, with a tendency to be increased in QSMAS over time (**Figure 26**). Additionally, N aerobic mineralization was higher in QSMAS before the first addition of inorganic fertilizers, being a potential source of starter N in the early stages of crop growth. Total P content in QSMAS also increased across time, although the proportion of organic and inorganic P pools remains similar among land use systems (**Figure 27**). Under the traditional practices used to produce maize and common bean in the SB system (where the source of nutrients are ashes after burning) and QSMAS (in which nutrients are provided by fertilizers and biomass from native species of trees and crop residues), yields of maize were higher in QSMAS, although they decrease over time (**Figure 28**). Yields in common bean were consistently low in SB system and QSMAS mainly due to low yield potential of the landrace used.

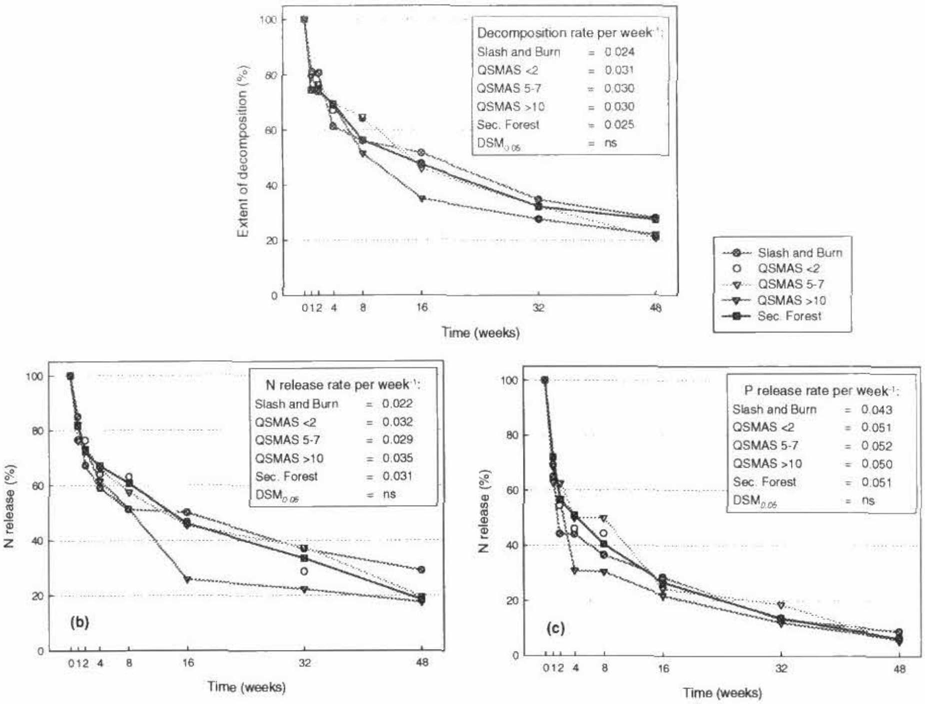

Figure 24: Decomposition of (a), and release of N (b) and P (c) from a mixture of vegetative materials of different quality in three land use systems in south-western Honduras.

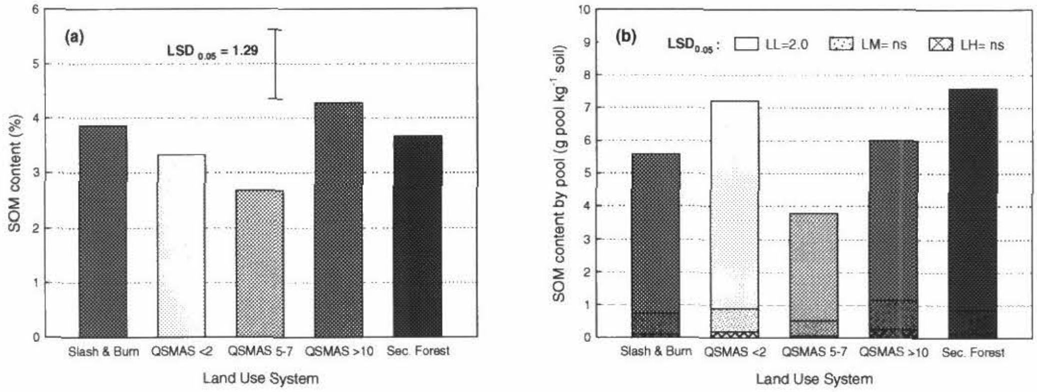

Figure 25: Soil organic matter (SOM) total content (a) and fractions (b, LL= light fraction, LM= intermediate fraction, and LH= heavy fraction) in three land use systems in south-western Honduras.

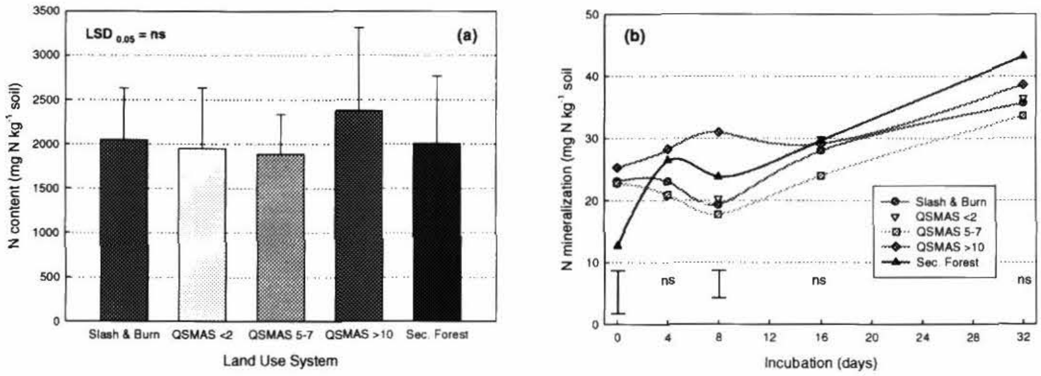

Figure 26: Total N content in soil (a) and N aerobic mineralization (b) in three land use systems in south-western Honduras.

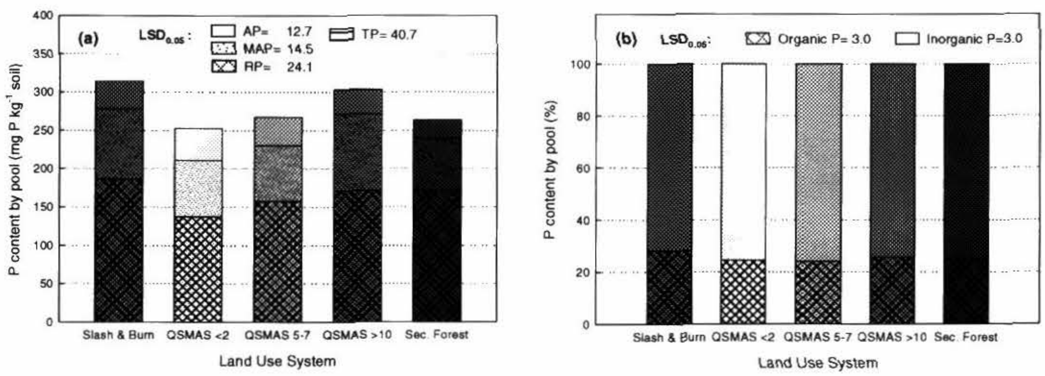

Figure 27: Total P content (a) and organic and inorganic P pools (b, AP= Available P; MAP= Moderately available P; RP= Residual P. TP= Total P) in three land use systems in south-western Honduras.

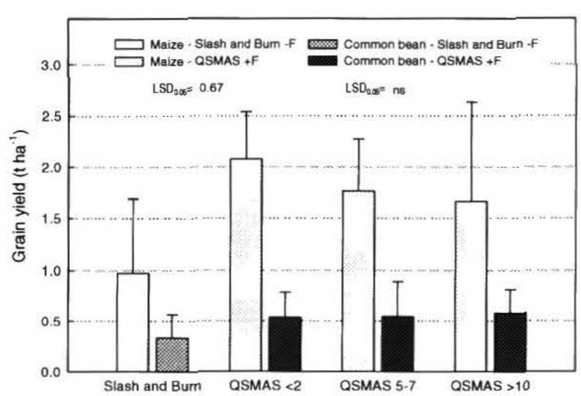

Figure28: Grain yield of maize and common bean in two land use systems in south-western Honduras.

Preliminary conclusions

Similarities in N dynamics in Quesungual and slash-and-burn systems indicate that they were equally effective in providing N, although in Quesungual system it is more the result of a biologically mediated process than of an accelerated source through burning.
Compared to slash-and-burn system, P pools of Quesungual system are more dynamic and favorable for crop production by reducing their flows towards unavailable forms.
Based on the availability of nutrients and grain yields over time, Quesungual system may be recommended as an option to replace the traditional slash-and-burn system.

Potential of Quesungual agroforestry system as a land use management strategy to generate multiple ecosystem services from sub-humid tropical hillsides

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Introduction and justification

Within the terrestrial ecosystems, the soil is the main provider of environmental services (ES). The soil is a living system essential to sustain biological productivity, air and water quality, and plant, animal and human health (MEA 2005). Unfortunately, soil degradation is a severe problem for food production in rural areas, particularly in developing countries. Therefore, it is necessary to contemplate strategies for land management representing the best possible communion between generation of multiple services while preserving the natural capital (Lavelle 2008).

The Quesungual Slash and Mulch Agroforestry System (QSMAS) is a smallholder production system that makes use of a group of technologies for the sustainable management of vegetation, water, soil and nutrient resources in drought-prone areas of hillside agroecosystems of the sub-humid tropics. The system was developed in southwest Honduras, Central America, by improving native farming practices with the participation of local farmers and technicians of Food and Agriculture Organization (FAO) and other national and international institutions. The system is based on planting annual crops (maize, common bean, and sorghum) with naturally regenerated trees and shrubs. QSMAS is being practiced by smallholders in Honduras, where the system has been successfully adopted by over 6,000 resource-poor farmers on 7,000 ha. This resulted in a locally recognized suitable alternative to the traditional slash and burn (SB) system, with biophysical and socioeconomic benefits at multiple scales ranging from farm level (increased crop water productivity, food security) to landscape (increased amount and quality of available water).

The set of technologies responsible for the success of QSMAS can be summarized in four basic principles of conservation agriculture that contribute synergistically to its superior performance: (1) no SB, but through the management of natural vegetation; (2) permanent soil cover, through the continual deposition of biomass from trees, shrubs, and weeds, and through crop residues; (3) minimal disturbance of soil, through the use of no tillage, direct seeding, and reduced soil disturbance during agronomic practices; and (4) efficient use of fertilizer, through the appropriate application of fertilizers. The main objective of this research work was to determine the key principles behind the biophysical resilience of QSMAS and its capacity to sustain crop production and alleviate water deficits on steeper slopes with greater risk for soil erosion.

Materials and methods

The performance of QSMAS was studied in southwest Honduras, within the Lempa River upper watershed department (district) of Lempira, from 2005 to 2007. Mean annual (bimodal) precipitation is ~1400 mm falling from early May to late October, with a long dry season of up to 6 months. Field plots were established to compare 5 main treatments (replicated on three different farms): QSMAS of three different ages (<2, 5-7 and >10 years-old), the traditional SB system, and secondary forest (SF) as a reference land use system (LUS). Annual management of QSMAS plots included slashing and mulching through pruning of trees and through crop residues while SB plots were managed through slashing and burning of native vegetation, before the onset of the rainy season. Maize and common bean were established in the early (late May) and later (late August) part of the rainy season, respectively, and managed following the timing, spatial arrangement and management practices that are commonly used in the region for the production systems under comparison. The four production system treatments (QSMAS of different ages and SB) were split in order to apply a fertilizer treatment (addition vs. no addition). In the fertilized treatments, the maize received 101 kg/ha of N and 55 kg/ha of P, while the common bean received 46 kg/ha of N and 51 kg/ha of P. Studies included monitoring and analysis of soil water dynamics, crop water productivity (CWP), greenhouse gas (GHG) fluxes, carbon sequestration and global warming potential (GWP).

Water infiltration and runoff were measured through rainfall simulation for 30 minutes using two intensities (80 and 115 mm/h). Soil water content was determined through soil sampling at three depths (0-10, 10-20 and 20-40 cm). Susceptibility of the soil to erosion was assessed in erosion plots (5 m length x 1.5 m width) over 3 years. Soil losses were determined through the comparison of the indices of soil erodibility K-USLE and Ki-WEPP corresponding to the Universal Soil Loss Equation (Wischmeier and Smith 1978) and to the Water Erosion Prediction Project (Nearing *et al.* 1989), respectively. Nutrient losses through erosion were quantified by determining total contents of N, P, K, Ca and Mg from samples of eroded soils. Water quality was assessed through the determination of NO_3^-, NH_4^+, total P, and PO_4^{-3} in samples collected at 45 DAP. Both eroded soil and water samples were collected in erosion plots in 2007. CWP, expressed as kg of grain produced per m^3 of water used as evapotranspiration, was calculated using the crop yield and soil water data obtained in 2007 and by estimating the evapotranspiration (ET) according to the method of Penman and Monteith (FAO 1998).

Annual GHG fluxes between soil and atmosphere were monitored using the closed chamber technique as described by Rondón (2000). At the beginning of the study, 4 PVC rings (height 8 cm, ø= 25 cm) were located in the experimental plots. In every chamber and at each sampling date (16 dates), 4 air samples were taken at 0, 10, 20 and 30 minutes, after installing the chamber (height 10 cm, over the PVC ring). Air samples were extracted from the closed chamber using a syringe with an adapted valve and then introduced into glass containers (pre-vacuumed vials by freeze drying). N_2O and CH_4 concentrations were determined in the laboratory, using a Shimadzu GC-14A gas chromatograph, equipped with FID (flame ionization detector) and ECD (electron capture detector) for methane (CH_4) and nitrous oxide (N_2O) detection, respectively. For CO_2 concentration, we used a Qubit Systems S151 gas analyzer, with infrared technology. GWP of the different LUS was calculated by using CH_4 and N_2O fluxes between soil and atmosphere, and C stocks from soil and tree biomass. For the traditional SB system direct emissions of CO_2, CH_4 and N_2O, from the biomass burning were also included. GHG fluxes of each LUS were multiplied by the global warming potential value, corresponding to the GHG (CO_2=1, CH_4=72 and N_2O=289) in a 20 year time horizon (IPCC 2001).

An emergy (from "embodied energy", a measure of the total energy used to make a product or service) evaluation was conducted as in Diemont *et al* (2006) to quantify resource use and system sustainability, using data from plots and relationships (energy input per unit of energy output) reported in other studies. The Environmental Loading Ratio (ELR, a measure of ecosystem stress due to a production activity) was given by the ratio from purchased and nonrenewable local inputs, to the emergy from renewable resources.

Preliminary results

Evaluation of water dynamics at the middle of the rainy and dry seasons of 2007 showed a lower infiltration and higher runoff in SB system. During the rainy season, SB had the lowest infiltration (29.8 mm) and highest runoff (12 mm); in contrast, QSMAS >10 years had the highest infiltration (38.5 mm) and lowest runoff (4.8 mm). During the dry season differences between treatments in infiltration and runoff were small. Infiltration for 30 minutes ranged from around 44 mm in both QSMAS treatments to 41.9 mm in SB. Runoff ranged from 0.91 mm in QSMAS to 2.4 mm in SB. In 2007, precipitation and ET were 1005 and 491 mm in the early part of rainy season, and 419 and 272 mm in the later part, respectively. In the early part of the rainy season available soil water (0-40 cm soil depth) varied between 0.09 and 0.104 m^3/m^3, with QSMAS <2 and QSMAS 5-7 and was 10% and 16% higher, respectively, than in SF. In the later part of the rainy season the amount of available soil water varied between 0.11 and 0.127 m^3/m^3 in SB and QSMAS <2, respectively. The mean value of available soil water content (0-40 cm) in QSMAS systems (average of the three different ages) was significantly greater than that of the SB system, suggesting increased availability of water for crop growth. These improvements in QSMAS were related to changes in soil porosity due to increases in mesoporosity (30%) and macroporosity (19%), and decreased the soil bulk density. This increased the plant available soil water storage capacity and availability of water for crops in the dry season, and increased the capture of rainfall at the beginning of the rainy season. The highest soil loss occurred in 2005, and was markedly higher in SB followed by QSMAS and SF. The same trend was observed in 2006 and 2007, although differences were greater in 2005 due to higher rainfall intensity and to the recent conversion of SB plots from SF that resulted in bare soil and therefore higher susceptibility to erosion. Total soil losses over the 3 years from SB were 5.6 times greater than from the three QSMAS treatments, and 22 times greater than from SF. As a result, the SB system had the highest nutrient losses (kg/ha) of N (9.9), P (1.3), K (6.9), Ca (22.8) and Mg (24.2), while SF had the lowest losses of N (1.7), P (0.2), K (1.2), Ca (2.6) and Mg (2.7). Water quality was poorest in the SB system, with highest concentration (mg/L) of total P and PO_4^{-3} (2.30 and 0.29, respectively), and was much better in QSMAS >10 (0.18 and 0.25, respectively). SB also had the highest concentration of (mg/L) of NO_3^- and NH_4^+ (7.97 and 0.70, respectively), while QSMAS 5-7 had the lowest concentration of NO_3^- (6.13) and QSMAS >10 of NH_4^+ (0.24). SF had values of 0.65 for P, 0.43 for PO_4^{-3}, 4.73 for NO_3^-, and 0.92 for NH_4^+.

There was no interaction between LUS and fertilizer treatment on CWP. CWP (kg grain m^{-3}) for maize was greatest in fertilized systems of QSMAS <2 (0.48) and least with QSMAS >10 (0.18). In plots with no fertilizer application, the highest CWP was observed with QSMAS <2 (0.26) and the lowest with SB (0.10). In both fertilized and non-fertilized systems, CWP for common bean was greatest in QSMAS <2 (0.32 and 0.27 kg grain m^{-3}, respectively) and least with SB (0.10 and 0.07 kg grain m^{-3}, respectively). Fertilization increased CWP of maize (by

92%) and common bean (by 23%). These results may reflect adequate available soil water during the maize crop (from sowing to physiological maturity) in the early part of the rainy season, as precipitation was higher than ET. In the case of common bean grown in the later (drier) part of the rainy season, available water content in the soil decreased from flowering to physiological maturity, with lower precipitation than ET and therefore with a negative water balance. Under these conditions, QSMAS showed greater available water content in soil that resulted in greater grain yield and CWP.

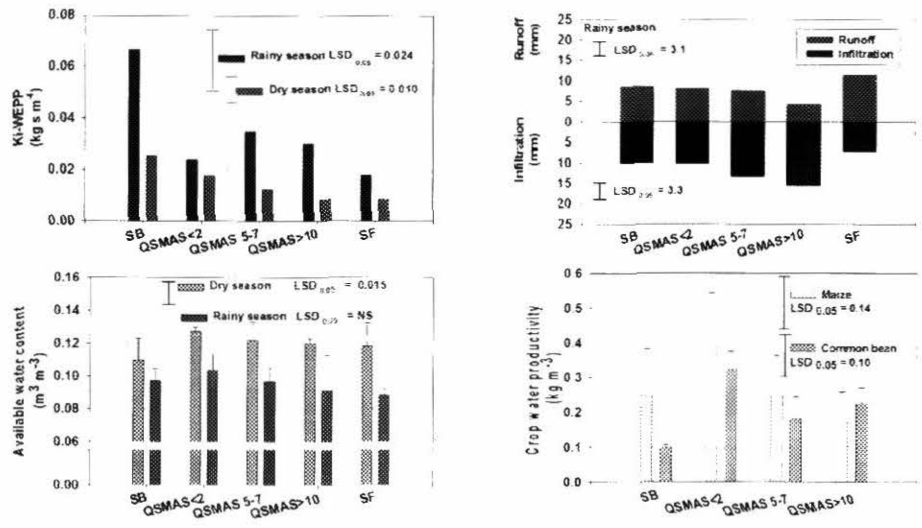

Figure 29: Provisioning services provided by QSMAS: improved water cycling through reduced susceptibility to erosion (top left), increased infiltration and decreased runoff (top right) and improved soil water storage capacity (bottom left), and improved food security through enhanced crop water productivity (bottom right).

C stocks were higher in SF and QSMAS, with higher accumulation in SF for aboveground C (C in trees and shrubs) and in QSMAS >10 for belowground (soil organic) C **(Figure 29).** The SB system could generate higher annual losses of above ground C due to burning, while young QSMAS plots (<2 and 5-7 years old) generate some losses of below ground C. QSMAS also had a much lower GWP (10.5 Mg Equiv. CO_2) than SB traditional system (40.9 Mg Equiv. CO_2). SF had a very low GWP (1.14 Mg Equiv. CO_2) **(Figure 30)**. Based on the current adoption of QSMAS and consequent regeneration of SF in the Lempira department where QSMAS is practised and projecting its impact on GWP for a period of 20 years, it is estimated that the adoption of QSMAS will result in a decrease of 0.10 Tg Equiv. CO_2 compared to SB. Higher C stocks in soil and the aboveground tree biomass indicate a gradual accumulation of C in SF and QSMAS >10. According to the emergy evaluation SF and QSMAS had less environmental impact than SB (highly affected by levels of soil erosion) as noted in the ELR with values of 0.63, 0.14, and 0.02, respectively.

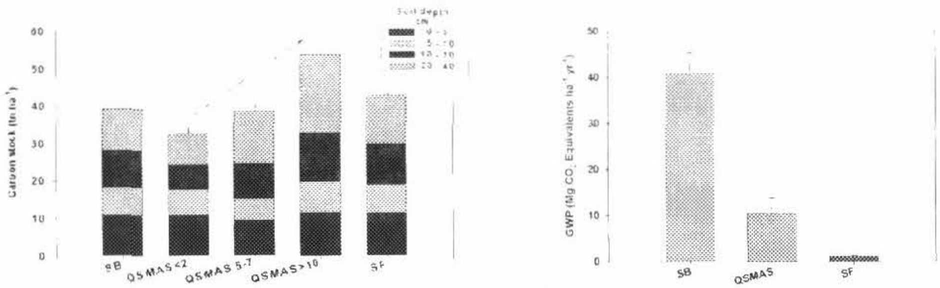

Figure 30: Regulating services provided by QSMAS: reduced global warming potential through improved C accumulation (left) and lower methane emission (right).

Preliminary conclusions

The results indicate that the production practices used for managing QSMAS have beneficial effects on the soil-plant-atmosphere continuum, soil quality, landscape and the environment. Compared to SB system QSMAS is eco-efficient through the use of renewable natural resources, and also provides ecosystem services including: (1) Provisioning services: food security through improved crop water productivity and yields at lower costs; and improved water cycling through reduced runoff, erosion, water turbidity and surface evaporation, and increased infiltration, soil water storage capacity and use of green water; (2) Regulating services: reduced global warming potential through lower methane emission and improved C accumulation; (3) Supporting services: mitigation of soil degradation through improved structure, biological activity, organic matter, nutrient cycling and fertilizer use efficiency, and restoration and conservation of biodiversity; and (4) Cultural services: improved quality of life through the regeneration of the landscape. Potential on the payment for environmental services provided by QSMAS could enhance its attractiveness to local and national authorities in countries with policies to protect ecosystems in the face of climate change.

Output 1. Processes and principles
Output Targets 2010: The role of **organic matter** in regulating water, nutrient-limited and actual yield levels underlying **cassava and rice-based systems** in the humid lowland impact zone and **banana-based systems** in the mid-altitude impact zone quantified.

NO ACTIVITIES

Output 1. Processes and principles
Output Targets 2010: Relationships between **crop nutritional quality** and soil fertility status quantified for the major crops in the **different impact zones**.

NO ACTIVITIES

Output 1. Processes and principles
Output Targets 2011: The medium- to long term role of **soil organic matter** in regulating soil-based functions (e.g., acidity buffering, ECEC formation) underlying fertilizer use efficiency and crop production quantified for **cereal-legume systems** in the Sahel and moist savanna impact zones.

Comparison of organic versus mineral resource effects on short-term aggregate C and N dynamics in a sandy soil versus a fine textured soil

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Introduction and justification

Aggregation and stabilization of soil organic C (SOC) and N are highly dependent on soil texture and addition of organic resources (ORs). While OR quality may influence SOC and N stabilization within aggregates, the addition of N-fertilizers may enhance OR decomposition resulting in lower SOC. However, the interactions between OR quality and N-fertilizers on SOC stabilization in soil may be influenced by soil texture. Lower aggregation in sandy soils associated with lower protection of added ORs, may shift the optimum residue quality for N use and C stabilization towards low quality ORs to counterbalance the lack of physical protection. The objectives of this study were to quantify SOC and N dynamics in aggregate-associated SOM fractions as affected by i) OR quality, ii) N-fertilizer addition, and iii) soil texture.

Materials and methods

A mecocosm study was conducted on a clayey soil at Embu and a sandy soil at Machanga in central Kenya to determine the influence of soil texture, OR quality and N-fertilizer on aggregation, SOC and N. *Tithonia diversifolia* (high quality), *Calliandra calothyrsus* (medium quality) and *Zea mays* (maize; low quality) residues, natural abundance or labeled with ^{15}N, were applied to soil at an equivalent rate of 4 Mg C ha^{-1} compared to no input control. Each treatment was fertilized with 120 kg ^{14}N or ^{15}N ha^{-1} as $(NH_2)_2CO$, or not fertilized. Soil samples were collected at installation of the mesocosms (start), and 8 months after installation (end). Soils were separated into different aggregate fractions by wet sieving into macroaggregates (>250 µm), microaggregates (53-250 µm), and silt and clay (<53 µm) fractions. Macroaggregates were further fractionated to isolate microaggregates-within-macroaggregates and coarse particulate organic matter (cPOM). Total soil and aggregate fractions were analyzed for SOC and N.

Preliminary results

Contrary to our hypothesis, low quality OR, maize did not result in greater SOC and N than higher quality ORs in both soils. While there were no significant differences in SOC and N among OR quality in both soils, in the sandy soil high quality *Tithonia* tended to have greater SOC and N than other treatments **(Table 8)**.

Table 8: Total organic C and N of soil amended with organic resources of different quality applied at 4 Mg C ha^{-1}, alone or in combination with 120 kg fertilizer-N ha^{-1} at Machanga (sandy soil) and Embu (clayey soil), Kenya. Soils were sampled at installation of the experiment (start) and eight months after residue incorporation (end).

Organic resource	**N- fertilizer (kg ha^{-1})**	**Organic C (g C kg^{-1} dry soil)**		**Total N (g N kg^{-1} soil)**	
		Sandy	Clayey	Sandy	Clayey
Control	0	5.42	25.78	0.44	2.24
	120	5.09	26.38	0.43	2.32
Tithonia	0	7.47	30.90	0.68	2.68
	120	8.40	31.54	0.72	2.77
Calliandra	0	5.22	30.20	0.42	2.65
	120	5.95	30.80	0.54	2.72
Maize	0	4.74	32.49	0.38	2.84
	120	5.20	31.03	0.42	2.68
†SED OR		1.47	1.80	0.12	0.16
‡SED N-fertilizer		0.69	0.98	0.05	0.10
Time					
Start		6.24	29.8	0.58	2.68
End		6.08	30.0	0.43	2.55
¶SED Time		0.36	0.51	0.02	0.05

§Statistical significance are determined at ***$p<0.001$, **$p<0.01$ and *$p<0.05$. ns = not significant at $p<0.05$. †SED OR, ‡SED N-fertilizer and ¶SED time represent standard error of the difference between paired means with organic resource (OR), N-fertilizer, and sampling time, respectively.

On average, 20% and 70% of SOC and N was in the macroaggregates in the sandy and clayey soils, respectively. Although there were generally no differences in total N between *Tithonia* and *Calliandra* in the aggregate-associated SOM fractions of the sandy soil, *Calliandra* generally had greater proportions of OR derived N than other ORs in the cPOM **(Figure 31)**. Since cPOM is unprotected SOM, its accumulation is dependent not only on OR additions but also on the quality of added Ors. Additionally, the cPOM fraction has been shown to be a sensitive fraction to management practices, implying that the differences between *Tithonia* and *Calliandra* were due to a slower decomposition with *Calliandra* compared to *Tithonia*. Thus, in support of previous studies, the high polyphenol content in *Calliandra* likely slowed down its decomposition in the sandy soil. In contrast, however, in the clayey soil there were no differences in OR derived N in aggregate associated SOM fractions of soil treated with *Tithonia* and *Calliandra*, nor were there differences in whole SOC and N among all ORs . In the clayey soil, maize residues had greater proportions or maize derived N in the macroaggregates and all the fractions separated from macroaggregates, including cPOM than other ORs. Thus, although there were no differences among ORs in the same fractions in elemental N, maize residues seem to have a slower decomposition with greater stabilization in macroaggregates compared to high N ORs, *Calliandra* and *Tithonia*. However, although polyphenols have been shown to influence decomposition and stabilization of added ORs in soil, this seemed to hold only in the sandy soil. In the clayey soil there were generally no differences N and OR derived N between *Calliandra* and *Tithonia* in whole soil and aggregate fractions. Thus, results from this study suggest that polyphenol content only influences OR decomposition and its stabilization in SOC in sandy soils and not in clayey soils. In the clayey soil, we observed strong influences of N fertilizer on macroaggregate dynamics but only for low quality OR, maize residues, in the short but the differences became smaller with time.

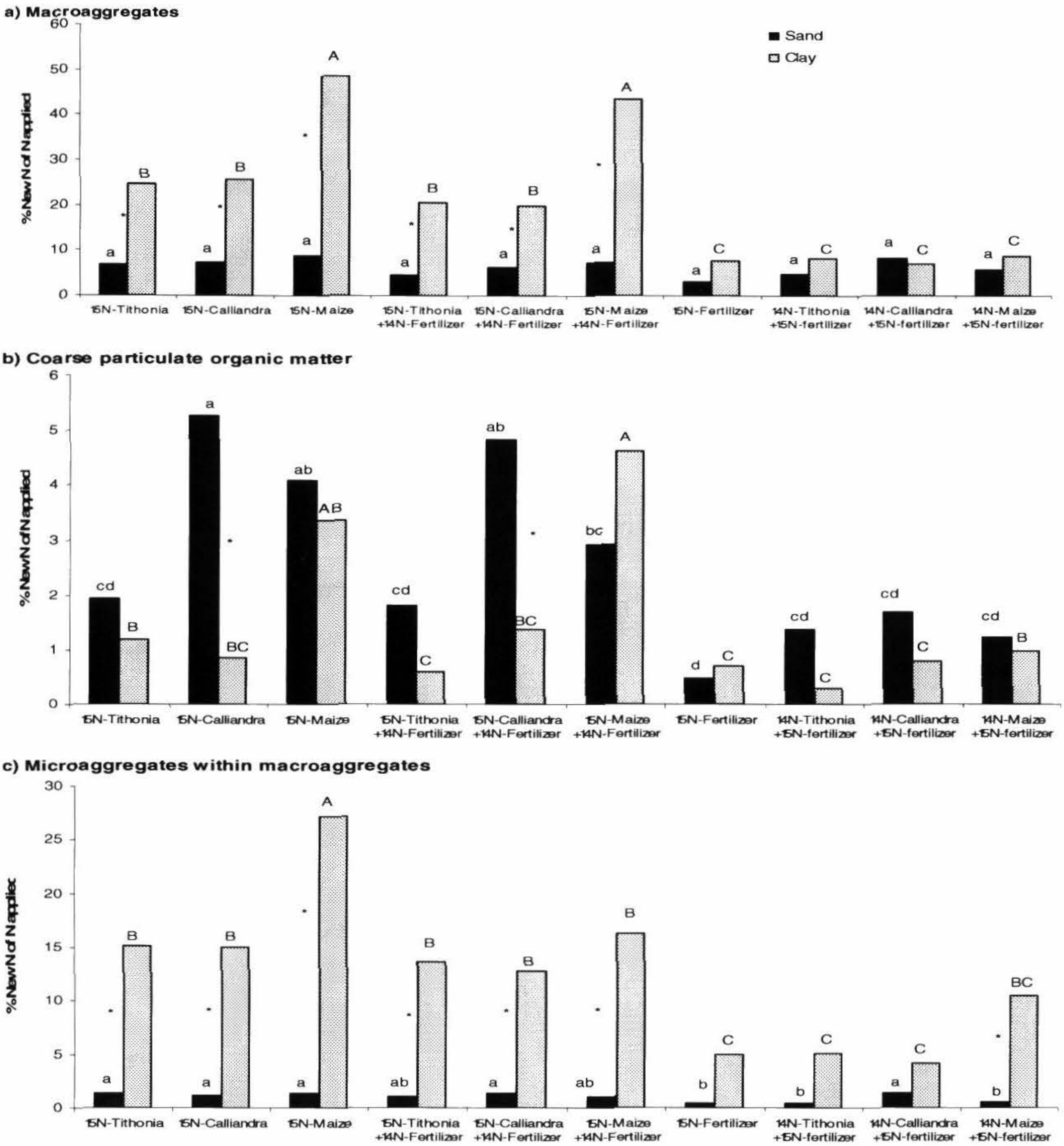

Figure 31: Percent N_{new} of N applied in: a) macroaggregates, b) coarse particulate organic matter, and c) microaggregates within macroaggregates, of soil amended with ^{15}N- organic resources, ^{15}N-organic resources + ^{14}N-fertilizer, ^{14}N-organic resources + ^{15}N-fertilizer, and ^{15}N-fertilizer. Organic resources of varying quality (*Tithonia, Calliandra, and* Maize) were applied at an equivalent rate of 4 Mg C ha^{-1} with or without 120 kg fertilizer N ha^{-1} to a sandy soil from Machanga and a clay soil from Embu in the central highlands of Kenya. Values with different letters a-d, and A-D are significantly different ($p<0.05$) among treatments for Machanga and Embu, respectively. * Denotes significant differences between Machanga and Embu ($p< 0.05$).

Preliminary conclusions

We conclude that the preservation of OR derived N is affected by the chemical recalcitrance of the residues in sandy soil, whereas macroaggregate protection, and not OR quality, is the major factor in clayey soils. The addition of N-fertilizers with low quality ORs in clayey soils enhances OR decomposition and faster aggregate turnover leading to less accumulation of SOC and N, mostly in the macroaggregates, than when ORs are applied alone.

The fate of nitrogen following the combined application of organic residues with mineral fertilizer

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Introduction and justification

Strategic management of organic resources (ORs) and N fertilizers is essential to reduce N losses from the soil through leaching or gaseous N_2O emissions. This is particularly important in SSA where, in addition to the rising global environmental concerns, fertilizers are expensive and/or are not readily available to smallholder farmers. The combined application of ORs and N fertilizers offers potential to improve N cycling and may reduce N losses through leaching and N_2O emissions compared to when N fertilizers are added alone. However, the C source from ORs may stimulate microbial activity, which may create anaerobic sites while the N fertilizer will stimulate nitrifiers and denitrifiers such that N_2O emissions may be greater with the combined application of ORs and N fertilizers than when either resource is added alone. Thus, depending on OR quality, N losses may be greater following the combined application of ORs and N fertilizers. This study sought to quantify N losses through leaching and N_2O following the addition of different quality ORs, alone and in combination with N fertilizers and the influence of soil texture.

Materials and methods

A mesocosm study was carried out at two sites in the Central Highlands of Kenya: a sandy soil at Machanga and a clayey soil at Embu. Three ORs of differing quality, *Tithonia diversifolia* (high quality), *Calliandra calothyrsus* (intermediate quality), *Zea mays* (maize; low quality) were added to the soil at an equivalent rate of 4 Mg C ha^{-1}, with or without 120 kg fertilizer-N ha^{-1} as urea [$(NH_2)_2CO$]. The soils had received similar treatments in the field for three and four years on the clayey and sandy soils, respectively. No crops were grown in the mesocosms. N_2O emissions and N leaching measurements were taken periodically over an eight month period.

Preliminary results

The importance of leaching as a N loss pathway over N_2O in these central Kenyan agro-ecosystems was demonstrated by the much larger N leaching losses which were on average in excess of 250 kg N ha^{-1} compared to < 1 kg N ha^{-1} which was lost as N_2O over eight months **(Figure 32 and 33)**. The low N_2O emissions were most likely because the two soils used in our study are well drained such that the anaerobic microsites that promote denitrification were few. While these observations are in agreement with those in other studies on similar agro ecosystems, the magnitude of N leaching losses we observed in our study was way greater than those observed in other studies most likely because our mesocosms were not cropped such that mineralized N was prone to losses more than in the other studies. Nonetheless, N leaching and N_2O emissions were influenced by OR quality and soil texture. On the sandy soil in Machanga, the sole addition of low quality maize residues resulted in less than half of the N_2O emissions observed with sole added *Tithonia* and *Calliandra* **(Figure 33)**. Similarly on the clayey soil maize had the least N_2O emissions compared to other ORs. This was likely because of lower amounts of N being added by maize but also due to its low quality, maize could have induced N immobilization. The greatest N_2O emissions on the sandy soil were observed following the addition of *Tithonia* and N fertilizers and this was significantly greater than *Tithonia* added alone **(Figure 32)**. In contrast on the clayey soil in Embu, there were no differences in N_2O emissions among sole added different quality ORs but maize tended to have lower N_2O emissions than *Calliandra* and *Tithonia* but also the control **(Figure 33)**. While the addition of N fertilizer tended to increase N_2O emissions, this was only significant with *Calliandra* where the addition of N fertilizer almost doubled the N_2O emissions compared to sole added *Calliandra* **(Figure 33)**. While N_2O emissions were generally low in the two soils (< 1 kg N_2O-N ha^{-1}), greater emissions were observed on the clayey soil than on the sandy soil. The sandy soil has a greater proportion of macropores than micropores, aiding faster drainage of water but with a smaller capacity for moisture storage. Thus there are fewer anaerobic microsites where denitrification would occur. The macropores may also aid the emissions of NO before the formation of N_2O. Additionally, the sandy soil had lower SOC such that there was likely less N mineralization than in the clayey soil. Furthermore, a proportional loss of N through leaching compared to the control was greater in the sandy soil than the clayey soil, reducing mineral N that could have been denitrified to N_2O.

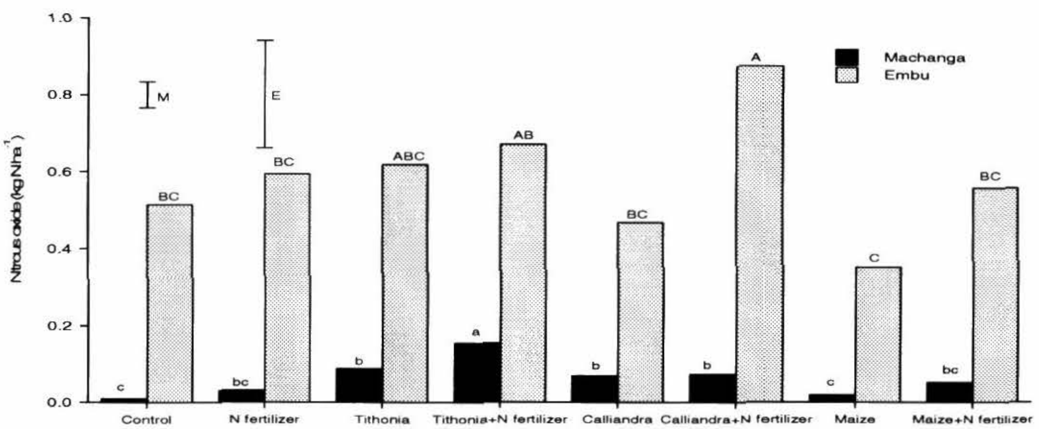

Figure 32: N_2O emissions on a sandy soil in Machanga and a clayey soil in Embu following the addition of different quality ORs (*Tithonia*, *Calliandra*, *and* Maize), applied at an equivalent rate of 4 Mg C ha^{-1} with or without 120 kg fertilizer N ha^{-1}.alone or in combination with N fertilizer. The bars represent sum N_2O emissions over eight months following the addition of ORs. Values with different letters a-d, and A-D are significantly different ($p<0.05$) among treatments for Machanga and Embu, respectively. * Denotes significant differences between Machanga and Embu ($p< 0.05$). SED^M and SED^E represent standard error of the difference between two treatments in Machanga and Embu, respectively.

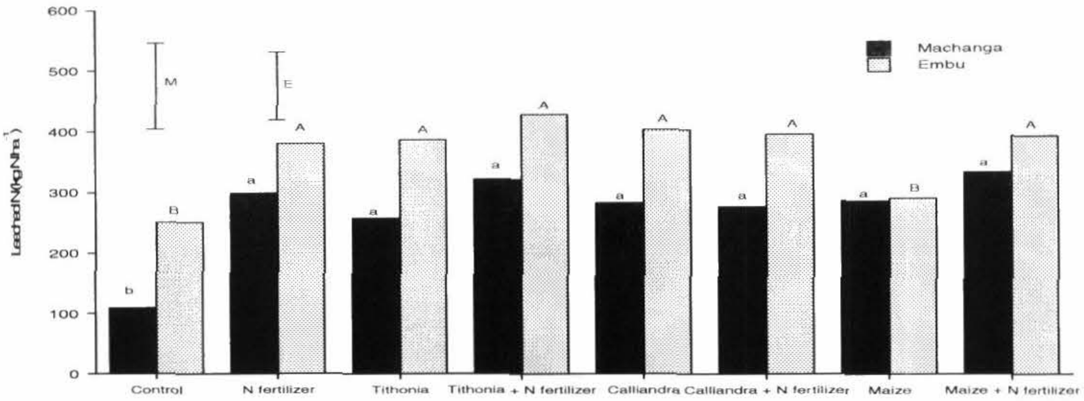

Figure 33: N leaching on a sandy soil in Machanga and a clayey soil in Embu following the addition of different quality ORs (*Tithonia, Calliandra, and* Maize), applied at an equivalent rate of 4 Mg C ha^{-1} with or without 120 kg fertilizer N ha^{-1}.alone or in combination with N fertilizer. The bars represent sum N leached emissions over eight months following the addition of ORs. Values with different letters a-d, and A-D are significantly different ($p<0.05$) *among treatments* for Machanga and Embu, respectively. * Denotes significant differences between Machanga and Embu ($p< 0.05$). SED^M and SED^E represent standard error of the difference between two treatments in Machanga and Embu, respectively.

There were no treatment differences in leached N in the sandy soil probably reflecting the large variation in observations made on the soil. On the clayey soil on the contrary, low quality maize residues added alone caused the least leaching and was not different from the input control. Similar to N_2O, this was likely due to less N being added but also the low quality may have induced N immobilization. This was however, altered by the addition of N fertilizer as there were no differences with other OR when maize was added with N fertilizer.

Preliminary conclusions

Lower N losses were observed with low quality maize residues compared to higher quality ORs. The addition of fertilizer N with maize residues tended to increase the losses. Greater N2O emissions and N leaching losses were observed in the clayey soil than the sandy soil. However, proportional N leaching losses were greater in the sandy soil most likely due to the lower nutrient holding capacity of the soil.

Output 1. Processes and principles
Output Targets 2011: Cassava, rice, and banana nutrient requirements and impacts on nutritional quality of respective food products quantified within the respective impact zones.

NO ACTIVITIES

Output 1. Processes and principles
Output Targets 2011: Modeling tools (e.g., DSSAT, APSIM, NUANCES) for ISFM-based nutrient management used and adapted for **cassava and rice-based systems** in the humid lowland impact zone *[2 yrs is not sufficient to get this output for banana-based systems].*

NO ACTIVITIES

III.2. OUTPUT 2 - MANAGEMENT PRACTICES THAT ARE IN RESONANCE WITH THE RESOURCE-BASE AND SOCIO-ECONOMIC ENVIRONMENT OF SMALLHOLDER FARMERS.

Outputs (Intended users)	Outcome (Impact)
Description: Management practices that are in resonance with the resource-base and socio-economic environment of smallholder farmers. Intended users: CGIAR, ARI, researchers from NARS and local universities, NGOs, farmer groups, private sector agents, extension services, and regional consortia.	Outcome: A large number of farmers in the target impact zones evaluate, adapt, and adopt improved technologies and systems. Impact: Improved technologies and systems, based on ISFM, improve food security, income and health of farmers in the target impact zones.

Output 2. Management practices: Knowledge generated in Output 1 needs to be translated in ISFM-based management practices for the target cropping systems and impact zones. Those practices can contain appropriate nutrient and water management strategies and improved agronomy and system design. Specific attention will be given to farmer-lead diagnosis and decision making in relation to best-fit practices, taking into account available resources, biophysical heterogeneity, and the overall social and economic environment. The major Outcome of this Output is a large number of farmers that are evaluating, adapting and adopting such improved practices This Outcome is the most crucial Outcome of this Program.

Output 2: Management practices
Output Targets 2009: Local diagnosis of soil fertility constraints and farmer understanding of important soil processes underlying ISFM for all impact zones.

COMPLETED WORK

The diversity of rural livelihoods and their influence on soil fertility in agricultural systems of East Africa - A typology of smallholder farms.

(2010) Agricultural Systems 103:83-97

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[1]CIAT-TSBF, Kenya; [2]Wageningen University, the Netherlands; [3]CIRAD-Persyst, France; [4]Kenya Agricultural Research Institute, Nairobi, Kenya; [5]World Agro forestry Centre (ICRAF),Kenya; [6]Kenyatta University, Kenya; [7]Soil Fertility Management Program, National Agricultural Research Organisation, Uganda

Abstract: Technological interventions to address the problem of poor productivity of smallholder agricultural systems must be designed to target socially diverse and spatially heterogeneous farms and farming systems. This paper proposes a categorisation of household diversity based on a functional typology of livelihood strategies, and analyses the influence of such diversity on current soil fertility status and spatial variability on a sample of 250

randomly selected farms from six districts of Kenya and Uganda. In spite of the agro-ecological and socio-economic diversity observed across the region (e.g., 4 months $year^{-1}$ of food self sufficiency in Vihiga, Kenya vs. 10 in Tororo, Uganda) consistent patterns of variability were also observed. For example, all the households with less than 3 months $year^{-1}$ of food self-sufficiency had a land: labour ratio (LLR) < 1, and all those with LLR > 1 produced enough food to cover their diet for at least five months. Households with LLR < 1 were also those who generated more than 50% of their total income outside the farm. Dependence on off-/non-farm income was one of the main factors associated with household diversity. Based on indicators of resource endowment and income strategies and using principal components analysis, farmers' rankings and cluster analysis, the 250 households surveyed were grouped into five Farm Types: 1. Farms that rely mainly on permanent off-farm employment (10-28% of farms); 2. Larger, wealthier farms growing cash crops (from 8 to 20% of the farmers interviewed, according to site); 3. Medium resource endowment, food self-sufficient farms (20-38%); 4. Medium to low resource endowment relying partly on non-farm activities (18-30%); and 5. Poor households with family members employed locally as agricultural labourers by wealthier farmers (13-25%). Due to differential soil management practices over a number of decades, and large diversity in resource endowments (land, livestock, labour) and access to cash, the five farm types exhibited different soil carbon and nutrient stocks (e.g., Type 2 farms had average C, N, P and K stocks that were 2 to 3 times larger than for Types 4 or 5). In general, soil spatial variability was larger in farms (and sites) with poorer soils and smaller in farms owning livestock. Farm Types 2 and 3 were identified as most promising domains in terms of adoption potential for targeting agricultural technology innovations, whereas Farm Types 4 and especially 5 will require social support to benefit from agricultural innovations.

Effect of farmer management strategies on spatial variability of soil fertility and crop nutrient uptake in contrasting agro-ecological zones in Zimbabwe. *(2009) Nutrient Cycling in Agroecoystems: Published online*

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Abstract: Variability of soil fertility within, and across farms, poses a major challenge for increasing crop productivity in smallholder systems of sub-Saharan Africa. This study assessed the effect of farmers' resource endowment and nutrient management strategies on variability in soil fertility and plant nutrient uptake between different fields in Gokwe South (ave. rainfall ~650 mm $year^{-1}$; 16.3 persons km^{-2}) and Murewa (ave. rainfall ~850 mm $year^{-1}$; 44.1 persons km^{-2}) districts, Zimbabwe. In Murewa, resource-endowed farmers applied manure (>3.5 t ha^{-1} $year^{-1}$) on fields closest to their homesteads (home fields) and none to fields further away (outfields). In Gokwe the manure was not targeted to any particular field, and farmers quickly abandoned outfields and opened up new fields further way from the homestead once fertility had declined, but home fields were continually cultivated. Soil available P was higher in home fields (8-13 mg kg^{-1}) of resource-endowed farmers than on outfields and all fields on resource constrained farms (2-6 mg kg^{-1}) in Murewa. Soil fertility decreased with increasing distance from the homestead in Murewa while the reverse trend occurred in Gokwe South, indicating the impact of different soil fertility management strategies on spatial soil fertility gradients. In both districts, maize showed deficiency of N and P, implying that these were the most limiting nutrients. It was concluded that besides

farmers' access to resources, the direction of soil fertility gradients also depends on agro-ecological conditions which influence resource management strategies.

Simulation of soil organic carbon response at forest cultivation sequences using ^{13}C measurements *(2009) Organic Geochemistry 41: 41-54*

Gottschalk[1] P., Bellarby[1] J., Chenu[2] C., Foereid[1] B., Smith[1] P., Wattenbach[1] M., Zingore S.[3], Smith J.[1]
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Abstract: When deforestation is followed by continuous arable cropping, a permanent decline of between 22% and 42% in the soil organic carbon (SOC) has been reported. This systematic loss of soil carbon (C) is mainly attributed to the loss of physically protected SOC. The Rothamsted Carbon model (RothC) does not include a description of the processes of physical protection of SOC and so losses of C during continuous cultivation of previously uncultivated land are not likely to be accurately simulated. Our results show that in the first years following deforestation, RothC does not capture the fast drop in forest derived soil C. However, the model does satisfactorily simulate the changes in SOC derived from the following crops. Uncertainty in input data and accounting for erosion, does not explain the underestimation of decomposition after deforestation by RothC. A simple approach to increase decomposition by multiplying rate constants is evaluated. This approach needs high multiplication rates and leads to an overestimation of plant input values to sustain SOC equilibrium levels. However, the ability of RothC to simulate changes in the forest derived SOC can be greatly improved with an implementation of a simple approach to account for SOC dynamics due to the loss of physically protected C. This approach implements a new soil carbon pool into RothC which represents the labile but protected carbon fraction which builds up under minimally disturbed land uses, and which loses its protection once the soil is disturbed. The new pool is calibrated using 13C natural abundance analysis in conjunction with soil fractionation.

Determinants of the decision to adopt Integrated Soil Fertility Management practices by smallholder farmers in the Central highlands of Kenya. *(2009) Experimental Agriculture 45: 61–75*

Mugwe[1], J., Mugendi[1], D., Mucheru-Muna[1], M., Merckx[2], R., Chianu[3], J. and Vanlauwe[3], B.
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Abstract: Declining soil fertility is a major cause of low per capita food production on smallholder farms of sub-Saharan Africa. This study attempted to provide an empirical explanation of the factors associated with farmers' decisions to adopt or not to adopt newly introduced integrated soil fertility management (ISFM) technologies consisting of combinations of organics and mineral fertilizer in Meru South district of the central highlands of Kenya. Out of 106 households interviewed, 46% were 'adopters' while 54% were 'non-adopters'. A logistic regression model showed that the factors that significantly influenced adoption positively were farm management, ability to hire labour and months in a year households bought food for their families, while age of household head and number of mature cattle negatively influenced adoption. The implication of these results is that the adoption of ISFM practices could be enhanced through targeting of younger families where both spouses work on the farm full-time and food insecure households. It is also important to target farmers that lack access to other sources of soil fertility improvement. Examples

include farmers that do not own cattle or those owning few and who, therefore, have limited access to animal manure.

On-Farm Assessment of Legume Fallows and Other Soil Fertility Management Options Used by Smallholder Farmers in Southern Malawi.

(2009) Agricultural Journal 4 (6): 260–271

Akinnifesi[1], F. K., Sileshi[1], G., Franzel[2], S., Ajayi[1], O. C., Harawa[3], R., Makumba[4], W., Chakeredza[1], S., Mngomba[1], S., de Wolf[1], J. J. and Chianu[5], J. N.
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Abstract: This study evaluated the performance of tree legumes and other soil fertility management innovations used by farmers. The objectives of the study were to: examine the extent that farm attributes, typology of farmers and field management practices have affected the adaptation and use of agro forestry technologies for soil fertility management and compare the agronomic performance and farmer assessment of agro forestry and other soil fertility management options, across a wide range of farmer types and field conditions, with a view to establishing the contribution of management variables to variations in yield estimation. Maize yield and farmer rating were assessed in Type II (researcher-designed, farmer-managed), Type III (farmer-designed and managed) trials and extension farmers. Results from 152 farmers show that agro forestry increased the yield of maize by 54-76% compared to unfertilized sole maize used as the control. When amended with fertilizer, the yield increase over the control was 73-76% across tree species. This indicates that farmers who had combined agro forestry with inorganic fertilizer experienced increase in maize yield attributable to the synergy between organic and inorganic fertilizer. In gliricidia-maize intercropping, higher maize yield was obtained by farmers who pruned twice. Combination of two prunings and fertilizer use gave the highest yield increase (148%) over the control and the third pruning was superfluous when fertilizer was applied. Without fertilizer, maize yield in agro forestry plots intercropped with pigeon pea was higher than those plots without pigeon pea. Planting date, fertilizer application, use of agro forestry and maize variety explained about 44% of the variation in maize yield on farmers' fields.

WORK IN PROGRESS

K and Mg deficiencies corroborate farmers' knowledge of soil fertility in the highlands of Sud-Kivu province, Democratic Republic of Congo.

Submitted for publication in Nutrient Cycling in Agroecosystems (currently under review).

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Abstract: Intensification of crop production is required in the densely populated highlands of the Sud-Kivu province. Soil fertility constraints for maize and bean production were assessed in eight replicate field trials with sole or combined applications of fertilizer, farmyard manure (FYM) and lime, and a complimentary greenhouse nutrient omission trial with 30 representative soils. Farmers distinguished soils based on landscape position ("Civu" and

"Kalongo") and fertility level ("fertile" and "poor"). Fertile soils were slightly lower in soil organic matter content than poor soils. Only in fertile soils, fertilizer application increased crop yields by 40-100%, but highest yield increases were obtained with FYM application. Leaf samples analysis and interpretation using the Diagnosis and Recommendation Integrated System revealed that P and N were the most deficient nutrients. Poor soils were also deficient in K and Mg as confirmed by the nutrient omission trial: K omission only reduced yields in poor soils by 30%, and yield losses caused by sole application of N, P and K were correlated with plant Mg concentrations. This demonstrates that farmers aptly assess soil constraints using their local soil fertility classification, which corresponds with levels of "basic" cations (K, Mg and Ca) rather than with soil organic matter.

Resources flow and Use Strategies in selected Wetlands in Rwanda

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Introduction and justification

Understanding the current farming systems strategies serves the potential to integrate these 'new' options into these farming systems thereby increasing potential adoption. The study characterized resource flow strategies within the household farming systems of Rwanda by analyzing labour and nutrient flow between wetland and hill slopes using a farm systems approach in two wetland in Rwanda.

Materials and methods

Nutrient budgets for each farm household were estimated by outflows in crop products (OUT1) and outflows in crop residues (OUT2); and inflows in inorganic (IN1) and organic fertilizers (IN2). Household nutrient flows were estimated using collected yield data, calculated crop residue data and secondary literature.

Preliminary results

Farmers in the wetlands differ in terms of their resource richness. The variation is not only between different agro-ecological zones but also within the zones. More labour was allocated to wetland compared to upland plots. Resource groups differ in labour allocation in both wetland and hill slope plots. Richer resource households were able to allocate more labour to their plots (up to 440 man-days per season in the wetland plots and 326 man-days per season in the hill slope plots) by hiring additional labour.

N balances were negative (up to -124 kg per hectare per season) in rice fields in the wetlands. Removal of rice crop grain (a maximum of 176 kg N in grain per hectares per season) and burning of crop residues significantly contributed to this alarming rate of nutrient depletion. Only 75 kg N per hectare of inorganic and 198 kg N per hectare per season organic inputs were applied to the wetland plots. However nutrients from hill slope are recycling in homestead plots as farmyard manure is applied back in these plots. 57 kg K per hectare per season is exported from wetland to hill slope especially in Rugeramigozi through collection of crop residues for feed to livestock. K export from wetlands raises eyebrows on the sustainability of wetland farming in the long run. Seasonal P balances were relatively low: the maximum P balances was -37 kg per hectare per year. This negative balance poses a threat to the viability of legumes as N-fixing crops in the crop rotation trials. Considering that P is an important part for N-fixation process, negative P balances can reduce the nitrogen fixing potential for leguminous crops included in the options for wetland management in Rwanda.

Table 9: Partial Nutrient Balances for Hill slope and Wetland plots in Cyabayanga and Rugeramigozi wetland, Rwanda in Season b in 2008

	Cyabayanga (n=6)			Rugeramigozi (n=9)		
	N	P	K	N	P	K
Hill slope plots						
Poor	-53.0	-16.9	-90.0	-73.1	-9.30	-50
Moderate	-80.0	-23.3	-120.0	-16.7	10.5	-65.0
Rich	-21.0	-4.10	-57.0	-17.3	-5.10	-164
Mean	-52.0	-14.8	-89	-35.7	-1.30	-93
Wetland plots						
Poor	-12.0	15.3	14.0	-14.9	-0.80	-26.0
Moderate	-56.0	-3.2	3.00	-54.3	-2.80	-102
Rich	-73.0	18.0	14.0	-7.20	19.3	-44.0
Mean	-47.0	12.2	11.0	-25.5	5.20	-57.0

This concern could be significant in Rwandan Ferralsols that have low inherent available P. Addition of P fertilizers to the legumes would improve the legumes' N-fixing potential in the trials.

Preliminary conclusion

This study highlights the assertion that farmers may not necessarily be concentrating nutrients around homestead because of the short distance. Rather farmers apply nutrients in plots where they perceive to be fertile and secure to produce satisfactory yields. Furthermore, the case study highlights the importance of linking hill slope and wetlands in analyzing farm household systems in wetlands in Rwanda. This should be followed by a complete analysis of household dietary patterns, labour allocation and nutrient flows for a clear understanding of the farm resources dynamics in the wetlands.

Output 2. Management practices
Output Targets 2009: ISFM practices for **cereal-legume systems** tested, adapted, and validated to farmer conditions in the Sahel and moist savanna impact zones, including issues of **conservation agriculture**.

COMPLETED WORK

Fertilizer micro dosing for the prosperity of resource poor farmers: a success story. ***(2009) Proceedings of the CGIAR Challenge Program on Water and Food International Workshop on Rain fed Cropping Systems, Tamale, Ghana, 22-25 September 2008.***

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Abstract: Fertilizer micro dosing is the application of tiny doses of fertilizers in the planting hole at sowing, or next to the plant two to three weeks after planting. The technology increases fertilizer use efficiency and yield while minimizing the cost of inputs. The results reported here show that solving the soil fertility problem unleashes the yield potential of improved crop varieties, roughly doubling yield. Two crucial advantages of micro dosing are its adoptability and profitability. High rates of fertilizer have been recommended to farmers for a long time to maximize yields, but farmers could not afford to do so. By using much lower rates of fertilizer than the recommended rate, in more efficient ways that deliver economically optimum returns, farmers are much more able and inclined to adopt the practice, and are increasingly doing so. Once fertilizer micro dosing is adopted, it establishes a pattern for future productivity as farmers become accustomed to increasing their investments in inputs in order to generate increased returns. Micro dosing is thus a strategic first step on a sustainable development pathway, in addition to generating large benefits itself. The micro dosing technology has been demonstrated and promoted in Burkina Faso, Mali and Niger during the past few years with very encouraging results. Sorghum and millet yields increased by 45 to 120 % in comparison with farmer practice while farmers' incomes went up by 50 to 130 %. This paper highlights these outstanding past results and the ongoing efforts to further scale up the technology.

Tillage, residue management and fertilizer application effects on crop water productivity in Western Kenya. *(2009) Proceedings of the CGIAR Challenge Program on Water and Food International Workshop on Rain fed Cropping Systems, Tamale, Ghana, 22-25 September 2008.*

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Abstract: A long-term conservation tillage experiment was established in Nyabeda, western Kenya in March 2003 to investigate the effects of tillage and residue management on crop water productivity (CWP, kg grain m^3 rain) in continuous maize and maize-legume cropping systems. Seasonal CWP of maize over the first eight cropping seasons ranged from 0.1 to 0.8 kg m^3 of in season rainfall. For continuous maize, there was a consistent trend for lower CWP with reduced tillage (RT) compared to conventional tillage (CT) for the first few years, for respective residue retained/removed treatments, but with few significant differences. After 5 seasons, CWP was similar with RT and CT, with and without crop residues (CR). There was also a consistent trend for higher CWP of RT with CR than without CR for the first 5 seasons, but with no significant differences. Similar trends in maize CWP occurred in the maize-legume rotation, except in the first year where CR led to reduced yields, presumably due to N immobilization as no N fertilizer was applied. CWP of soybean was not affected by tillage treatment or residue management. With low rainfall, crop residue (CR) application increased yield by up to 30% under RT. The yield advantage of CR (over no CR) decreased with increasing rainfall (R^2 = 0.9 for continuous maize and R^2 = 0.7 for soybean-maize rotation). CR disappearance was fast (daily % loss of 106 $e^{0.019x}$). Phosphorus (P) and nitrogen (N) application had large effects on CWP. In the maize-soybean rotation, P application increased CWP of maize by 120%, while application of N with P increased CWP by a further 35%. Thus fertilizer application is important for increased CWP. The results suggest that RT with mulching gives similar maize CWP in continuous maize and maize-

legume rotations. Rotation with soybeans brings further benefits including reduced N fertilizer requirement, while soybean CWP is also maintained in the RT.

Genetic diversity of indigenous Bradyrhizobium nodulating promiscuous soybean [Glycine max (L) Merr.] varieties in Kenya: Impact of phosphorus and lime fertilization in two contrasting sites. *(2009) Plant and Soil 322:151-163*

Wasike[1,2,3], V.W., Lesueur[2,4], D., Wachira[3], F.N., Mungai[3], N.W., Mumera[3], L.M., Sanginga[2], N., Mburu[2], H.N. Mugadi[2], D., Wango[2], P. and Vanlauwe[2], B.
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Abstract: While soybean is an exotic crop introduced in Kenya early last century, promiscuous (TGx) varieties which nodulate with indigenous rhizobia have only recently been introduced. Since farmers in Kenya generally cannot afford or access fertilizer or inoculants, the identification of effective indigenous Bradyrhizobium strains which nodulate promiscuous soybean could be useful in the development of inoculant strains. Genetic diversity and phylogeny of indigenous Bradyrhizobium strains nodulating seven introduced promiscuous soybean varieties grown in two different sites in Kenya was assayed using the Polymerase Chain Reaction-Restriction Fragment Length Polymorphism (PCR-RFLP) of the 16S-23S rDNA intergenic spacer region and 16S rRNA gene sequencing. PCR-RFLP analysis directly applied on 289 nodules using Msp I distinguished 18 intergenic spacer groups (IGS) I–XVIII. Predominant IGS groups were I, III, II, IV and VI which constituted 43.9%, 24.6%, 8.3% 7.6% and 6.9% respectively of all the analyzed nodules from the two sites while IGS group VII, IX, X, XI, XII, XIV, XVI, XVII, XVIII each constituted 1% or less. The IGS groups were specific to sites and treatments but not varieties. Phylogenetic analysis of the 16S rRNA gene sequences showed that all indigenous strains belong to the genus Bradyrhizobium. Bradyrhizobium elkanii, Bradyrhizobium spp and Bradyrhizobium japonicum related strains were the most predominant and accounted for 37.9%, 34.5%, and 20.7% respectively while B. yuanmigense related accounted for 6.9% of all strains identified in the two combined sites. The diversity identified in Bradyrhizobium populations in the two sites represent a valuable genetic resource that has potential utility for the selection of more competitive and effective strains to improve biological nitrogen fixation and thus increase soybean yields at low cost.

WORK IN PROGRESS

Improved dual-purpose soybean and climbing bean varieties increase subsequent maize yields in the highlands of Sud-Kivu, DR Congo

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Introduction and justification

Rotational benefits from dual-purpose soybean, producing high yields of both grain and biomass have been demonstrated. In the highlands of Central Africa, beans are the predominant legume cultivated by farmers. Climbing beans, and especially improved varieties, have similar low harvest indices as dual-purpose soybean, and can therefore potentially have important rotational benefits on a subsequent cereal crop.

Materials and methods

Demonstration trials were established with 4 farmer groups in Luhihi, Sud-Kivu (DR Congo). The trial followed a full factorial split-plot design with two factors laid out with cropping system (species × variety) in the main plots and fertilizer addition in the subplots. Five cropping systems were evaluated: a maize mono-cropping system, two climbing bean – maize rotation system, and two soybean – maize rotation systems. In the legume rotation system, the local and an improved soybean or climbing variety were compared. Fertilizer application using compound 17:17:17 NPK at a rate of 100 kg ha^{-1} was compared relative to a control without inputs. The trial was established in two replicate blocks with each farmer group. Currently, observations on biomass production, biological nitrogen fixation (BNF), and grain yield have been taken during two full rotation cycles (4 seasons). Participatory farmer evaluations were organized at different stages.

Preliminary results

The legumes had significant rotational benefits on the grain yield of the subsequent maize crop (**Figure 34**). These benefits were more pronounced for improved (dual-purpose) varieties than for local varieties, and were larger in the 4th season (2nd cycle) than in the 2nd season (1st cycle). Local legume varieties increased subsequent maize yields by 30-50%, while improved varieties increased yields by 67-90%, relative to the maize monocrop. Soybean and climbing bean resulted in similar rotational benefits. Fertilizer application increased maize yields by 20%, independent of the preceding crop. Farmers evaluated the trials and showed strong preference for improved legume varieties, despite the longer growing period and the smaller grain size. Farmers also expressed interest in improved intercropping systems, as this is the common practice for maize cultivation. Currently, maize-legume intercropping options are being demonstrated and evaluated with farmers in the area.

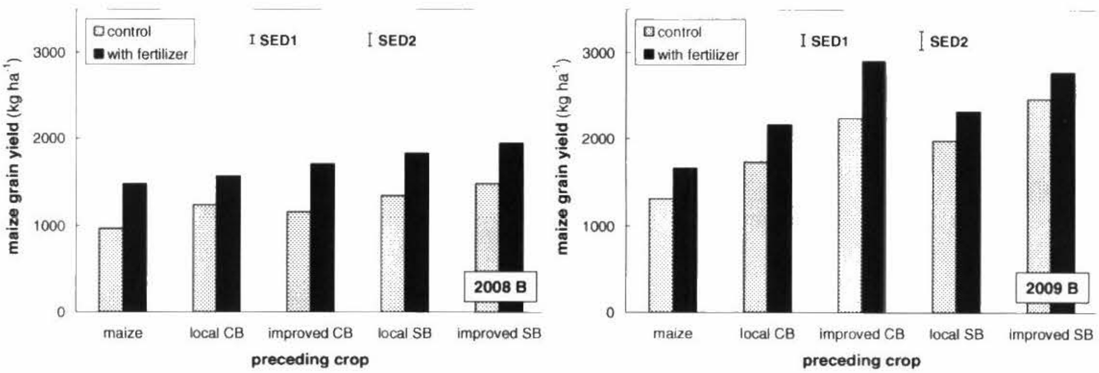

Figure 34: Maize grain yield as affected by the preceding crop and fertilizer application during the 2nd and 4th season of the trial. The preceding crop was either a local or an improved variety of climbing bean or soybean. A maize mono-cropping system was included for reference.

Similar demonstration trials on legume-cereal rotation or intercropping are conducted in Rwanda and in Bas-Congo. In Rwanda, themes addressed include combined application of fertilizer and organic inputs (relative to sole application of either input), rotational benefits from soybean (relative to bush beans), and improved intercropping using the MBILI arrangement. In Bas-Congo, similarly, rotational benefits of dual-purpose soybean are demonstrated, as well as the use of mineral fertilizer or the use of *Mucuna pruriens* fallow for soil fertility and weed control.

Measuring Nitrogen Fixation in Fodder Trees on Smallholder Farms in Kenya

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Introduction and justification

Biological nitrogen fixation is one of the most important biological processes that make nitrogen gas available to plants. It is the process whereby a number of species of bacteria use nitrogenase enzyme to convert atmospheric dinitrogen (N_2) into ammonia (NH_3), a form of nitrogen which can be taken up by bacteria and associated plants.To harness this process of nitrogen fixation for it to provide renewable source of N for human and animal protein, to develop more sustainable farming systems and to maintain natural ecosystems, it is necessary for it to be reliably measured. There are several methods of measuring nitrogen fixation which include N difference, ^{15}N natural abundance method, ^{15}N isotope dilution and the ureide method. ^{15}N natural abundance method is more advantageous under field conditions because no addition of ^{15}N fertilizer is required and can easily be done on farm so far as there are appropriate non-nitrogen fixing reference plants. However the challenge is choosing appropriate non-nitrogen fixing reference plants with the same rooting depth as the nitrogen fixing plants. Further, the ^{15}N enrichment variation with soil depth is not clearly understood, and this may influences the appropriateness of different reference plants. The objectives of the experiment were to: (i) measure nitrogen fixation in fodder trees on smallholder farms in central and western Kenya and (ii) determine variation in ^{15}N enrichment with soil depth using maize as test crop in so as to be able to choose appropriate reference plants for ^{15}N natural abundance method of nitrogen fixation measurement.

Materials and methods

Field experiment: Calliandra calothyrsus and *Leucaena trichandra* seedlings were established in a nursery for three months before planting out in the identified niches in four sites of the two regions in Kenya. The sites were Kirege and Machanga in central Kenya and Emuhaya and Teso in western Kenya. The identified niches where the experiments were set are contour hedges, internal boundaries and degraded part of the farms within farmers' fields. The experiment was set up in a randomized complete block design within the niche while the treatments were *Calliandra calothyrsus* and *Leucaena trichandra* with *Senna siamea* and Napier grass planted as control. The two legume species were replicated four times while the non nitrogen fixing species were not. Each treatment was a six metre double hedgerow of the plant species planted at spacing of 0.5 m inter-row and between rows in a zigzag manner. Hedges were kept weed free. The tree seedlings were pruned to a height of one metre, pruning's fresh weights were taken and sun dried. Samples for the legume fodder trees and reference plants were kept for % N and ^{15}N-enrichment analysis.

Pot experiment: Based on the challenge of choosing appropriate non nitrogen fixing reference plants with the same rooting depth as the nitrogen fixing plants and the fact that ^{15}N enrichment along soil depth is not clearly understood it was felt that there was need to have a pot experiment alongside field experiment to determine the level of ^{15}N enrichment along soil depth so as to be able to guide on the choice of reference plants to use for a particular experiment. Thus soils were collected for pot experiment up to a depth of 2 m (i.e. 0-20, 20-40, 40-60, 60-100, 100-150 and 150-200 cm depth).The soils were potted and blanket application of P, K, S, Ca, Mg and micronutrients were applied to the pots. No nitrogen was applied. Pots per depth were replicated three times. The pot experiment was set up in a greenhouse for five weeks. Soils were collected from 2 farms (one in Vihiga and another in Teso) in western Kenya and 3 in central Kenya (two in Kirege including Samuel's experiment and another in Machanga).

Preliminary results

Biomass yield of cut fodder trees in Kenya grown for one year in different niches in different sites are as shown **(Figure 35)**. At all niches *Calliandra calothyrsus* performed better than *Leucaena trichandra*. Tree biomass yield was better in Teso but lowest in Machanga in all niches. The two plant species performed poorly on degraded land except in Teso site which was better than in other niches. Most tree seedlings planted on internal boundaries in Machanga dried and thus could not get biomass.

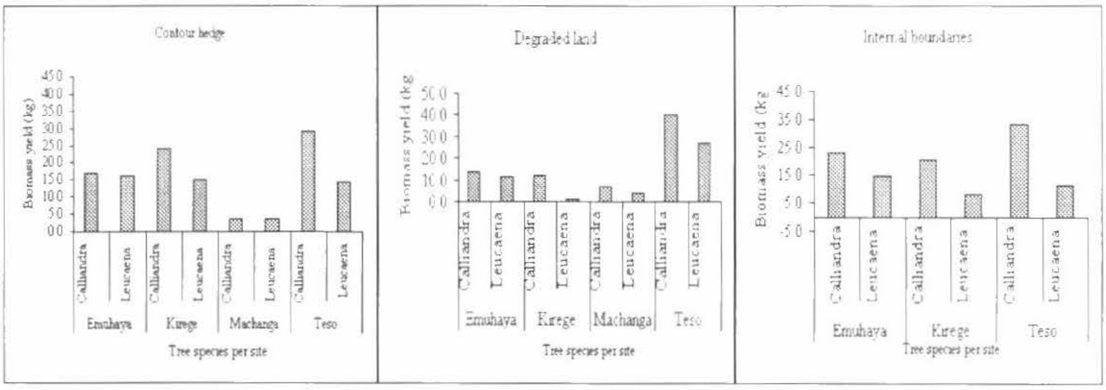

Figure 35: Biomass yield of Calliandra and Leucaena cuttings grown in different niches in Kenya for one year.

Figure 36 shows the biomass yield of maize at various depths as grown in the greenhouse. Most soils showed declining biomass yield with increase in soil depth except at John Njue's farm from Machanga site which was consistently low at all depths.

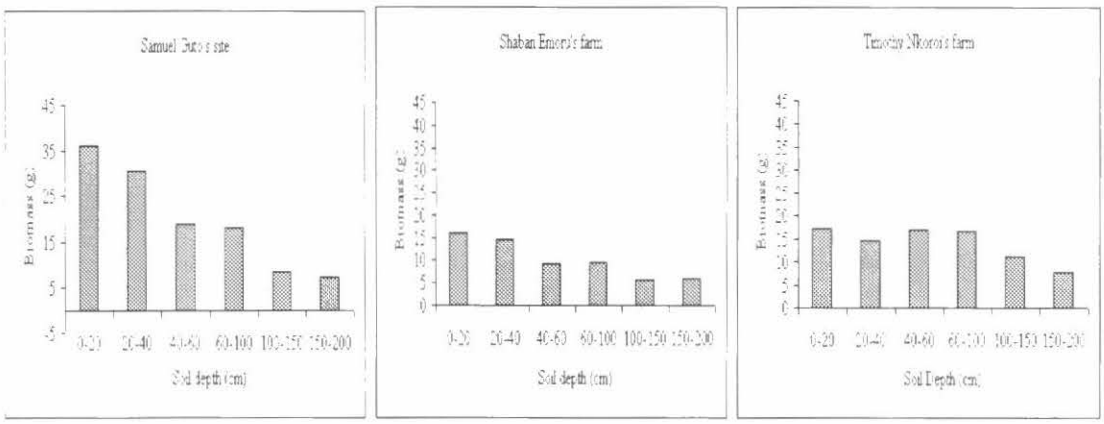

Figure 36: Biomass yield of maize grown on soils collected from 5 farms in Kenya in a greenhouse for 5 weeks at TSBF-CIAT Nairobi. The maize was grown at different depths from 0-2 m.

Preliminary conclusions

Growth of fodder trees was better in niches where the soils were better like contours and internal boundaries but poor on degraded lands. Degraded lands require application of manure for better growth of the fodder trees.

Survival of agro-forestry tree species planted by farmers in different niches within mixed smallholder farms of Kenya

B.T. Kibor[1], K.E. Giller[1], N. de Ridder[1] and B. Vanlauwe[2]
[1]Plant Production Systems, Department of Plant Sciences, Wageningen University, the Netherlands; [2]CIAT-TSBF, Kenya

Introduction and justification

Farmers' plant trees with the intention of getting tree products and services which will improve their livelihoods and their survival will be greatly influenced by the value attached to each tree species by the farmers. The objectives of the study were: (i) through farmer participation, establish niches where farmers grow agro forestry tree species in mixed crop/livestock farms in Kenya and (ii) to determine the survival of the various agro forestry tree species grown in different niches by farmers.

Materials and methods

Tree seedlings were categorized into four main functional uses (Fruit, fodder, Wood (timber, fuel wood) and medicinal). The four categories of agro forestry tree seedlings were issued to three farmers per farm type during the onset of rains for planting in their farms without specifying to the farmers on where to plant. One farm per site was identified as control where planting of the four functional groups of the tree seedlings were planted by myself. Four seedlings per species were issued to the farmers. Prior to issuing the seedlings to the farmers, a group discussion was called for the selected farmers. During the group discussion the level of farmer knowledge of the tree species and their uses was ascertained by asking them to identify and state the uses of the trees. Bao game was used to rank the trees based on farmers' perceived potential usefulness and farmers' interest in planting them. Thereafter additional information that may not have been discussed with the farmers was explained to them before issuing the seedlings to the farmers to plant where they wish in their farms. Follow up was made to the farms which received seedlings to confirm whether the farmers planted the seedlings after a week. Another follow was made after three months to identify the niches where the seedlings were planted on. The number of seedlings death and alive were counted to determine the survival rate of the seedlings. Management of the seedlings was also observed.

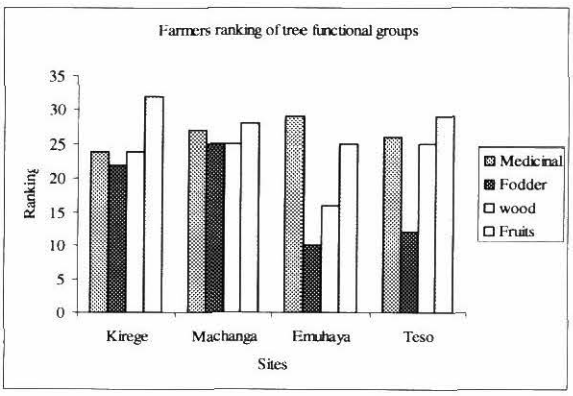

Figure 37: Farmers ranking of trees based on their perceived usefulness in four sites in Kenva.

Preliminary results

Fruit trees were ranked first followed by medicinal trees and the least were fodder trees. Wood trees were intermediate (**Figure 37**).**Figure 38** shows tree seedlings survival in the four sites after three months. Except in Emuhaya, fodder trees had the least number of trees alive in all the four sites indicating that farmers perceive fodder trees to have the least value compared to other categories of trees issued. This relates to the ranking accorded to fodder trees by farmers in the four sites.

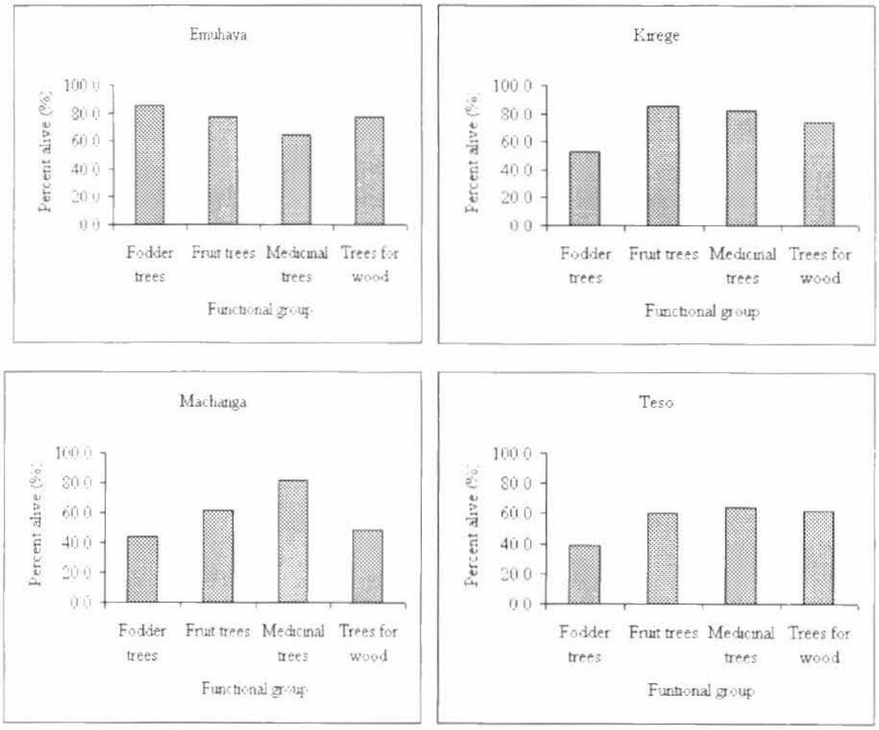

Figure 38: Survival of tree seedlings per function group in the four sites of Kenya.

Preliminary conclusions

Other than environmental conditions, tree survival was dependent on farmers' perceived usefulness. Trees of great value to the farmer will be taken care of and the probability that they will survive will be high.

Landscape organic and inorganic responses on Maize, soyeabeans yields in Cyabayaga Watershed

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Introduction and justification

The conversion of wetlands to agricultural production has increased rapidly over the last decades due the acute scarcity of agricultural land on hillsides. The objective of the study was to test the responses of maize, beans and soybean using organic and inorganic manures application along the landscape in Cyabayaga catchment.

Materials and methods

Maize and legumes plant tests were installed in wetland in hillside, foothill and wetland. Two different fertilizer were used namely FYM and DAP. The treatments compared were control without fertilizer, 3 tonnes/ha of FYM dry matter basis and the combination of FYM and DAP. The layout of the experiment was a split plot where the main plot was the position in watershed and the subplot was input used and each farm was representing the replication. A total of 29 farms were used.

Preliminary results

Results of this study showed that the organic manure combined with the DAP generated a high improvement of the yield, there was a highly significant difference (P = 0.001) for all crops used as test (**Table 10**).

Table 10: Average bean, soybean, and maize yields in the various plots along a typical landscape in Rwanda.

Crop	Landscape position	Grain yields (t/ha)		
		No Inputs	Farmyard manure	Farmyard manure + DAP fertilier
Beans	foothill	0.92	1.25	1.44
	hillside	0.66	0.75	1.13
	wetland	0.86	1.38	1.66
Soyabean	foothill	1.32	1.41	1.44
	hillside	0.90	0.98	1.08
	wetland	1.42	1.50	1.61
Maize	foothill	3.22	4.46	5.23
	hillside	3.16	3.60	4.35
	wetland	4.64	5.19	5.67

Preliminary conclusion

The high yield obtained in wetlands may be due to the availability of moisture throughout the cropping season. There increase of yield by using either fertilizer with higher yield when organic and inorganic inputs are combined. In this experiment, soybean scored higher yield comparatively to beans, this may be due to promiscuous soybean variety used (SB 24).

Contribution of *Desmodium spp* to Soil Nitrogen Rehabilitation in "Push-Pull" Intercropping Systems in Western Kenya

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[1]Moi University, Kenya [2]CIAT-TSBF, Kenya, [3]ICIPE, Kenya [4] Rothamsted Research, UK.

Introduction and justification

One promising intergrated method to balance nutrients and reduce pest and weed infestation. is "Push-Pull" (PP) technology which involves intercropping maize with *Desmodium spp,* which is capable of controlling striga and stemborer infestation. Despite the fact that Desmodium is a leguminous crop, its contribution to overall improvement of soil nitrogen is not well understood. The objective of this study is to evaluate the effect of varying Desmodium harvesting time on biological N fixation and mineral N dynamics

Materials and methods

Field trials were established in Siaya and Busia districts of western Kenya in April and August, 2009. Treatments consisted of three cropping systems; *Desmodium uncinatum* and *Desmodium intortum* intercropped with maize and sole maize crop, three Desmodium harvesting regimes (9, 12 and 18 weeks after maize planting (WAMP)). The treatments were replicated 3 times in plot size of 10 x 10 m. Sampling of soil and plant samples during long rains 2009 was only done at crop harvest because this season was meant to get a good Desmodium cover. Good Desmodium cover was achieved during the 2009 short rains season **(Photograph 6).** In this season, maize shoots/grain harvesting and sampling for mineral N (up to 120cm) was conducted at 9, 10, 12, 13, 15 and 18 WAMP while Desmodium was harvested at 9, 12 and 18 WAMP .

Photograph 6: Good *Desmodium* establishment during the second season (short rains 2009) in Busia.

Preliminary Results

In both Busia and Siaya the soils were acidic (5.32 and 4.89 respectively), had low N (0.071 and 0.091% N), very low available P (3.78 and 2.35 mg P/kg) and moderate organic carbon (1.73 and 2.42%C). Generally, during the long rains mono maize performed better than intercropped maize. Higher maize grain yields **(Figure 39)** and Desmodium shoots yields were observed in Siaya and Busia respectively. During the short rains 2009, fresh maize shoots resulting from mono maize, maize intercroped with *Desmodium uncinatum* and maize intercropped with *Desmodium intortum* ranged from 20.6, 13.1, and 13.8 t/ha to 42.8, 28.3 and 29.3 t/ha in sampling done between 9 and 15 weeks after planting maize (WAPM) respectively. Fresh maize cobs for mono maize, maize intercroped with *Desmodium uncinatum* and maize intercropped with *Desmodium intortum* was 3.99, 4.05 and 3.4 t/ha at 18 WAPM. The highest Desmodium biomass accumulation (D. *uncinatum* (14.4 t/ha) and *D. intortum* (22.3 t/ha) were obtained at 12 weeks after planting maize. Analysis of soil mineral N is on-going and will be reported in the next report.

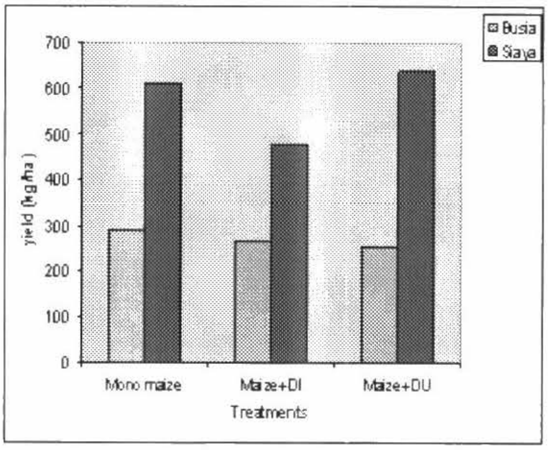

Figure 39: Treatments effect on dry maize grain yields (kg/ha) during long rains 2009 in Busia and Siaya Districts of Western Kenya (DI- Desmodium intortum, DU- Desmodium uncinatum).

Preliminary conclusions

The study is ongoing and chemical analysis of both soils and plant materials is on the process. Preliminary field results showed that a whole season is required to get a good Desmodium establishment/cover. Generally for the two seasons (LR and SR 2009) mono maize performed better than maize intercropped with both *Desmodium spp.* This shows that maize is not likely to benefit from the intercrop during the early seasons but maybe in the subsequent seasons.

The performance of tillage and crop-residue management systems depends on the variability within smallholder farmers' fields in central Kenya.

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[1]Ministry of Agriculture, Kenya; [2] CIAT-TSBF, Kenya; [3]Wageningen University, the Netherlands.

Introduction and justification

Differences in soil fertility status among fields within the same smallholder farm have been reported (Tittonell *et al.*, 2005; Zingore *et al.*, 2007) either due to inherent soil properties related to position along the landscape (soilscapes) or induced differences due to management history (fieldscapes). The performance of soil improvement technologies has been shown to vary between fields within the same farm (Vanlauwe *et al.*, 2006; Ebanyat *et al.*, 2009) but there is limited information available on the performance of tillage and crop-residue management systems within spatially heterogeneous smallholder farms. A study on tillage and crop-residue management systems was therefore initiated in Murugi South Location in Meru South District whose overall aim was to determine field specific (fieldscapes) responses to tillage and crop-reside management in smallholder farms.

Materials and methods

Three field classes (good, medium and poor) were selected from sixteen farm-households (six fields from each field class). A 2 by 2 full factorial experiment was established in each of the fields comparing two tillage systems (with and without tillage) and two residue management systems (maize crop residues removed or retained). Grain yields were assessed in four seasons (SR 07 to LR 09) and crop residue cover in two seasons (SR08 and LR 09).

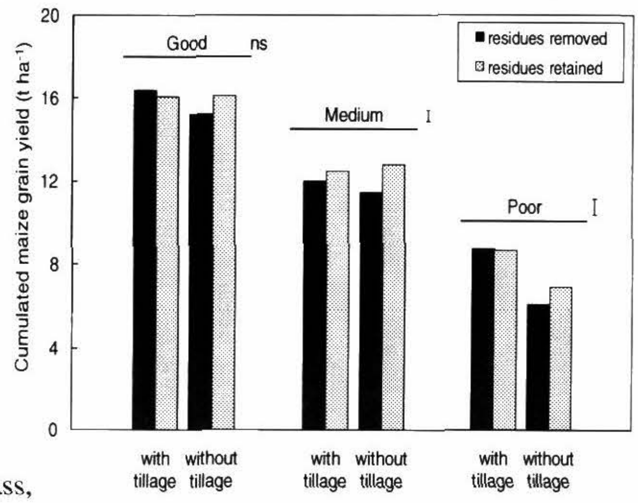

Figure 40: Cumulated maize grain yields (t ha^{-1}) for 4 seasons (short rains '07-long rains '09) as affected by field class, tillage and residue management systems. Error bars represent SEDs for effects of residue management and tillage in the "medium".

Preliminary results

The cumulative grain yields across the four seasons (SR07 to LR 09) were significantly affected by three-way interaction of field class, tillage and residue management system (**Figure 40**).The cumulative grain yields across the four seasons (SR07 to LR 09) were significantly affected by three-way interaction of field class, tillage and residue management system (**Figure 40**). The overall responses for all the treatment combinations in the good fields were similar whereas the best overall treatment performance in the medium fields was no-till and crop-residue retention. Conversely, tillage in the poor fields enhanced crop performance compared to no-till. The relationship between residue cover, time, field class and tillage system was best described by second order polynomial equations (**Table 11**). Relationship coefficients (R^2) were strong (above 0.9) and always significant. The residue cover reduced at a faster rate early in the season (2.03 – 3.72% $week^{-1}$) but less rapidly towards the end of the season (0.063 – 0.097% $week^{-1}$) for all the field classes; though much slower without than with tillage. In the poor fields however, the rate of residue reduction was higher without (2.89-3.41% $week^{-1}$) than with tillage (2.03-2.75 % $week^{-1}$) in both seasons.

Table 11: Second order polynomial relationships between residue cover (%) and time (weeks) for the short '08 and long '09 rain seasons.
*Correlation significant at P<0.05; ** Correlation significant at P<0.01; *** Correlation significant at P<0.001

Field Class	Tillage	Short rains '08	Long rains '09
Good	With	$48 - 3.41w + 0.091w^2$	$67 - 1.58w + 0$
		$R^2 = 0.995$***	$R^2 = 0.897$**
	Without	$54 - 3.22w + 0.087w^2$	$84 - 3.72w + 0.085w^2$
		$R^2 = 0.989$**	$R^2 = 0.992$***
Medium	With	$29 - 2.88w + 0.088w^2$	$49 - 3.03w + 0.063w^2$
		$R^2 = 0.969$**	$R^2 = 0.985$**
	Without	$38 - 2.85w + 0.086w^2$	$58 - 2.95w + 0.667w^2$
		$R^2 = 0.979$**	$R^2 = 0.995$***
Poor	With	$13 - 2.03w + 0.072w^2$	$25 - 2.89w + 0.0819w^2$
		$R^2 = 0.919$*	$R^2 = 0.996$***
	Without	$22 - 2.75w + 0.087w^2$	$33 - 3.41w + 0.097w^2$
		$R^2 = 0.980$**	$R^2 = 0.996$***

Preliminary conclusions

The transition period from tillage to no-till was shortest for fields in the good class, followed by those in the medium whereas it was not possible to establish the transition period for the poor fields within the confines of this study. It thus appears possible to realize benefits of no-till as early as one season after adoption for fields in the good class. Fields in the poor class however, appear to require either more time under no till or alternative soil management options for rehabilitation such as crop residue transfer from the good fields.

Long-term effects of pigeon pea on maize productivity within rotation and intercropping systems across multiple sites in Malawi

S. Zingore[1]
[1]*TSBF - CIAT, Malawi*

Introduction and justification

Maize and pigeon pea intercropping is a promising cropping pattern for growing maize and pigeon pea together especially in southern Malawi where average land-holding size is limited. Pigeon pea contributes substantial amounts of organic matter and N to the soil through fallen leaves and biological nitrogen fixation. In order to clearly understand long term effects of pigeon pea on maize productivity under rotation and intercropping systems, there is need to obtain information on soil and crop yields from the field experiments on a long-term basis. The objective of this study was to determine the long term effects of maize pigeon pea rotation and intercropping system on maizeproductivity in Malawi.

Materials and methods

The experiment was conducted at five sites using a split plot design with cropping systems as main plot treatment and crop residue management as subplots.

Preliminary results

Maize grain yields differed significantly (p<0.001) among sites with Chitedze having the highest maize grain yields (4890 kg ha-1) and lowest maize yields obtained at Lisasadzi (731 kg ha-1) across ten cropping seasons. Maize grain yield differed significantly (p<0.001) among cropping systems with highest yields obtained in maize/pigeon pea rotation systems (5726 kg ha-1) and lowest yields obtained in continuous maize cropping systems (2444 kg ha-1). No significant differences were observed across the ten cropping seasons, the two sites and cropping systems on maize grain yields due to stover or stem addition or removal. Pigeon pea grain yield differed among sites and across cropping systems with highest yields obtained at Makoka (1015 kg ha-1) from rotation plots.

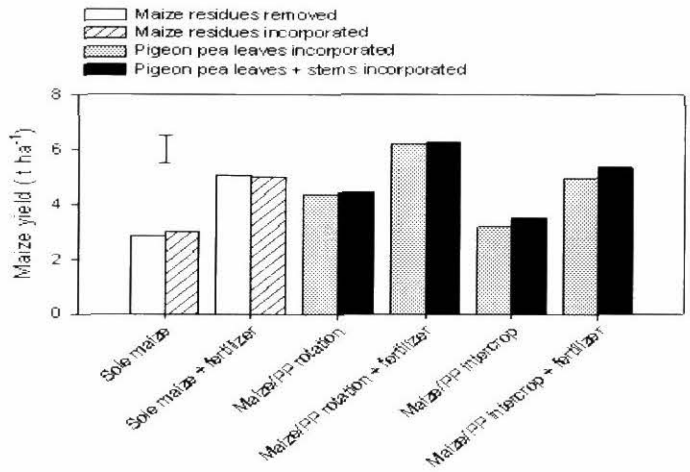

Figure 41: Maize grain yield from different cropping systems.

The impact of soil fertility management technologies on crop productivity in maize-based farming systems of southern Africa

S. Zingore[1]

[1]TSBF - CIAT, Malawi

In southern Africa, problems of declining soil fertility are widespread, largely as a consequence of continued cultivation of crops with low levels of nutrient inputs. Farmers face serious challenges in maintaining and restoring soil fertility, and increasing crop productivity. In the face of a growing food crisis, there are renewed calls to transform the landscape of smallholder agriculture from low-external-input to intensive cropping systems, supported in particular by increased fertilizer use. While increased use of mineral fertilizers is key to improved crop productivity, mineral fertilizers are on their own inadequate to sustainably increase crop yields due to multiple and complex biophysical and socio-economic constraints to crop productivity of smallholder farms in sub-Saharan Africa.

In southern Africa, fertilizer use is profitable and highly efficient on fertile fields, but less efficient in lower fertility soils. There is evidence that integrated use of mineral fertilizers with organic nutrient resources is essential for increasing crop productivity and fertilizer use efficiency, particularly on these infertile soils, as mineral and organic nutrient resources have different functions on soil fertility and crop production and their use in combination can have synergic effects. Organic resources play an important role in restoration and maintenance of soil fertility due to multiple benefits that include, supply of nutrients, and increase in soil pH and soil organic matter. Use of animal manure and incorporating crop residues are technologies with good potential for leveraging the benefits of increased fertilizer use in southern Africa. Symbiotic biological N2-fixation is an important option for supplying high quality organic resources for improving soil N budgets and supplementing N derived from fertilizers. The main N2-fixation based technologies with good potential to complement mineral fertilizer in southern Africa include grain legumes with low N harvest and tree legumes. When combined with mineral fertilizer, these technologies have potential to improve productivity and fertilizer use efficiency by 10-60%, depending on soil fertility conditions and fertilizer application rates. Most of soil fertility management technologies have been developed and tested in field experiments. Although increasingly we need to improve targeting the technologies within heterogeneous smallholder farming systems, taking into account variability n soil fertility at various spatial scales, availability of resources for crop production, input and output markets and policy constraints.

Nutrient management strategies for increasing maize productivity in irrigation landscapes in southern Malawi

S. Zingore[1]
[1]TSBF - CIAT, Malawi

Introduction and justification

Improving crop productivity in irrigation-based cropping system in sub-Saharan African agriculture can contribute significantly to alleviating insecurity the region. Southern Malawi is arid and densely populated. Greater food security in the area has to be achieved by increasing the productivity of the arable land. At Nkhate, large investments have been made in irrigation infrastructure in an attempt to increase productivity. However, a large gap between potential and actual yields still exists due to a combination of poor water management and low fertilizer use (efficiency). Improving the current nutrient management strategies is thus important to achieve higher productivity and profitability of the smallholder farms.

Materials and methods

This research focused on the evaluation of the current nutrient management strategies for maize and rice. Moreover, suggestions were formulated to improve present and future productivity and/or profitability. The evaluation was conducted at field and farm scale since farmers face multiple trade-offs at farm scale when allocating their scarce labour, water and nutrient resources. An exploration of the long term effects of the nutrient management strategies was done using the FIELD model.

Preliminary results

Field experiment and model based results showed that farmers' current management practices closely match the optimum fertilizer distribution in the short term. The present fertilizer distribution between the different fields of the farm closely matches the optimum distribution as predicted by the QUEFTS model. However, fertilizer use efficiency can be increased by concentrating the available compound fertilizer on the rice crop, since yield responses of maize to P fertilizer are poor. Exchanging a fraction of the compound fertilizer for urea could also improve profitability. Higher economic returns could be achieved in years with sufficient rainfall by applying small amounts of fertilizer to the rain fed fields. However, farmers perceive the rainfall variability as a high risk factor for the application of fertilizers on the rain fed fields. Instead of burning the residues in the irrigated fields, they could be collected and composted.

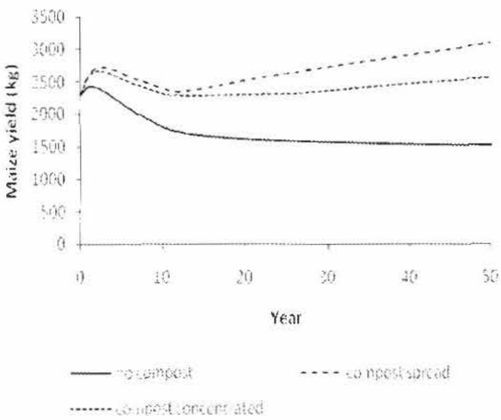

Figure 42: Simulated long – term effects of compost on maize yields under irrigation in Malawi.

Preliminary conclusion

The field experiment indicates that additional compost applications will result in higher fertilizer N recovery in the short term. The most probable reason is that additions of compost can result in temporary immobilization of fertilizer N. However, simulations with FIELD indicate that temporary yield reduction in the short term can be avoided if a fraction of inorganic fertilizer is exchanged for organic fertilizers. In the long term, continuous cultivation with sole fertilizers will diminish yields. FIELD simulated yield decreases of about 40% over a period of 50 years. The simulated yield decline is mainly a consequence of the decline in SOC. Lower SOC contents can lower the supply and recovery of nutrients. Other effects include a decrease in available water capacity and a deterioration of soil structure or other physical properties. However, these are not simulated by FIELD. Simultaneous additions of compost will maintain or even increase maize yields after 50 years of cultivation. The increase is related to a simulated increase in SOC upon application of compost.

Output 2. Management practices
Output Targets 2009: Trade-off analysis is informing the identification of best ISFM practices for cereal-legume systems in the Sahel and moist savanna impact zones.

COMPLETED WORK

An integrated evaluation of strategies for enhancing productivity and profitability of resource-constrained smallholder farms in Zimbabwe.
(2009) Agricultural Systems vol. 101 (1-2): 57-68

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.

Output 2. Management practices
Output Targets 2010: Decision support systems for locally adapted ISFM practices for **cereal-legume systems** in the Sahel and moist savanna impact zones.

NO ACTIVITY

Output 2. Management practices
Output Targets 2010: ISFM practices for **cassava and rice systems** tested, adapted, and validated to farmer conditions in the humid lowland impact zone.

WORK IN PROGRESS

Fertilizer application and legume integration for increased productivity of cassava-based systems in the Humid Tropics

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[1]UNIKIN, DR Congo; [2]CIAT-TSBF, Kenya

Introduction

Integrated Soil Fertility Management (ISFM) has potential for improving productivity in cassava-based systems in the Humid Tropics. Integration of grain legumes can provide additional revenue from the produce and at the same time provide biomass for soil fertility improvement, but intercropping may have a negative impact on cassava storage root yields. Poor soil fertility is an important limitation for crops, and both cassava and legumes are highly responsive to fertilizer. Nevertheless, fertilizer is little used. Farmers commonly collect cassava leaves during the season for human consumption, and this may negatively affect cassava yields. A study was conducted to evaluate the effect of legume intercropping, leaf collection and fertilizer application on cassava biomass and storage root yield.

Materials and methods

An on-station trial was conducted at N'Djili Brasseries, at about 50 km outside of Kinshasa. [Need short site description]. The trial was installed following a complete factorial randomized complete block design with three factors: legume intercrop (none, beans, cowpea, groundnut and soybean), leaf collection (with and without) and fertilizer application (with and without compound NPK fertilizer applied at XXX kg ha^{-1}). Observations included legume biomass and grain yield, cassava leaf biomass from the different collections, and cassava stem and storage root yields at harvest (13 months after planting).

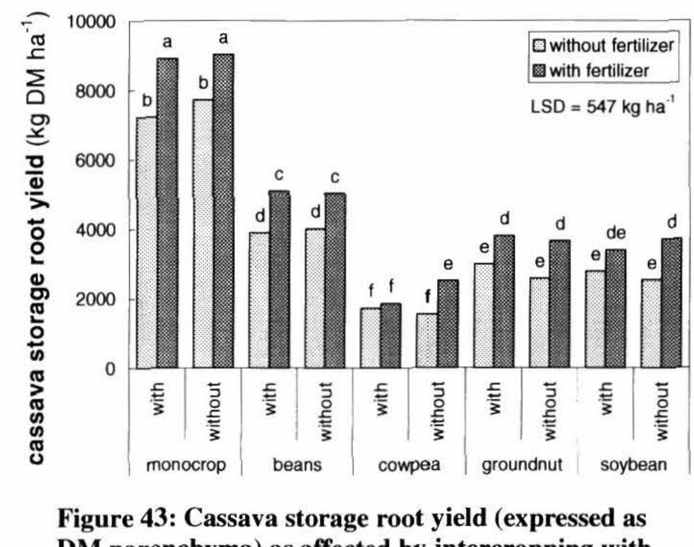

Figure 43: Cassava storage root yield (expressed as DM parenchyma) as affected by intercropping with different legume species, with and without regular cassava leave collection, and with and without fertilizer application. Means with different miniscule letters are significantly different at P<0.05.

Preliminary results

Fertilizer application resulted in a cassava storage root yield increase of on average 1 t DM ha^{-1}, independent of the intercrop or leaf collection, except when cowpea was grown. Yields of the cassava monocrop were much higher than in the intercropping systems. Yield reductions were largest (70-80%) when cowpea was grown as intercrop, and smallest with a bean intercrop (about 45%). Cassava is most sensitive to shading during early stages (esp. during the root initiation stage). Cowpea biomass production was larger and shaded the cassava crop during a longer period, relative to the other legumes, which may explain the larger negative impact.

Preliminary conclusions

A full financial analysis is required to evaluate whether cassava yield losses are compensated by revenue obtained from the legume produce. Leaf collection did not have any effect on cassava storage root yield, except when cowpea was intercropped. Collection of cassava leafs can thus be recommended, provided that a sufficiently long intervals to allow the cassava to recover.

Farmer adaptive testing confirms increased crop productivity through integrated soil fertility management in cassava-legume intercropping systems in the highlands of Sud-Kivu, DR Congo

P. Pieter[1], J. Sanginga[2], J. Walangululu and B. Vanlauwe[1]
[1]CIAT-TSBF, Kenya; [2]CIAT-TSBF, DR Congo

Introduction and Justification

Cassava is one of the major staple crops in the highlands of Sud-Kivu, DR Congo. In farmers' common practice, cassava is intercropped with legumes such as common beans (*Phaseolus vulgaris* L.) or soybean (*Glycine max* L. Merril). Farmers use local germplasm and apply moderate amounts of compost or animal manure. Integrated Soil Fertility Management (ISFM) technologies can increase crop production through the use of improved crop varieties, judicious application of mineral fertilizer, organic matter management and adapted agronomic practices (crop arrangement) (Vanlauwe et al., 2010). Results from previous demonstration trials conducted with farmer groups showed that these technologies can increase legume yields by 150% and cassava storage root yield by 50%. Subsequently, farmer-managed trials were organized with the objectives to (i) evaluate the effect of judicious fertilizer use and adapted agronomic practices on legume and cassava storage root yields across a wide range of field types and fertility gradients, and (ii) promote farmers to take up, experiment and adapt the ISFM technologies.

Materials and methods

Adaptive trials were carried out with 585 households in four sites during two consecutive cropping cycles. Two sites located north of Bukavu were characterized by a higher inherent soil fertility and lower altitudes (1400-1700 m above sea level), relative to two sites located south of Bukavu (1600-2000 m above sea level). Farmers received "packages" containing cassava and legume planting material, NPK (17:17:17) fertilizer, a leaflet with basic information, and a field book for data collection. Farmers received training prior to distribution of the packages and trial installation. Site facilitators and technical teams of farmers were employed to assist the participants with trial installation and data collection. During the season, all trials were visited by agronomists to verify correct implementation and data collection. At harvest, facilitators and technical teams assisted farmers to ensure correct measurement of crop yields. Two packages were formulated to evaluate different aspects of the technologies through a simple design with three plots. In both packages, the first plot was a farmer's common practice, where the legume seed was broadcast and cassava cuttings were planted without a specific arrangement. In the second and third plot of the first package, cassava was planted at the recommended spacing of 1m by 1m, and two bean lines were planted in between the cassava rows. In the third plot, fertilizer was applied at 100 kg ha^{-1}. In the second plot of the second package, cassava and beans were planted similarly as in the first package. In the third plot, however, cassava was planted at a modified spacing of 2 m between lines by 50 cm within the line, with four lines of beans between the cassava rows. Plant densities were identical in all plots (10,000 cassava plants and 100,000 bean plants ha^{-1}). In the second package, all three plots received fertilizer at 100 kg ha^{-1}. After harvest of the beans, the bimodal rainfall pattern allowed a second intercrop, and soybean was planted. One line was planted in between the cassava in the 1 m by 1 m arrangement, while in the 2 m by 50 cm arrangement, two legume lines were planted (100,000 soybean plants ha^{-1} in both arrangements). Additional fertilizer (50 kg ha^{-1}) was applied in the respective treatments. Following data was collected: planting, weeding and harvest dates, emergence rates, weed cover, plant stand at harvest, legume grain yield and cassava storage root yield and numbers. At harvest, farmers scored each plot in terms of labour demand, vegetative growth, disease prevalence, yield and produce quality.

Preliminary results

About one quarter of the farmers did not correctly implement the trial or did not collect all essential information, and were excluded from the analysis. In the traditional practice, average bean grain yields were 1000 kg ha^{-1} on the northern axis, and 600 kg ha^{-1} on the southern axis **(Figure 44).** The subsequent soybean crop yielded about 700 kg ha^{-1} on both axes. Fertilizer addition increased bean grain yields by 11 and 24 % on the northern and southern axis, respectively, and modifying the cassava crop arrangement from 1 m by 1 m to 2 m by 50 cm increased yields by 6 and 17 %, respectively. Effects were more pronounced on the subsequent soybean crop: fertilizer application and improved crop arrangement increased grain yields by 23 % and 21 % respectively. Relative to the traditional practice, these measures represented an increase in legume productivity by 44-60 %. Legume yields varied largely between participants. Bean yields in the farmers' practice without fertilizer addition varied between 0 and 3.0 t ha^{-1}, and yields of the subsequent soybean crop varied between 0 and 2.1 t ha^{-1}. Fertilizer application increased bean and subsequent soybean yields by more than 20 % in 40 % and 48 % of the cases, respectively. Changing the cassava crop arrangement from 1 m by 1 m to 2 m by 50 cm increased bean and subsequent soybean grain yields by more than 20 % in 35 % and 44 % of the cases, respectively. Fertilizer application or the modified crop arrangement rarely resulted in yield decreases exceeding 20 %. Cassava storage root yields were much larger on the northern axis (on average 23 t ha^{-1}) than on the southern axis (on average 7 t ha^{-1}). Fertilizer application increased cassava yields by almost 20 % on both axes. The cassava crop arrangement of 2 m by 50 cm did not negatively affect cassava yields, relative to the recommended 1 m by 1 m arrangement. Variability between farmer participants was likewise high. Yields varying between 0 and 58 t ha^{-1} were recorded. In 43 % of the cases, fertilizer application resulted in more than 20 % yield increase. In two thirds of the cases, cassava crop arrangement did not result in more than 20 % yield difference. Negative effects of fertilizer application or modified crop arrangement were rarely observed.

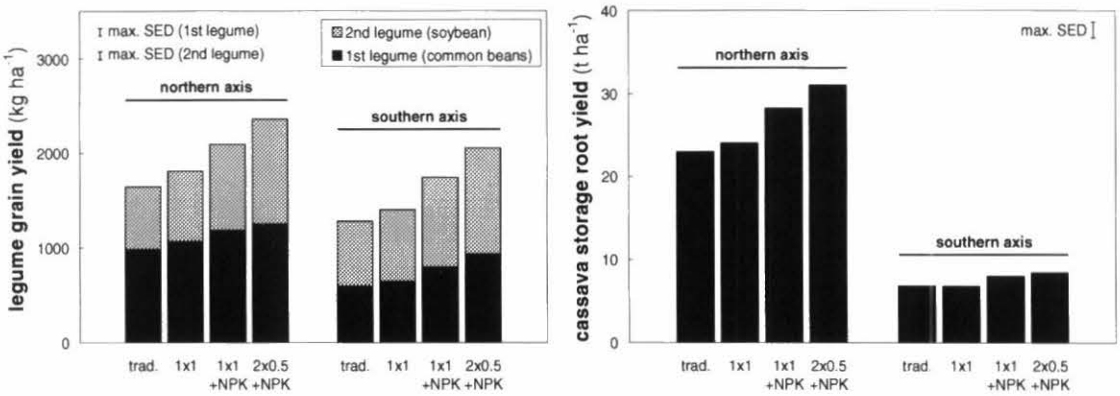

Figure 44: Legume grain yield (left) and cassava storage root yield (right) on two axes as affected by cassava crop arrangement (traditional, 1m by 1 m or 2 m by 0.5 m) and application of fertilizer. Sites on the southern axis are characterized by a higher altitude and lower inherent soil fertility, relative to sites on the northern axis. Error bars represent maximal standard errors of difference between means.

Preliminary conclusions

In conclusion, farmer adaptive testing confirms that a simple agronomic measure modifying the crop arrangement can largely increase legume productivity in cassava-legume intercropping systems, without negatively affecting cassava production. Additional judicious fertilizer application can further increase both legume and cassava yields. Variability in crop response to fertilizer and modified crop arrangement will be explored, and related to differences in soil fertility, soil type and management.

Output 2. Management practices
Output Targets 2010: Trade-off analysis is informing the identification of best ISFM practices for cassava and rice-based systems in the humid lowland impact zone.

NO ACTIVITY

Output 2. Management practices
Output Targets 2011: Decision support systems for locally adapted ISFM practices for **cassava and rice-based systems** in the humid lowland impact zone.

NO ACTIVITY

Output 2. Management practices
Output Targets 2011: ISFM practices for **banana-based systems** tested, adapted, and validated to farmer conditions in the humid lowland impact zone.

WORK IN PROGRESS

Indigenous AMF inoculation of TC banana cultivar (Mpolongoma (AAA) and Kamaramasenge (AB)) plantlets and their subsequent performance under field conditions in two contrasting sites in Rwanda.

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Introduction and justification

Commercial AMF inoculants are available but may not have advantages compared to indigenous inoculants that are more adapted to both biotic and abiotic soil conditions. There is still limited information on the local AMF and their ability to improve plant growth under low soil fertility and high prevalence of pests and diseases.

Materials and methods

Indigenous AMF inoculants with origin from banana growing areas were evaluated for their effectiveness on growth of two banana cultivars "Mpolongoma" (AAA-subgroup) and "Kamaramasenge" (AB-subgroup) in sites at Kibungo with lower P level of 65.5 mg/kg and Rubona with P level of 18.8 mg/kg P. The study evaluated effects of two mixed and a single inoculant *Glomus mosseae* from hardening to field establishment. Initially, the five bio-geographical zones were evaluated for AMF diversity.

Preliminary results

The study confirmed that bananas are naturally colonized by mycorrhizae. A total of 16 distinct morphotypes were described from five banana growing regions of Rwanda and Burundi, The most dominant *Acaulospora and Glomus spp.* There was variation in number of AMF species found in banana systems. Inoculation studies using indigenous AMF showed significant ($P<0.001$) differences between the indigenous AMF inoculants. Mixed Kibungo inoculant and Mixed Rubona inoculant had higher infectivity compared to single spore culture *Glomus mosseae*. The non-inoculated field soils from the two banana growing sites (Kibungo and Rubona) had low infectivity. The effect of AMF on performance of the two banana cultivars was evident under under greenhouse and field conditions **(Photograph 7).** AMF inoculation improved plant height, girth and leaf surface. This was however variable in the soils from Kibungo and Runona. Both cultivars responded to AMF inoculation when established in soils from Rubona more than Kibungo and the cultivar Mpolongoma (AAA) was slightly more responsive to AMF inoculation than Kamaramasenge (AB) **(Figure 45)**.

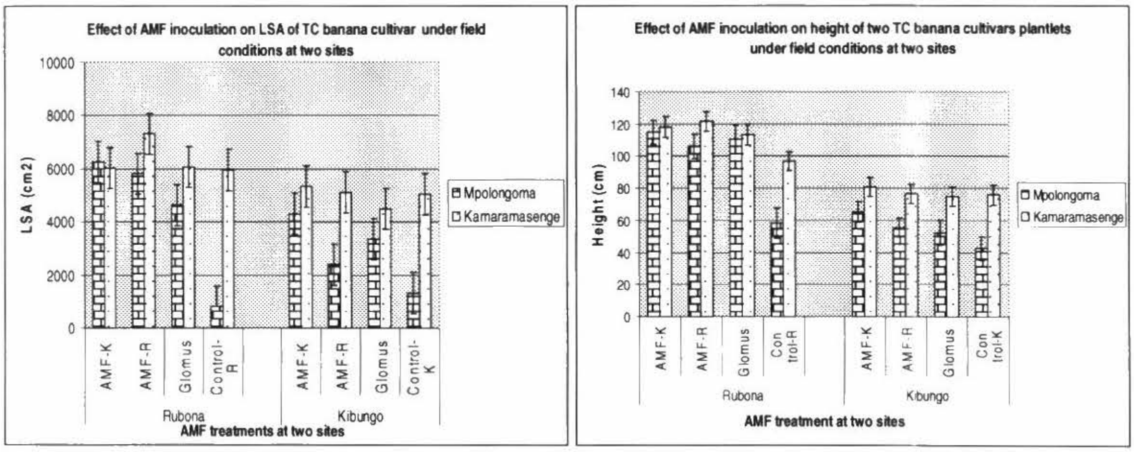
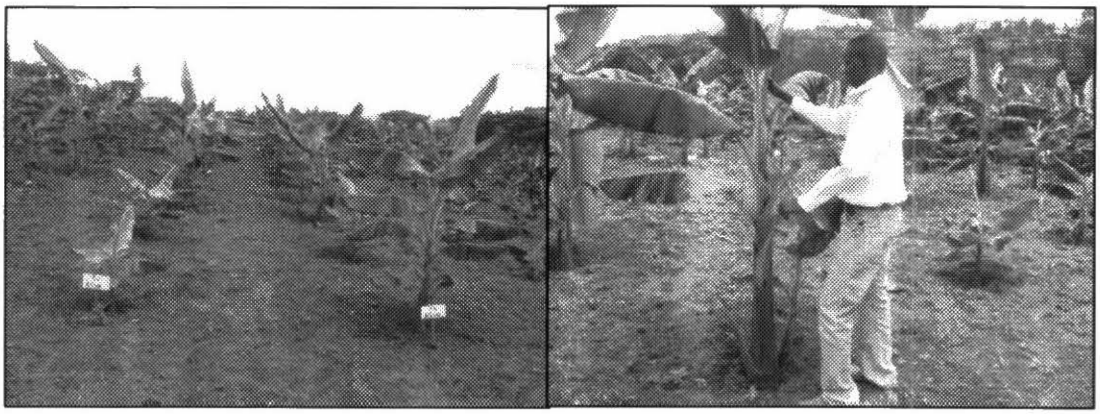


Figure 45: Effect of AMF inoculants on height and leaf surface area (LSA) of the two banana ciltivars at sites in Rubona and Kibungo.
AMF-K = Arbuscular mycorhiza fungi isolated from Kibungo soil
AMF-K = Arbuscular mycorhiza fungi isolated from Rubona soil
Control-k = soil collected from Kibungo
Control-R = soil collected from Rubona



Photograph 7: AMF inoculation banana trial at 16 weeks after field establishment in Rwanda.

Preliminary conclusions

The degree of response of TC bananas varies with cultivar with ploidy AAA (Mpolongoma) more responsive than AB (Kamaramasenge), indicating more AMF dependency of the former ploidy than the latter. The response to AMF by the banana cultivars depends on soil conditions. The soils in Rubona were more responsive to inoculation than soils in Kibungo. Indigenous AMF have great potential to improve banana production and the high diversity in the region should be further exploited.

III.3. OUTPUT 3 - ENABLING ENVIRONMENTS FOR DISSEMINATION OF ISFM PRACTICES, FOCUSING ON VIABLE INPUT AND OUTPUT MARKET LINKAGES AND APPROPRIATE NUTRITIONAL KNOWLEDGE AND HEALTH.

Outputs (Intended users)	**Outcome (Impact)**
Description: Enabling environments for dissemination of ISFM practices, focusing on viable input and output market linkages and appropriate nutritional knowledge and health. Intended users: CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, extension services, policy makers.	Outcome: Farmers are generating more revenue and are knowledgeable about health and nutrition and using that income and knowledge to implement ISFM practices within their farms. Impact: Improved income and health and nutrition for the farmers in the target impact zones through adoption of ISFM-based production systems.

Output 3. Enabling environment: Major components of ISFM practices require an investment in inputs, be it fertilizer, organic matter, beneficial organisms, or improved germplasm. As such, linking farmers to output and input markets is going to be essential to ensure sufficient revenues for investing in ISFM. This logic also underlies the market-led hypothesis which states that '*ISFM research will have more leverage if the apparent gaps between investment in the natural resource base and income generation can be bridged*'. Another factor that can create the required environment for large-scale dissemination of ISFM is an increased knowledge about good health and nutrition, especially related to an enhanced inclusion of legume germplasm in existing cropping systems. Besides engaging in the practice of implementing market and health/nutrition-related activities, such activities are supported by specific research questions. The major Outcome of this Output is related to farmers generating more revenue and being knowledgeable about health and nutrition and using that income and knowledge to implement ISFM practices within their farms.

Output 3. Enabling environment
Output Targets 2009: Linkages with the **private sector** to improve access to fertilizer and develop recommendations for its use by farmers and other stakeholders involved in the **Sahel and moist savanna** impact zones.

COMPLETED WORK

Crop storage efficiency and market competitiveness: Case of groundnut and cowpea in Ghana. (2009) *African Journal of Marketing Management, 1(3): 081-088. Available online http://www.academicjournals.org/ajmm*

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Abstract: Using groundnut (*Arachis hypogea*) and cowpea (*Vigna unguiculata*), this study empirically demonstrated the correlation between crop storage and economic competitiveness of producers, captured from the degree of market integration and producer shares of the prices paid by consumers, among others. Secondary data covering 1963–1997 were used and complemented with primary data. Results from analysis of market integration showed delayed information flow among groundnut and cowpea markets, especially the latter. This suggests the absence of perfect competition and negatively affects participation of smallholder farmers in profitable marketing of groundnut and cowpea, especially during the lean season. The Harris' inverse margins from estimated equations indicated that cowpea traders, more than groundnut traders, colluded in pricing, implicating price determination outside the market forces. The attack by weevils [*Callosobruchus maculatus* (Fabricius)] and bruchids limits farmers' success in storing cowpea, creating monopoly for traders with better storage facilities coupled with chemical treatments to reduce such attacks. Price spread estimations showed that groundnut unlike cowpea farmers enjoyed a larger share of consumers' payments. The study concludes with recommendations on the need to intensify efforts in effective storage of agricultural commodities at the farm-level, as a way of improving the welfare of farm families without necessarily expanding the land area under cultivation.

Promoting a Versatile but yet Minor Crop: Soybean in the Farming Systems of Kenya. *(2009) Journal of Sustainable Development in Africa, 10 (4): 324–344*

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Abstract: Crop promotion is critical for market creation and rural growth in Africa. How to achieve this for crops, other than major staples (e.g., maize) and traditional export crops (e.g., tea), remains a problem since most African countries tend to focus policy attention to major staples and traditional export crops. Using a three-tier-approach, developed based on successful soybean promotion strategies in Nigeria and Zimbabwe, this study assesses the effect of market development at household-level, community level, and linking farmers' groups to industrial processors on sustainable soybean promotion in Kenya. Results show an increase in farmers' confidence to produce, process, and consume more soybeans than before. Trained farmers' groups are also developing new soybean products for cash income, a process that has proved to be very profitable. Net returns have been increased from four to 14 times for some products. Selected farmers' groups are supplying large-scale processors with soybean grains, substituting some imports.

WORK IN PROGRESS

Potential of warrantage agricultural marketing system in improving rural livelihoods in Africa: Millet (*Eleusine coracana* L.) in *Madana* community, Nigeria

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Introduction and justification

Low agricultural commodity prices are the key causes of poverty in many sub-Saharan African (SSA) countries. Efforts to improve rural livelihoods must improve agricultural produce marketing. This study was carried out to ascertain how *Warrantage* (micro-credit scheme) could be used to improve millet (*Eleusine coracana* L.) prices, marketing, returns to investment and overall livelihoods among rural farmers.

Materials and methods

The study was carried out in *Madana* community, Jigawa State of Nigeria. The design was an action research approach, based on supervised enterprise project framework developed by the University of Cape Coast, Ghana. Data were collected using questionnaires, interviews, focus group discussions, and in-depth interviews. Data analysis was carried out using qualitative and quantitative analytical methods.

Preliminary results

Results demonstrated how farmers could take advantage of the price differences of 50–78% between selling immediately after harvest and waiting for a few months, with the benefit–cost ratio for waiting of 1.4 to 8.7. The increase in total value of the stored millet ranges from ~9 to ~58%.

Preliminary conclusions

The study concluded with recommendations on how the warrantage system could be expanded, institutionalized and used to increase farmers' access to modern farm inputs so as to increase their farm productivity and improved their livelihoods.

Motivating adoption of ISFM technologies through strategic storage and credit schemes: The case of warrantage schemes in CIALCA project, South Kivu Province, DRC.

E. Birachi[1], B. Kasereka[2], B.vanlauwe[3],[4] Frank Manyundo

[1]CIAT-TSBF, Kigali, [2] CIAT-TSBF Bukavu, [3]CIAT-TSBF, Nairobi, GEL, Bukavu

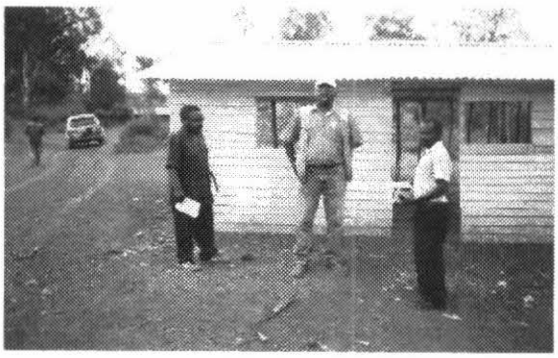
Introduction and justification

The interest in markets by farmers in south Kivu led them to begin building stores for their products. Increased productivity arising from use of fertilizers, improved germplasm and better agronomic practices, all promoted by CIAT-TSBF (CIALCA) through the ISFM program contributed to this interest. Without a market, the benefits of these technologies may not be realized and/or sustained. However, inability to invest in the technology due to shortage of funds may have negative effects on adoption of the technologies, thus contributing to the poverty vicious cycle in many households. One intervention that can be used to bridge the financial gap for farmers after harvesting grains is the warrantage system. A warrantage system is a form of credit scheme where producers come together to store their products for sale at a more convenient period and are financed by a third party for the duration of storage of the products. Repayment of the credit occurs once the warrantage is exercised in the presence of producers and financiers. The products act as a form of collateral for the credit. The successful adoption of new cereal technologies in many West African countries can be attributed to innovations in the market, represented by warrantage systems.

Methods and materials

The warrantage pilot program in South Kivu is supported by CIAT-TSBF (CIALCA) initially in two associations. Technology transfer is carried out through the ISFM program which provides a strong base on which to operate the warrantage system. Currently two associations are implementing the scheme on pilot basis, supported by CIALCA, GEL and a credit cooperative society. The implementing associations were first assessed for ability to implement the scheme.

A warrantage system operates at two levels of credit: Farmer organization secure a credit facility from a financial institution using its assets as security. The credit is then extended to farmers using their harvested grain products as security (bean and soybean). Farmer group members pay back the borrowed funds through the farmer group. The amount of credit depends on how much cereals he/she has delivered to the group in warrantage. Through a warrantage system, farmers are provided with credit that they can repay over a period of time. Interest is charged over the period at 3% per month. For the current associations, the credit facility is to help them bridge financial requirements such as school fees.



Photograph 8: One of the stores the associations are constructing in preparation for warranatge schemes in Burhale, South Kivu, one of the CIALCA sites.

The grains are kept in stores (**Photograph 8**) with three padlocks, one padlock with the cashier of the credit cooperative, one by GEL that is supporting the associations by monitoring them and one by the farmers associations. The two ensure that the grains are secure until sale time. Prices paid are the prevailing prices at the time of warrantage. Low prices are usually preferred since they imply lower amounts are borrowed. The stores are situated strategically at market centers. Through the warrantage system, associations expect to sell when the prices rise. An intervention at the input level may increase yields thus breaking the poverty cycle.

Operationalizing the warrantage system in South Kivu (CIALCA mandate area)

To operationalize the warrantage system, the following are be required:

- There must be a storable product- These are beans and Soybeans
- Good storage facilities: Part of the financing will also be used to improve the stores further to minimize post harvest losses.
- To guard against theft, sentries have been hired for the duration of the warrantage schemes. The stores are located in market areas for ease of access to markets.
- There must be supporting technologies have been provided by CIAT-TSBF (CIALCA) to support expanded production.
- The attractiveness of the scheme is realized for products whose supply and/or prices vary with seasons. Associations have used historical price performance of the grains to estimate selling dates for the grains as they take advantage of price changes.

- A strong management committee to manage market linkages, cash and member relations. Control systems must be put in place by members. Market committees have been trained by CIALCA and will continue being strengthened by CIAT-TSBF.
- Linkages with microfinance financiers are being established to secure credit lines especially when the outputs increase in the coming seasons.
- The current warrantage is operating at the association/network level- where a number of associations have come together to create an umbrella organization to implement it.
- Post harvest management training will be provided to the associations to ensure that the grain is well stored and that they maintain good quality.

Preliminary results

The requested financing is USD 1000. On the other hand, the association expects the value of the products in September to be US$ is 2333 (**Table 12**). Upon successful implementation of the system, this should have positive impacts on food security level of the farmers, more women participating in the economic activities. Middlemen are reduced in the product chains, with farmers capturing some of the value for themselves.

Table 12: A summary of the warrantage scheme is as follows:

Product	**Quantity (kg)**	**Current prices and valuation in US$**		**Projected price and valuation at sale time in September, US$**	
		Current price per kg	Current valuation in $	Price in US$	Value at projected price in US $
Soybeans	1,500	0.44	667	1.10	1,667
Beans	500	0.66	333	1.33	667
TOTAL			**1,000**		**2.333**

There are some costs that the associations will incur during the warrantage period (**Table 13**). These costs are to be offset against the revenues from the sale of the products in September. The credit received is used to pay for these warrantage costs before that take place before September 2010.

Table 13: Profitability of the warrantage scheme for the farmer association in Luhihi

Item	**Warrantage Period : April to September 2010**		
	Receipts (USD)	**Expenditure, (USD)**	**Net return (USD)**
Emprunt bancaire	1,000		
Payments to association members		800	
Improvement of store		35	
Product conservation		10	
Local authority charges		60	
Security costs		90	
Total expenditure before sale of stocks		995	
Solde de l'emprunt et décaissement			5
Revenue from sale of product in September 2010	2,333		
Reimbursement of credit		1,000	
Interest on credit @ 3% per month		180	
Net return on warrantage			1,158

Output 3. Enabling environment
Output Targets 2009: Knowledge of extension staff and farmers that are involved in adaptation and dissemination of ISFM practices on appropriate **nutrition and health practices** sufficiently developed in the **Sahel and moist savanna** impact zones.

WORK IN PROGRESS

Stimulate Consumption of Diversified, Nutritious Food Baskets

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Introduction and justification

To impact on nutrition and health of vulnerable communities in the CIALCA mandate areas, the nutrition and health research component focuses on three broad of objectives: to improve access and utilization of soy beans and other legumes to improve quality of diets of communities affected by malnutrition, to develop the capacity (knowledge, skills and practices) of communities in soy bean processing and value addition to improved dietary quality and to demonstrate impact of consumption of improved diets on nutrition status of vulnerable communities. From the CIALCA baselines, the primary underlying cause of malnutrition in the great lakes region is poor quality diets characterized by high intakes of food staples, but low consumption of animal and fish products, fruits, lentils, and vegetables, which are rich sources of protein, minerals and vitamins. Staple foods (overwhelmingly Cassava, maize and banana in this example) account for 80 percent of total per capita energy intakes. (CIALCA 2008). As such, most of the malnourished are those who cannot afford to purchase high-quality, but also lack access to agricultural technologies and knowledge to grow and consume these foods on a daily basis. The nutrition and health research strives to contribute to improve quality of diets in these communities by stimulating legume production to increase protein and micronutrient intake. Iron rich beans are promoted for supply of protein, iron and zinc and soy bean processing is promoted through development of soy milk, soy bean curd and soy flour to enriched foods regularly consumed.

Materials and methods

In partnership with selected health centers and hospitals, 10 focal point demonstration gardens were developed to show case selected soy bean varieties, iron rich beans and vegetables. NGO partners and farmer groups were mobilization to support and maintain demonstration gardens. Demonstration gardens were used to multiply seed for further distribution, train communities on production and demonstrate skill in food processing and utilization.
Planning workshops were conducted in each mandate area to review activities, develop work plans and identify roles and responsibilities of each partner. Over 500 trainers from farmer groups, NGO partners, health centers and hospitals were trained. Training topics included; processing and utilization of soy beans, hygienic practices in food processing/preparation, cooking demonstrations, food combination and formulating a balanced diet. Three nutrition studies were conducted. In Rwanda, nutrient retention studies were conducted to on three soy bean products; soy milk, bean curd and soy bean flour each processed using two different methods. Samples were evaluated at before and after processes. In addition different soy bean

varieties were tested for quality of soy milk. Nutrients evaluated included; protein, lipids, iron and vitamin A. Samples were processed and evaluated using atomic absorption at the National laboratories of ISAR. In Bukavu, DRC, soy bean acceptability studies were conducted with communities that were not accustomed to consuming soy beans. Soy milk, soy bean porridge, soy flour enriched vegetables and soy bean curd were prepared and served to 37 participants from different institutions. Participants were asked to provide their taste preferences on a harmonized comment sheet developed for this purpose. Results were tabulated for different products. In Bas Congo a study was conducted to determine the impact of consuming soy bean enriched foods on nutrition status of children less than five years of age. 300 malnourished children who were under weight for age were recruited to the study. Mothers were trained on soy bean processing and appropriate child feeding practices. I kg of soy bean was given to each child each week with serial monitoring of weight gain per month. The children will be followed up for six month. Monitoring and Evaluation was conducted at 3 levels; (i.) health centers level – access to demonstration gardens and overall dietary characteristics of beneficiaries was evaluated after every 3 harvesting seasons (ii.) Training of trainers at NGO, CBO and farmer group level – Number of people trained as trainers and by trainers at different community level and application of knowledge and skills acquired after training. (iii.) Partner/satellite level – beneficiaries, seed distributed, technology adoption and impact on communities.

Preliminary results

Training of Trainers: Over 600 trainers have been trained in each site. In Rwanda for example, 45 community health workers were trained along with 604 farmer group representatives and 564 women attending post- natal clinics in selected health centers. In Bukavu over 400 trainers have been trained, most of who are from NGO partners. In Bas Congo, over 200 partners from various NGOs have been trained. Further training at the community level has mainly been conducted by NGO partners. An evaluation of training outcomes and application of acquired knowledge and skills is on –going.

Knowledge about Soy beans and Acceptability studies: Across sites over 80% of farmer group representatives showed significant familiarity with soy beans. 20% of the rural health community grew and consumed soy bean in the past one year but with limited knowledge on processing techniques, negative attitude towards cooking qualities and taste. While only 6% of the farmers regularly use soy bean flour as a weaning product, they did not grow or process it at home. The health community particularly in South Kivu and Bas Congo occasional consumed soy milk and Soya biscuits -which they purchased locally. Soy milk and soy bean curd were readily available from a soy factory in central Rwanda. In Bas Congo unlike Rwanda and South Kivu more men than women knew about Soy products, only 19% of those who knew soy in Bas Congo were women. Less than 35% of the households consumed soy in the past one year. Generally there was no source of knowledge on soy bean production, processing and utilization across sites. Majority of the farmers 89% had vague information about the nutrition and health benefits of soy. However some of them, 15% had also negative but inaccurate information about side effects of consuming soy. Processed products were tested by different groups. Qualities tested were attributed to general preference, taste, flavor and appearance. Different flavors of soy milk, soy vegetables enriched with milk and flour, soy bean porridge, bread, biscuits and curd were tested. In Bas Congo and South Kivu the most preferred product was soy milk with sugar, 92%, followed by soy porridge, bread and soy enriched vegetables. The least preferred was soy bean curd. In Rwanda, 86% of farmers favored all products. Selected products will be promoted at the community level for household consumption and for sale. Product development manuals and commodity fact sheets were summarized and incorporated in the training guide. Majority of those interested in the recipe development were women. For example, in South Kivu 70% of those involved were women.

Soy bean nutrient retention and consumption studies: Preliminary results show that there are no significantly losses in soy bean protein and lipids given different processing methods. However results on vitamins and mineral did were did not tally with expectations and provided considerable difference with literature. The evaluations will be repeated. Children consuming soy beans have showed considerable progress in weight gain at a glance. Preliminary data indicates consistent weight gain in children after two months of consumption. Comparative average weight gain for children who consumed soy bean and who did not consumed soy beans will be the basis for recommendations to scale up such interventions.

Preliminary conclusions

In significant losses after processes indicate that using soy bean products may improve nutrient quality of foods commonly consumed. With the high acceptability registered, increased production and training on soy bean processing and utilization shows promise to improve protein and micronutrient content foods consumed. While agricultural extension workers may have received training in food and nutrition focusing on soy bean processing, there is much scope for health workers to focus on issues of agricultural production in relation to food and nutrition security linking locally perceived nutrition related health problems and food and agricultural issues. An analysis of the steps in the food chain, including production, application of new processing and preparation knowledge, skills and practices and consumption of nutritious food baskets may demonstrate and evaluate how specific changes affect nutrition outcomes at household level and community level.

Output 3. Enabling environment
Output Targets 2010: Linkages with the **private sector** to improve access to fertilizer and develop recommendations for its use by farmers and other stakeholders involved in the **humid lowland** impact zone.

NO ACTIVITY

Output 3. Enabling environment
Output Targets 2010: Knowledge of extension staff and farmers that are involved in adaptation and dissemination of ISFM practices on appropriate **nutrition and health practices** sufficiently developed in the **humid lowland** impact zone.

NO ACTIVITY

Output 3. Enabling environment
Output Targets 2011: Linkages with the **private sector** to improve access to fertilizer and develop recommendations for its use by farmers and other stakeholders involved in the **humid lowland** impact zone.

NO ACTIVITY

Output 3. Enabling environment
Output Targets 2011: Knowledge of extension staff and farmers that are involved in adaptation and dissemination of ISFM practices on appropriate **nutrition and health practices** sufficiently developed in the **mid-altitude** impact zone.

NO ACTIVITY

Output 3. Enabling environment
Output Targets 2011: The relative **role of access to markets** and access to knowledge on **health and nutrition** in adoption of ISFM practices evaluated for all impact zones.

NO ACTIVITY

III.4. OUTPUT 4 - EFFECTIVE PARTNERSHIPS ALONG EACH STEP OF THE VALUE CHAIN FOR INNOVATIVE, EFFECTIVE AND EFFICIENT DISSEMINATION AND IMPACT.

Outputs (Intended users)	Outcome (Impact)
Description: Effective partnerships along each step of the value chain for innovative, effective and efficient dissemination and impact. Intended users: CGIAR, ARIs, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, private sector agents, extension services, policy makers.	Outcome: Partners are involved in addressing all components of the value chains related to the ISFM-based production systems. Impact: Improved ISFM-based production systems contribute to food and nutrition security and income and health of farmers in the target impact zones.

Output 4. Effective partnerships: Effective partnerships are needed to ensure that all segments of the value chain are actively engaged in linking farmer to markets and to ensure that all aspects of ISFM are addressed. Included in the former partnerships are farmer associations, active governmental or non-governmental extension systems, private sector entrepreneurs, policy makers, and research for development partners. The latter partnerships include research for development partners that have expertise in the various dimensions of ISFM development and dissemination, including technical, social, economic, and policy issues. Important to address will be to find ways to fully engage the required partners from project initiation and identify the necessary incentives for those partners to remain engaged, e.g., through innovation platforms. Specific attention will be given to appropriate communication channels and planning and evaluation activities. The major Outcome of this Output is related to active engagement of all required partners in developing, evaluating, and disseminating appropriate ISFM practices within the target impact zones.

Output 4. Enabling environment
Output Targets 2009: Strategic alliances formed for disseminating ISFM practices within **cereal-legume systems** in the Sahel and moist savanna impact zones.

COMPLETED WORK

Promoting a Versatile but yet Minor Crop: Soybean in the Farming Systems of Kenya, (2009) *Journal of Sustainable Development in Africa, 10 (4): 324–344*

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Abstract: Crop promotion is critical for market creation and rural growth in Africa. How to achieve this for crops, other than major staples (e.g., maize) and traditional export crops (e.g.,

tea), remains a problem since most African countries tend to focus policy attention to major staples and traditional export crops. Using a three-tier-approach, developed based on successful soybean promotion strategies in Nigeria and Zimbabwe, this study assesses the effect of market development at household-level, community level, and linking farmers' groups to industrial processors on sustainable soybean promotion in Kenya. Results show an increase in farmers' confidence to produce, process, and consume more soybeans than before. Trained farmers' groups are also developing new soybean products for cash income, a process that has proved to be very profitable. Net returns have been increased from four to 14 times for some products. Selected farmers' groups are supplying large-scale processors with soybean grains, substituting some imports.

Strategy for Soybean Production and Marketing in Kenya. *(2009) Crops Management Directorate, Ministry of Agriculture, Kenya*

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Background

Production of soybean in Kenya is growing. However, production is only estimated at 5000 metric tones annually against demand of more than 75,000 metric tones with the shortfall being imported. Soyabean is a rich source of protein and can significantly contribute to food and nutrition security. Being a nitrogen fixing legume, it has the potential to contribute significantly to soil fertility improvement through biological nitrogen fixation especially when inoculated with appropriate rhizobia. In spite of the importance of this crop, it has not received the research and development support it deserves. Most of the research and dissemination efforts have been supported by donor agencies, international research organizations and NGOs. This is commendable. However, it is necessary that a national strategy that guides and supports the research and development of the soybean sub-sector be developed. The proposed strategy could act as a fundraising as well as coordinating tool for realizing a sustainable soybean subsector in Kenya.

The Ministry of Agriculture with support from the Alliance for a Green Revolution in Africa (AGRA) developed a draft strategy to guide soybean sub-sector development in Kenya. Development of this strategy involved field visits, stakeholder consultations drew on lessons learnt from previous initiatives, success stories from elsewhere and expert opinion and input from CIAT-TSBF in developing the strategy. CIAT-TSBF representation in the strategy development was provided by Dr. Bernard Vanlauwe, Dr. Jonas Chianu, Dr. Peter Okoth and Mr. Victor Wasike.

A national stakeholder consultative workshop was held to discuss and enrich the draft strategy. The strategy proposes promotion of the soybean subsector through a coordinated multi-sectoral and multi-institutional focused area approach. The following objectives and actions are suggested as key to successful and sustainable soybean promotion in Kenya.

(i) Develop / strengthen the capacity to promote soybean production , processing, marketing and utilization
(ii) Develop and strengthen the capacity for appropriate technology interventions to enhance productivity, seed production and distribution
(iii)Improving and support soybean-processing at the household, community and industrial level.

(iv) Strengthen the institutional capacity and linkages to develop appropriate technology interventions to enhance soybean productivity
(v) Developing soya based food products which improve health and nutrition of vulnerable groups such as children, lactating mothers, and households living with HIV/AIDS
(vi) Reviewing policy, legal framework and enforcement and development of a framework and instruments for strengthening institutional capacity

The strategy proposes harnessing synergy of the stakeholders along the soybean sub-sector chain including Farmers, (small and large), Ministry of Agriculture, Ministries of Public Health and Sanitation, Youth Affairs, Ministry of Gender Culture and Sports, Cooperative Development and Marketing, Trade, Water and Irrigation, Kenya Agricultural Research Institute (KARI), Tropical Soil Fertility Institute of CIAT (CIAT-TSBF), Kenya Plant Health Inspectorate Service (KEPHIS), Kenya Industrial Research Development Institute (KIRDI), Universities, Community Based organizations (CBO), Non-Governmental Organizations (NGO), the Kenya Soybean Farmers Association (KESOFA), donor agencies, local and foreign investors and other relevant private sector players.

It is proposed that that executing agency will be the Ministry of Agriculture while the implementing institutions will be KARI and CIAT-TSBF and other research organizations. The draft strategy has been forwarded to the Ministry of Agriculture and awaits official launch by the Minister for Agriculture.

Developing the multipurpose soybean value chain to increase income of smallholder farm families and other rural entrepreneurs in East Africa, supported by the Rockefeller Foundation. *(2009) CIAT-TSBF, Final TL II Project Report (Phase II)*

J. Chianu[1]
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The TL II survey was carried out in Kenya and Tanzania, under objective 7. Using a detailed and structured questionnaire, the Tanzania arm of the TL II (Soybean) baseline survey was carried out in April-May, 2008. Six trained enumerators carried out the actual data collection in which 240 farmers were sampled. Some of the topics covered in the questionnaire for both countries are as follows: general information about the household, household composition, resources, institutional settings, and agricultural production (crop production, accessibility and productivity; soybean production including soybean seed systems and variety description; and livestock production and marketing). The Tanzania results show that most farmers started planting improved soybean varieties in the last 10 years (> 90%). The proportion of farmers growing both improved and local soybean varieties was 39%, with 14% of farm-size placed under soybean per household. Over 55% of the farmers received incentives to plant soybean. Lack of seed was the most important constraint for not planting soybean in Tanzania. There were 114 farmers studied in Kenya, with 44% male and 56% female composition. The most important food security crops that play key role in smoothing household consumption in western Kenya included maize (33%), beans (25%) and 10 other crops that included soybean. Most seeds for planting were sourced from seed companies, markets, saved seeds, other farmers, or researchers. Soybean was mostly sourced from saved seeds. Most farmers (58%) expressed that price stability of various agricultural products in western Kenya was low. Various livestock products showed higher price instability than crop products that were investigated.

Output 4. Enabling environment
Output Targets 2009: Best **approaches developed** for disseminating ISFM practices within **cereal-legume systems** in the Sahel and moist savanna impact zones.

COMPLETED WORK

Adoption potential of selected organic resources for improving soil fertility in the central highlands of Kenya. *(2009)Agroforestry Systems, 76 (2): 467-485*

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Abstract: Soil fertility decline is the major cause of declining crop yields in the central highlands of Kenya and elsewhere within the African continent. This paper reports a study conducted to assess adoption potential of two leguminous trees, two herbaceous legumes, cattle manure, and Tithonia diversifolia either solely applied or combined with inorganic fertilizer, for replenishing soil fertility in the central highlands of Kenya. The study examined biophysical performance, profitability, feasibility and acceptability, and farmers experiences in managing and testing the inputs. The study was based on a series of studies incorporating both sociological and experimental approaches for two and a half years. Results of on farm trials showed that manure+ fertilizer and tithonia + fertilizer treatments increased yields by more than 100% above the control. These treatments were the most profitable having highest net benefits and benefit cost ratios. They were also the most commonly preferred by farmers who used them on larger plots compared to the other inputs. In conclusion, cattle manure and tithonia were found to be the organic materials with the highest adoption potential for soil fertility improvement in this area. *Calliandra calothyrsus* and *Leucaena trichandra*, on the other hand, have potential for use as animal fodder. The herbaceous legumes had the least adoption potential due to poor performance recorded on the farms that possibly led to low preference by the farmers. However, issues of sustainable seed production could have played a role. This study recommends some policy issues for enhancing adoption and research issues focusing on exploring strategies for increasing biomass production and use efficiency on farms.

Institutional innovation: the potential of the warrantage system to underpin the green revolution in Africa. *(2009) Proceedings of the Workshop on Increasing the Productivity and Sustainability of Rain fed Cropping Systems of Poor, Smallholder Farmers, Tamale, Ghana, 22-25 September 2008*

Ramadjita[1], T., Bationo[2], A., Sawadogo [3], S.K., Hassane[1], O., Amadou[4], B., Siebou[3], P., Ouedraogo[3], S., Abdou[2], A., Fatondji[1], D., Sigue[3], H., Koala[2], S., Fosu[5], M., Maina[2], F.

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Abstract: The warrantage or inventory credit system was developed to address the liquidity constraints that farmers encounter while trying to intensify their production systems. The scheme removes barriers to the adoption of soil fertility restoration technologies by ensuring

that farmers have access to cash, technical advice, and inputs. Farmers use the credit to purchase external inputs, such as fertilizers and seeds, and to invest in dry season income generating activities, such as fattening of small ruminants, vegetable growing, trading, and groundnut oil extraction. In an earlier study funded by USAID, it was found that the incomes of farmers using the warrantage system, along with use of the fertilizer micro dosing technology increased by 52 to 134 %. In a project funded by the Challenge Program on Water and Food (CPWF), farmers are responding positively to the implementation of warrantage in two communities in the villages of Ziga and Saala in Burkina Faso. This scheme is getting increasing support from donors for its wider promotion in Sub-Saharan Africa. The constraints to the development and implementation of warrantage include lack of capital for Decentralized Financial Systems (DFS) to grant loans and for supervising bodies to provide guarantees, government interference through dumping imported commodities onto the market, lack of infrastructure at the village level, and lack of well organized farmer associations. An analysis of the constraints to the implementation of the scheme as well as the factors underlining the promotion and use of the warrantage system are also discussed.

WORK IN PROGRESS

Factors Determining Soybean Production in Rwanda

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Abstract: Soybean (*Glycine Max*) is a minor crop in the farming systems of Rwanda in terms of acreage and consumption. It constitutes however, one of the crops that the government of Rwanda is currently promoting because of its high nutritional value, adaptability to the country's agro-climatic zones, and potential to respond to organic and mineral fertilizer inputs. Resources are limited and need to be used efficiently. Using on-farm recorded data by collaborating farmers in Kamonyi district during two consecutive agricultural seasons (September 2007 to July 2008); this study identified key factors determining soybean production and assessed the efficiency of resource utilization in soybean production. The analysis of the data with Cobb-Douglas production models revealed that soybean plot size constitutes the most important factor of production with an elasticity of 0.4592 followed by intermediate inputs (fertilizers, pesticides and seeds) with a coefficient of 0.4447. When intermediate inputs are decomposed, fertilizers with an elasticity of 0.062 appear to contribute more to soybean production than pesticides (0.057) and seeds (0.034). Results show that variation in soybean output among farmers is mainly due to technical inefficiency, the inefficiency being responsible for at least 93% of total variation. The relative efficiency of resource use (allocative efficiency) being expressed by the ratio of marginal value product (MVP) to marginal factor cost (MFC), estimated ratios for soybean plot size (1.73), fertilizers (1.36) and pesticides (1.92) indicate that too little of these inputs are being used in relation to the prevailing market conditions.

Determinants of Mineral Fertilizer Use by Smallholder Farmers in Rwanda

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Abstract: The Rwandan government has two major parallel objectives with respect to fertilizer policy for agricultural intensification: First, increase the number of adopters, and second, increase the application rates of those adopting. This study aims at identifying factors

that influence household fertilizer use decisions. A total of 338 smallholder farmers were interviewed using a structured questionnaire in May and June 2008. Data collected were analyzed using descriptive statistics and the maximum-likelihood estimation of the Heckman two-step model. Analysis revealed that the set of factors influencing the household decision to adopt mineral fertilizers are not necessarily the same as the one of factors having impact on the intensity of use of mineral fertilizers. In fact only 6 out of the 12 factors that had impact on household decisions to use mineral fertilizers had also effect on the intensity of its use, the most important of these being: literacy of the head of household, potatoes plot area and access to extension services. Domestic assets, a proxy variable of household wealth had no effect on fertilizer adoption but had impact on the intensity of its use. Fertilizer adoption is also influenced by agro ecological zones, farmer association membership, distance to fertilizer market, landholding size, access to credit and age of household age.

Performance of Mineral Fertilizer Marketing in Rwanda

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Abstract: The agricultural intensification through increased use of mineral fertilizers under a private-sector oriented input distribution system constitutes one of the Government of Rwanda key objectives. This study focused on analyzing the effectiveness and efficiency of the functioning of the mineral fertilizer market. Descriptive analysis, marketing cost and margin analysis and analytical approaches build on structure-conduct-performance paradigm were used to analyze the data. The latter were collected through surveys of fertilizer traders from September to November 2008. Results showed that no inefficient expenditure was associated with mineral fertilizer distribution and thus, traders were allocatively efficient and earned reasonable margins in a government controlled market environment. On the other hand, other they revealed that, (i) even though new traders entered in the fertilizer business in the last five years a good number of others went out of the business; (ii) the fertilizer retailing system was highly concentrated in the Eastern and Northern province; (iii) the existence of horizontal and vertical integration were aimed at increasing the volume of sale rather than improving sale efficiency; (iv) barriers to entry into the sector at the wholesale level do exist; (v) shortage of mineral fertilizer at the retail level; (vi) the workable competition in the mineral fertilizer marketing did not exist. Thus, the mineral fertilizer marketing system was still unstable and inefficient.

Farmer & Researcher Collaboration for pro-poor development, through soybean production. How partnership with farmers made soybean production and its benefits accessible to resource-poor farmers in SW-Kenya.

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Introduction and justification

Agricultural research in the CGIAR is concerned with mobilizing science to benefit the poor (CGIAR, website). In collaborative research, farmers and researchers are considered partners from the initial stages of the process. While researchers are experts about experimental procedures and biophysical processes, farmers are experts in farming and have an understanding of the socio-economic and environmental conditions in which research needs to fit. Brought together, their complementary knowledge and expertise allows developing agricultural treatments which have high potential of being accessible and adoptable by resource-poor farmers: "Research for Development". The Tropical Soil Biology and Fertility Institute (CIAT-TSBF) introduced dual-purpose soybeans in the region of Migori (SW Kenya) in 2005 with the aim to: *"improve rural livelihoods [...] through enhanced access to cash income, improved human health conditions, and more sustainable agricultural production [...]"*. The purpose of my research (2006-2009) was to enhance the impact of this CIAT-TSBF project on the livelihoods of the resource-poor farmers in the region of Migori, by collaborating as partners with the farmers. The research is structured in three major sections. In the first, we look at how soybean agronomy could be adapted or contextualized to the resource-poor farmers' context in the region of Migori. In the second, we identify the constraints which block resource-poor farmers' to accessing the benefits of soybean (soil fertility, cash income, nutritious food) and attempt to curb these constraints. In the last section, we compare different strategies of collaboration with farmers and attempt to identify the impact they have on Research for Development.

Materials and methods

The analytical framework used in this research was based on two approaches: collaborative experimentation (CE) and farmer experimentation (FE). In the CE zones, we designed and managed experiments together with farmers. The approach proved efficient in identifying appropriate problems and treatments. As farmers could judge the feasibility of treatments, we could continuously direct and redirect the treatments to make them better fit their conditions and needs. The CE gave farmers a ground on which to test treatments perceived as "local" and "archaic" without fearing judgment from neighbours. We concluded that inclusion of farmers as equal partners in the research process allowed merging their knowledge and the researchers' knowledge into useful, appropriate and adoptable research. The farmer experimentation approach (FE) was initially designed because the research region was too large to organize experiments in all zones. The FE included a larger diversity of treatments and could be a source of inspiration for new experiments. Nevertheless, the experiments could not be analyzed statistically due to a lack of replicates and problems with the designs. When we compared farmers' soybean fields before (2006) and after (2008) the CE or FE intervention, we found that a larger variety of treatments were used by farmers in 2008 than in 2006 and that farmers had continued experimenting in their own fields. Several CE treatments had been adopted by farmers in not only the CE zones but also the FE zones who had not been in contact with the CE experiments. We concluded that the FE approach had created a channel for information transfer and thereby a channel for scaling-out the research results. Finally, we looked at the impact pathway that resulted from intentional and unintentional project actions from 2006 to 2008. We concluded that the project went through three major phases: 1) an initial phase of high but often non realistic hopes, during which farmers' interest in the project was at the highest; 2) the breakdown of preconceived hopes, period in which many farmers felt deceived and abandoned; 3) the revival of the project based on new, more realistic hopes. We identified that the negative effects of the 2^{nd} phase had been strengthened by communication incoherence and hierarchy between CIAT-TSBF, the cooperative, and the farmers. Deciphering the impact pathway allowed learning about past mistakes and successes to further re-direct the ongoing pathway of the project. It highlighted the importance of truthful communication within project members at different levels. As the soybean project is still ongoing, we cannot yet conclude about its final impact.

Preliminary conclusions

The learning experience during this project brings me to identify and advocate two major aspects of Pro-Poor Research for Development. 1) I advocate the use of local small scale technologies, not only for agronomic production but also for marketing and processing. Local small scale options may not be durable at the long run, but they allow resource-poor farmers to take immediate benefit from the project and to later adjust themselves to alternative and more demanding technologies.

Innovative agricultural market creation in Africa: Three-tier model for soybean development and promotion in Kenya

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Introduction and justification

Agricultural market creation is critical for rural growth in Africa. How to achieve this based on crops other than major staples (e.g., maize) and traditional export crops (e.g., tea, coffee, cotton) remains a problem since most African countries do not give them policy attention. This study uses a three-tier-model, developed based on successful strategies in Nigeria and Zimbabwe, to develop multi-level soybean market creation in Kenya.

Materials and methods

Data were from secondary sources, formal and informal interviews, farm-level data, and participant observations. Analysis was carried out using Microsoft Excel and SPSS.

Preliminary results

Result shows increase in farmers' confidence to produce, process, consume, and sell more soybeans than previously. Trained farmers' groups are developing new soybean products for cash, poverty reduction and improvements in livelihoods. Net returns have been increased from four to 14 times from processed products. Selected farmers' groups have begun to supply large-scale processors with soybean grains, substituting imports. The overall project's impact on number of participating farmer groups and the actual land area devoted to soybean cultivation ranges from a factor of 2.3 to a factor of 77.4 between the long rainy season of 2005/2006 and the short rainy season of 2009. Farmers have given testimonies on live improvements.

Preliminary conclusions

This study has demonstrated that through appropriate models, it is possible to usher in agricultural market and creation for the much desired rural growth in Africa based on the so-called non-traditional export crops and the policy-choice crops such as maize.

A survey of livestock production in South Kivu, DR Congo

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Introduction and justification

For a survey on livestock production with emphasis on monogastric animals, 20 villages in seven so-called '*groupements*' of South Kivu province in DR Congo were selected mostly along a North-South West axis, with the town of Bukavu in the center. This is one of the ten mandate areas chosen in 2005 by the Consortium for Improving Agriculture-based Livelihoods in Central Africa (CIALCA) to represent diverse agricultural production conditions, demography and access to markets. Most of the hilly agricultural land between the National Park of Kahuzi-Biega in the West and Lake Kivu in South Kivu province of DR Congo is located at above 1500 m asl.

Material and methods

The survey took place in elevations extending from about 900 m asl. in Kamanyola to 1900 m asl. in Burhale. A diagnostic survey approach was employed to rapidly obtain in-depth knowledge of constraints and opportunities in a defined social, economic, and natural environment. The survey took place during June 2009.

Preliminary conclusions

From the responses of 112 informants, it was concluded that livestock is an integral part of the mixed farming systems in the region of South Kivu, despite their presently low numbers per household. Farmers largely concentrate on small livestock, such as poultry, pigs, guinea swine and rabbits. Overall, the livestock mostly served for accumulating household reserves that were strongly invested in school education of the children. From the farmers' views, the most important issues of animal husbandry appeared to be related to animal diseases and feed resources, particularly in the dry season. Major challenges faced by introducing new and more productive forages into the region will be towards the agro-ecological adaptation of such plants with regard to mid-elevations of above 1500 m asl., prolonged growth into the dry season, high biomass-producing species in order to not use too much space of small farm land, and reducing labor demand for collecting forages. Four locations are proposed for forage research in South Kivu province in close collaboration with the CIALCA consortium, Kamanyola, Burhale, and the area of Mumosho/Nyangezi. It was suggested that other lowland areas towards Kasika can only be targeted if security has improved.

New activities

Towards the end of 2009, small plots with forage legumes and grass have been established in Kamanyola, Mulungu, Nyangezi and Tubimbi in order to evaluate ecological adaptation and agronomic performance. Additionally, focus group meetings will be held at these sites to mobilize collective action. These activities take place within the BMZ-funded project on "More Chicken and Pork in the Pot, and Money in the Pocket: Improving Forages for Monogastric Animals with Low-income Farmers".

Output 4. Enabling environment
Output Target 2010: Strategic alliances formed for disseminating ISFM practices within **cassava- and rice-based systems** in the humid lowland impact zone.

NO ACTIVITY

Output 4. Enabling environment
Output Target 2010: Best **approaches developed** for disseminating ISFM practices within **cassava- and rice-based systems** in the humid lowland impact zone.

NO ACTIVITY

Output 4. Enabling environment
Output Target 2011: **Strategic alliances** formed for disseminating ISFM practices within **banana-based systems** in the mid-altitude impact zone.

NO ACTIVITY

Output 4. Enabling environment
Output Target 2011: Best **approaches developed** for disseminating ISFM practices within **banana-based systems** in the mid-altitude impact zone.

NO ACTIVITY

III.5. OUTPUT 5 - STAKEHOLDER CAPACITY TO ADVANCE THE DEVELOPMENT AND ADAPTATION OF ABOVE OUTCOMES.

Outputs (Intended users)	Outcome (Impact)
Description: Stakeholder capacity to advance the development and adaptation of above outcomes. Intended users: CGIAR, ARI, researchers from NARS and local universities, NGOs, farmers, regional consortia, young professionals, private sector agents, policy makers.	Outcome: Stakeholders are leading the development and dissemination of ISFM practices in the context of initiatives lead by them. Impact: Large-scale impact of ISFM practices in the target impact zones.

Output 5. Stakeholder capacity: All partners that are required to reach the Outcome line goal need to have the required capacity to implement current initiatives aiming at developing and disseminating ISFM and to continue such activities beyond the timeframe of specific projects. Institutionalization of the approaches required for backstopping ISFM development and dissemination is going to be crucial to sustain such activities. Capacity building will include degree-related training, preferably with active linkages with Advanced Research Institutes, and covering all Outputs of the ISFM Outcome line, on-the-job training of staff involved in ISFM activities, group training on specific topics, and networking between the various partners. All training efforts will be based on formal capacity needs assessments and tightly linked to the above Outputs and focused on the target cropping systems and impact zones. Degree-related training that is often focused on specific research topics will also include the various dimensions of ISFM towards the development of 'T-shaped' capacity that includes detailed expertise on a few topics and a general knowledge on all aspects of ISFM. The major Outcome of this Output is related to the various stakeholders leading the development and dissemination of ISFM practices.

Output 5: Stakeholder capacity
Output Target 2009: Capacity of **agro-input dealers** to support farming communities for implementing ISFM strengthened in all impact zones.

WORK IN PROGRESS

Strengthening the capacity of agro-input dealers in Integrated Soil Fertility management Technologies in Eastern Tanzania: Results, challenges and opportunities

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Introduction and justification

Integrated Soil Fertility Management (ISFM) has been widely seen as a sustainable way of increasing agricultural productivity in sub-Saharan Africa (SSA). Due to the weakness in the functioning of formal extension services in most African countries, the study evaluates the results, challenges and opportunities in engaging agro-input dealers to complement formal extension systems in the extension of ISFM technologies.

Materials and methods

The study was carried out in *Kilosa* and *Mvomero* districts of Eastern Tanzania. Forty CNFA certified agro-input dealers (18 females, 22 males) were involved and trained on different components of ISFM (e.g., planting of improved maize varieties, use of mineral fertilizers, use of organic fertilizers, application of herbicides, control of crop storage pests, etc).

Preliminary results

Most of the agro-input-dealers had very limited knowledge on soils, mineral fertilizers, and correct methods of mineral fertilizer application. Results from end of course evaluation revealed that most (90%) agro-input dealers appreciated the knowledge gained and would extend the same to farmers, even through the use of demonstration plots. The agro-input dealers appreciated their interaction with research scientists and would wish scientists to visit and advise them more frequently. An initial challenge was to arouse and hold the interest of the agro-input dealers, given that they were not used to being involved in agricultural extension services. However, this was short-lived when agro-input dealers realized that getting involved in training on ISFM was a potential way of sustainably growing their business for increased turnover and better business returns. This even created a great opportunity to take advantage of the increasing network of agro-input dealers in Tanzania to expand the work and bring about the much desired increased agricultural productivity in the country and probably elsewhere in SSA.

Preliminary conclusions

The study concludes noting that capacity-building of agro-input dealers on ISFM has great potential in scaling out ISFM technologies to reach millions of small-scale farmers in SSA.

Training agro-input dealers on the use of soil test kits: Case of *Kilosa* and *Mvomero* districts in Eastern Tanzania

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Introduction and justification

Soil analytical data from laboratories is often the basis for recommending the quantity and type of fertilizers and soil amendments to apply for improved crop productivity. However, this is costly and takes time before data become available. Soil test kits are cheap and easy to handle and does not require very highly qualified personnel. Selected agro-input dealers were trained to use soil kits for quick testing of soils. This study examines the outcome.

Materials and methods

The study was carried out in *Kilosa* and *Mvomero* districts in Eastern Tanzania. The agro-input dealers were trained on how to interpret the nutrient indicator colours obtained following the use of the soil test kits in assessing the nutrient status of the target soils. Forty CNFA certified agro-input dealers (18 females, 22 males) were trained.

Preliminary results

At the end of the training, the agro-input dealers could accurately determine: (i) soil pH, (ii) soil nitrogen, (iii) soil phosphate, (iv) soil potash, and (v) soil organic matter. Based on their new ability to interpret the colours from the soil test kit, they are now able to at least inform their customers (farmers) about the nutrient status of their fields (e.g., in terms of whether the P-level is adequate, medium or completely inadequate).

Preliminary conclusions

The idea and approach of training agro-input dealers on the use of soil test kits has been shown to have prospects of increasing the use of mineral fertilizers by smallholder farmers and also the use efficiency of such important and often scarce and costly farm inputs. The challenge is to ensure steady availability of the chemicals and the provision of such services at costs affordable by the target small-scale farmers.

Agro-input dealers taking a lead in demonstrating Integrated Soil Fertility Management Technologies in Eastern Tanzania: Challenges, opportunities and prospects

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[1]Agricultural Research Institute Ilonga, Tanzania; [2]CIAT-TSBF, Kenya; [3]CNFA/TAGMARK, Tanzania

Introduction and justification

Demonstration is often used to show or explain how something works or is done. Following the completion of training on fertilizer use and management as components of Integrated Soil Fertility Management (ISFM), 40 CNFA certified agro-input dealers (18 females, 22 males) were required to show their understanding of what they had learnt by leading the establishment of one ISFM technology demonstration plot. The aims were to make agro-input dealers practice what they learnt, expose them to the effects of various inputs (fertilizers and seed) and their interactions as affected by differences in soils and soil fertility status.

Materials and methods

The study was carried out in Kilosa and Mvomero districts of Eastern Tanzania. Maize (*Zea mays*) was the test crop. Agro-input dealer participatory approach was used in deciding the treatments: the control, 40 and 80 kg N ha^{-1} applied with 0 or 40 kg P ha^{-1}, and 80 kg N ha^{-1} as NPK (20:10:10). Nitrogen and P sources were urea and *Minjingu* phosphate rock (MPR). Soils sampled from all demonstration sites were analyzed using standard analytical procedures.

Preliminary results

Results showed that most sites were deficient in both N and P, with soil pH ranging from 5.6 to 8.2. Maize (var. TMV-1) responded to both fertilizers, with most sites giving higher yields (2.2–2.7 t ha-1) with MPR+urea and NPK treatments. Maize responses to the different fertilizer materials and rates are summarized in **(Figure 46).** Despite that maize showed a good response to MPR, agro-input dealers noted that MPR was not known to most farmers.

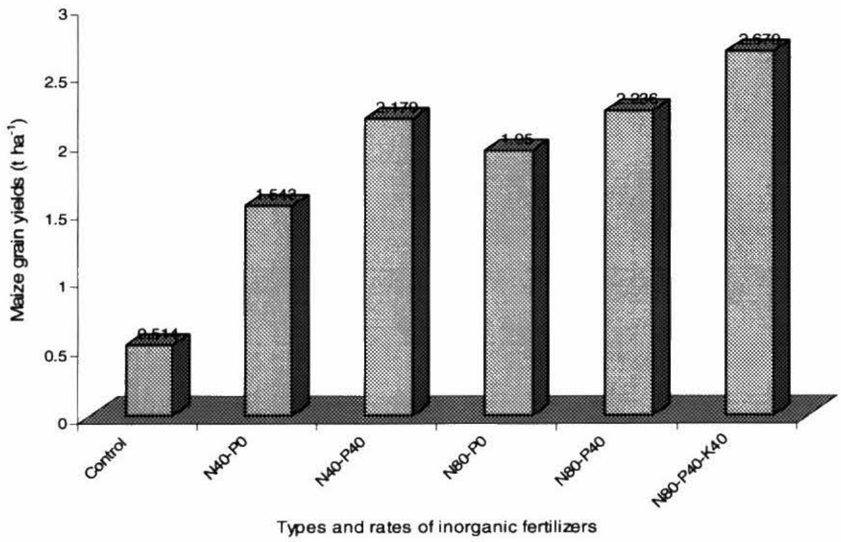

Figure 46: Influence of inorganic fertilizers on maize yields on fields of some agro-input dealers of Kilosa and Mvomera districts, Tanzania.

Preliminary conclusions

The successful agro-input dealer led demonstration of ISFM technologies was a clear indication of the prospect in involving trained agro-input dealers in related agricultural services extension to reach millions of farmers in Africa and create an overall increase in agricultural productivity and production. One clear and advantageous feature of agro-input dealers' involvement in field demonstrations was that they easily and frequently interact with small-scale farmers. Besides, in explaining the outcome of various demonstrations, agro-input dealers are able to apply local examples that are easily followed and understood by farmers.

Output 5. Stakeholder capacity
Output Targets 2009: Farmer-to-farmer knowledge sharing and extension on ISFM through various facilitated activities in all impact zones.

COMPLETED WORK

Strengthening Agro-dealer capacity in integrated soil fertility management in Kenya and Tanzania

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[1]*CIAT-TSBF, Kenya*

Agro dealers were interviewed in Kenya and Tanzania in the TSBF- CNFA project, on various aspects of agro-dealer retail businesses in 2008. Training in various aspects of ISFM knowledge was among the major aspects that were investigated in both the farmers and scientists.

Strengthening agro-dealers ISFM capacity in Kenya

The most important questions that were asked included ISFM capacity, type of training attended and training perceptions, and the training capacity of agro-dealers to train other farmers. Only 39% of the dealers were aware of ISFM as a specific concept, but further investigation of their knowledge showed that more had basic knowledge of core ISFM knowledge. 68% of the dealers were aware of fertilizer recommendations. It took dealers averagely 4-5 months to gain knowledge on various aspects of ISFM knowledge. However, in took them longer to train on how to generate knowledge (mean 4 months), than to share and apply skills (less than 1 month). This indicates that agro dealers are likely to be more conversant and effective with practical-oriented, rather than theoretical aspects of training. Males took longer period to train in ISFM, than female agro dealers. Most agro dealers (> 90%) advised farmers on fertilizer application methods, and this was their most conversant subject, compared to agro-chemical knowledge. The main trainers who trained agro-dealers were government institutions, international organizations, and agro-industries, mainly through demonstrations.

Strengthening agro-dealers ISFM capacity in Tanzania

In Tanzania, only 25% of the dealers were aware of ISFM as a specific concept, which was lower than in Kenyan dealers. Dealers took 2.5 months to develop ISFM capacity on various aspects in which males took longer (3 months) than females (2.5 months). In Tanzania it took dealers, the same period of time (2.7-2.9 months) to develop different aspects of ISFM knowledge including knowledge generation, and application of skills.

Farmer learning alliance and reflection meetings through farmer field schools change title

Birachi[1], E., Owamani[2], A., Nzamba[3], R., Mulindwa[4], J.
[1]*CIAT-TSBF, Rwanda,*[2]*CIAT, Rwanda,*[3]*A2N, Uganda,*[4]*UEEF, Uganda*

A farmer field day was conducted for two days 15th-16th February in Hoima, western Uganda. Besides the farmer associations, other partners present during the field days were BOKU representatives, staff from International Centre for Tropical Agriculture (CIAT), Uganda Environmental Education Foundation (UEEF), Africa 2000 Network, NAADS, Community Development representatives, sub-county officials, staff from Hoima District Farmers Association (HODIFA).

Objectives of the Field day

- Update participants with Association Progress and challenges since inception

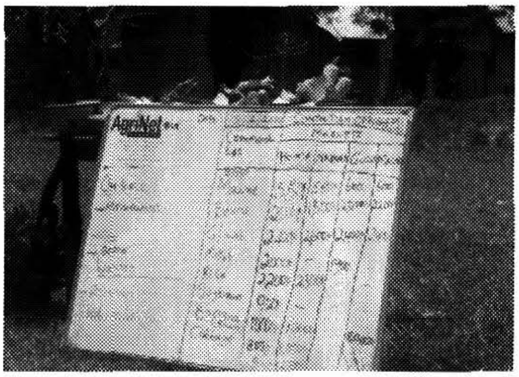
- Enable farmers share new technologies and innovations Allow experience sharing by different committees.
- To create room for interaction between groups, associations and external stakeholders.
- To display and sale different products or commodities produced by farmer communities.

Association Progress and challenges

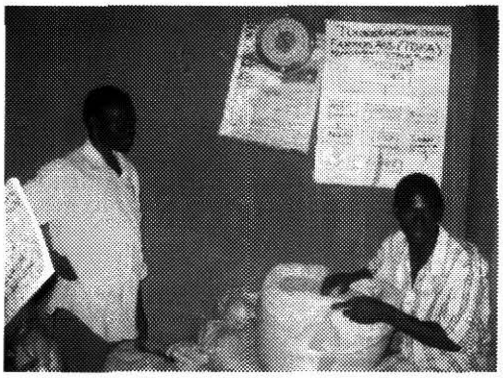
- Associations have been registered both at the sub-county and district level and have a bank account with Post Bank Uganda.
- They have work plans as well as business plans which have been submitted to A2N, HOFOKAM, Stalk Consult LTD in Kampala to lobby for funds.
- Have managed to sell more than 15 tons of products and have access to information
- New varieties were introduced to replace the traditional varieties, they have seed multiplication gardens.
- Members have savings and credit schemes from which members are already accessing credit to boost their various activities.
- Exchange visits have been carried out.

Challenges

1. The need to diversify enterprises will improve due to the emphasis placed on group savings and linkage to financial institutions. A point in reference is the introduction of fruit enterprise- mangoes.
2. There are Low production volumes of identified enterprises. However this is likely to improve due to the acquisition of a walking tractor that will help to expand farming areas.
3. There is also a need to find alternative markets for the identified enterprises particularly ginger. This has been hampered by the fact the marketing committees can only access markets in Hoima due to lack of financial resources.
4. Weather uncertainty that led to destruction of bean gardens leading to low harvests



Photograph 9: A farmer information board.



Photograph 10: Farmers weighing soya at the collection centres.

Photograph 11: Farmers trying out how to use the walking tractor acquired by loan.

Photograph 12: Farmers from Mukono sharing their experiences with farmers in Hoima.

Preliminary conclusions

Farmers Field Day (**Photograph 9, 10, 11, 12**) proved to be an important day for farmers, development partners and other stakeholders as it helped all parties to share experiences, skills, draw solutions as well as building their confidence in organic farming. This was because the day provided a platform for each party to analyze, assess, share and come up with viable solutions good enough to steer the programme to greater heights for their own benefit.

Adaptive research on ISFM technologies in Central Africa

Pypers[1], P., Sanginga[2], J.M., Bishikwabo[2], K., Walangululu[3], J.M., Ngoga[4] T., Gahigi[4], A., Ndayisaba[4], C., Lodi-Lama[2], J.P., Bimponda[5], W., Lunzihirwa[2], J., Nitumfuidi[5], J.J. and Vanlauwe[1], B.

[1]CIAT-TSBF, Kenya, [2]CIAT-TSBF, DR Congo, [3]UCB, DR Congo, [4]ISAR, Rwanda, [5]INERA, DR Congo

Farmer-to-farmer knowledge sharing is stimulated through farmer experimentation and adaptive research. Farmers receive inputs and training to implement small trials for evaluation of ISFM technologies. They record observations and findings in a field book, and discuss with visitors and fellow farmers in the area. This approach was implemented in various regions on different systems and ISFM themes:

- Eastern Province of Rwanda: organic-mineral interactions, legume rotation and intercropping;
- Sud-Kivu (DRC): cassava-legume intercrop arrangement and fertilizer use;
- Bas-Congo (DRC): intercropping with alternative legumes in cassava-based systems, organic-mineral interactions and use of *Mucuna pruriens* for weed control and soil fertility management.

Output 5. Stakeholder capacity
Output Targets 2009: Knowledge on principles and processes underlying ISFM practices embedded in soil fertility management **networks and regional consortia.**

COMPLETED WORK

Group training to empower farmer facilitators in East and Central Africa

Birachi[1], E, [2]Owuor G
[1]CIAT-TSBF, Rwanda; [2] Egerton University, Kenya

Two activities took place in the year as follows:

Table 14: Training activities

1	CIALCA/SSACP joint markets and agro enterprise training for trainers (24)	Ruhengeri, Rwanda	17-21 August 2009
2	INSPIRE/F2M/SSACP training on credit management for groups	Seeta, Mukono, Uganda	1-5 September 2009

Degree related capacity building

Various PhD and Msc projects were completed in 2009 – see Annex IV

WORK IN PROGRESS

Degree related capacity building

Various PhD and Msc projects are ongoing – see Annex IV

Output 5: Stakeholder capacity
Output Targets 2010: Curricula and technical manuals for developing, adapting, evaluating, and disseminating ISFM practices, applicable to all impact zones.

Work in progress

A manual for conducting field trials on Integrated Soil Fertility Management

P. Pypers[1] and B. Vanlauwe[1]
[1]CIAT-TSBF, Kenya

- A technical manual for experimentation on ISFM principles and technologies is being developed, based on experience gained in the activities in Central Africa (DRC, Rwanda and Burundi).

Output 5. Stakeholder capacity
Output Targets 2010: Extension materials for ISFM developed that are specific to the various aspect of drivers of ISFM and for the different impact zones.

Completed work

Identifying adapted and preferred legume germplasm

P. Pypers[1], A.Chifizi[2], S. Mapatano[2], J.M. Sanginga[3], K. Bishikwabo[3], T. Ngonga[4], A. Gahigi[4], S. Kantengwa[5], J.P. Lodi-Lama[3], W. Bimponda[6], J.J. Nitumbuidi[6] and B. Vanlauwe[1]
[1]CIAT-TSBF, Kenya; [2]DIOBASS, DR Congo; [3] CIAT-TSBF, DR Congo; [4]ISAR, Rwanda, [5]CIAT, Rwanda; [6]INERA, DR Congo

- Legume variety cards with technical information on improved germplasm of bush and climbing bean, and soybean, as well as practical guidelines for management and farmer-preferred traits have been produced in English, French and local languages, distributed to key development partners and farmers, and made available on the CIALCA website.
- A list of CIALCA products, including adapted and improved germplasm, and various technologies for improved legume and banana productivity and management has been created and distributed to key development partners for promotion and dissemination.
- A website is created and maintained to disseminate findings, reports, products and updates with the CIALCA project (www.cialca.org).

Work in progress

A knowledge resource centre in Central Africa

P.Pypers[1]
[1]CIAT-TSBF, Kenya

A knowledge resource centre (KRC) is being established in Bujumbura, Burundi, with as major task to develop various extension materials on CIALCA products, tailored to a wide range of end-users.

Output 5. Stakeholder capacity
Output Targets 2010: Group and degree-related training activities related to specific issues of ISFM development, evaluation, and dissemination for all impact zones.

COMPLETED WORK

Short –term group training activities

Pypers[1], P.
CIAT-TSBF, Kenya

- Training on ISFM principles for agronomists from national systems and various NGO's in Burundi, Rwanda and DR Congo (Butare, 4-5 May 2009).
- Seminars on ISFM themes for graduate and postgraduate students at national universities, e.g., "P availability and efficient use by crops" (Moi University, Eldoret, 3 Dec 2009), "ISFM and efficient use of fertilizer" (ISDR, Bukavu, 16 Dec 2009).
- Training sessions on statistical procedures and data analysis from agronomic trials for students from UNIKIN, UEA and UCB in DR Congo.

Degree related capacity building

Various PhD and Msc projects were completed in 2009 – see Annex IV

WORK IN PROGRESS

Degree related capacity building

Various PhD and Msc projects are ongoing – see Annex IV

Output 5. Stakeholder capacity
Output Targets 2011: Institutionalization of knowledge and approaches for developing, adapting, and evaluating ISFM practices within the **national research systems.**

NO ACTIVITY

Output 5. Stakeholder capacity
Output Targets 2011: Institutionalization of knowledge and approaches for evaluating, and disseminating ISFM practices within the governmental and non-governmental **extension systems.**

NO ACTIVITY

Output 5. Stakeholder capacity
Output Targets 2011: Local and national policy is informed about priorities for policy formulation that is required to facilitate the wide-spread adoption of ISFM practices.

COMPLETED WORK

Promotion of CIALCA technologies during exchange visits and field days

P. Pypers[1], A.Chifizi[2], S. Mapatano[2], J.M. Sanginga[3], K. Bishikwabo[3], T. Ngonga[4], A. Gahigi[4], S. Kantengwa[5], J.P. Lodi-Lama[3], W. Bimponda[6], J.J. Nitumbuidi[6] and B. Vanlauwe[1]
[1]CIAT-TSBF, Kenya; [2]DIOBASS, DR Congo; [3] CIAT-TSBF, DR Congo; [4]ISAR, Rwanda, [5]CIAT, Rwanda; [6]INERA, DR Congo

Farmer field days organized in Rwanda and DR Congo, with presence of national or provincial policy makers and national or regional press agencies.

IV. LIST OF STUDENTS

Country	Names	Degree	Institution	Status	Title
Austria	Sarah Prehlser	Masters	BOKU	In Progress	Farmer Participatory Research and the development of an 'experimental culture' among farmer groups.
Austria	Florian Herzog	Masters	BOKU	In Progress	Participatory Market Research and entrepreneurial culture among farmer groups.
Belgium	Abigael Otingal	PhD	KU Leuven	In progress	P fertility management in legume-cereal systems in the Rift Valley Province in Kenya.
Belgium	Josaphat Mugabo	PhD	KU Leuven	In progress	Agricultural intensification under high population pressure in Rwanda: an analysis of fertilizer policy and legume-based system incentives.
Belgium	Elke Vandamme	PhD	KU Leuven	In progress	Early root traits and phosphorus efficiency in soybean.
Belgium	Kasereka Bishikwabo	PhD	KU Leuven	In progress	Market access, collective action and the potential to use mineral fertilizer in South Kivu, DRC.
Belgium	Isabel Lambrechts	PhD	KU Leuven	In progress	Gender, soil fertility and food security in Central Africa.
Belgium	Laetitia Six	PhD	KU Leuven	In progress	Measurement of P availability in highly weathered soils using diffusive gradient thin (DGT) membrane technique.
Belgium	Ruth Njoroge	Masters	KU Leuven	In progress	Measurement of P availability in highly weathered soils using diffusive gradient thin (DGT) membrane technique.
Belgium	Bie Gielen	Masters	KU Leuven	Completed	Rainfall simulations in various tillage and mulching systems in Central Kenya.
DR Congo	Julie Lunzihirwa	Masters	UNIKIN	In Progress	L'impact des filières légumineuses sur le bien être des ménages du district des cataractes, Bas- Congo.
DR Congo	Lele Bonaventure	PhD	UNIKIN	In Progress	Improved productivity in cassava-based systems using ISFM interventions in Bas-Congo, DRC.
DR Congo	Raoul Mulumba	Masters	UNIKIN	In Progress	Economic analysis of ISFM interventions for increased productivity in cassava-based systems.
DR Congo	Muke Manzekele	Masters			Etudes du contrôle de l'érosion et d'amélioration de la production agricole sur les versants au Sud-Kivu.

DR Congo	Rachel Zozo	Masters	UNIKIN	Completed	
Kenya	Janvier Bashagaluke	Masters	Kenyatta University	In Progress	Soil characterization and fertilizer response in the highlands of Sud-Kivu, DRC.
Kenya	Kavoo Agnes Mumo	PhD	JKUAT	In progress	Efficacy of commercial biological and chemical products on root health and nutrient uptake of tissue culture banana under different soil conditions in Kenya.
Kenya	Celestin Ndayisaba	Masters	Kenyatta University	In Progress	Fertilzier and grain legumes as entry points for increased crop production in Eastern Rwanda.
Kenya	Ruth Lukwago	Masters	Moi University	In progress	Interaction of Microbiological and Chemical Commercial Products and their Effects on Growth and Health of Tissue Culture Banana.
Kenya	Rurangwa Edouard	Masters	JKUAT	In Progress	The influence of arbuscular mycorrhizae on nursery and initial field performance of banana.
Kenya	Juma Robinson Jalang'o	Masters	JKUAT		Response of giant cavendish established in two soil substrates to inoculation with commercial and indigenous arbuscular mycorrhizal fungi.
Kenya	John Nyanga	Masters	JKUAT		Effect of AMF Inoculation and management of Indigenous AMF population on the ex-situ performance of maize and beans in Embu and Taita, Kenya.
Kenya	Simon Nguru Wandeto	Masters	University of Nairobi		Developing strategies of restoration of disturbed sites in Kakamega forest using arbuscular mycorrhiza fungi (AMF).
Kenya	Thomas G. Ondara	Masters	JKUAT		Characterization of the mycorrhizal status of improved cassava (*Manihot Esculenta* Crantz) cultivars in different fertilizer regimes in western Kenya.
Kenya	Wivine Munyahali	MSc	KU, Kenya	In progress	Assessment of commercial chemical products on the improvement of maize yield in different agro-ecological zones in Kenya.
Kenya	Samuel Mathu	Masters	JKUAT	In progress	Evaluation of rhizobial and mycorrhizal inoculants for improving growth and nutrition in chickpea, groundnut, cowpea and pigeon pea.
Kenya	Mary Koech	PhD	Moi University	In progress	N and P dynamics in Desmodium-maize intercropping systems.
Kenya	Mary Atieno	Masters	Moi University	In progress	

Kenya	Victor Wasike	PhD	Egerton University	In Progress	Genetic diversity of dual-purpose soybean indigenous bradyrhizobia strains and their potential to fix nitrogen in Kenya.
Kenya	Keziah Ndungu	PhD	Moi University	In progress	Biosolubilization of poorly soluble phosphate rocks using phosphorus solubilizing microorganisms in Kenya.
Kenya	Moses Thuita	PhD	Moi University	In progress	Evaluation of new biological commercial products containing rhizobia for improving and sustaining legume yields in selected agro-ecological zones in sub-Saharan Africa: investigations on the mechanisms involved.
Kenya	Alice Murage	PhD	Egerton University	In progress	Economics of dissemination pathways for scaling up push-pull technology in Kenya.
Kenya	Kennedy Johnstone Onyango	Masters	University of Nairobi	In progress	Assessment of factors affecting organic resources management practices used in soil fertility management: Case of Meru South district, Kenya.
Kenya	Charles Ongwang	Masters	Maseno University	In progress	An economic analysis of cotton, maize, soybean and sugarcane enterprises as agribusiness investments in Matungu division, Western Kenya.
Kenya	Seline Obonyo	Masters	Maseno University	In progress	A Comparative analysis of maize, soybean, sugarcane and tobacco enterprises in the farming systems of Uriri division, Rongo district, Kenya.
Kenya	Monicah Mucheru-Muna	PhD	Kenyatta University	Completed	Integrated Soil Fertility Management for increased productivity in the highlands of Central Kenya.
Netherlands	Mary Nyawira Muriithi	PhD	Wageningen University	In Progress	The Impact of Arbuscular Mycorrhizal Fungi on agricultural management practices in Kenya- soil structure, nutrient use efficiency of crops, and interactions with macrofauna.
Netherlands	Benjamin Kibor	PhD	Wageningen University	In Progress	Exploring diversity and adoption of agroforestry technologies in mixed crop-livestock smallholder farming in Kenya.
Netherlands	Samuel Guto	PhD	Wageningen University	In Progress	Soil conservation using minimum tillage, crop residue retention and vegetative barriers in the highlands of Central Kenya
Netherlands	Silvia Perez Perdomo	PhD	Wageningen University	In progress	Value Chain Innovation: Innovation Network Internal Dynamics and the Role of Innovation Intermediaries.

Netherlands	Leon Nabahungu	PhD	Wageningen University	In progress	Options of Improved Management of Wetlands in Rwanda.
Senegal	Aliou Faye	PhD	University of Dakar	In progress	Use of Commercial Biofertilizeurs Based on Arbuscular Mycorrhizal Fungus in Agriculture and Performance on P uptake.
South Africa	Edidah Lubega	PhD	University of Pretoria	In progress	Effectiveness of Second-Tier Producer Associations and Cooperatives in Linking Smallholder Farmers to Markets in Uganda.
Tanzania	Justine Mushi	Masters	Sokoine University of Agriculture,	In progress	Assessment of mechanical dehulling effectiveness for different locally grown Soybean.
Tanzania	David Nyongesa	PhD	Dar es Salaam University	In progress	Empowering Farmer Groups in Developing and Strengthening Soybean Agro-enterprises for Improved Livelihoods in Kenya: A Resource-to-Consumption Approach.
Uganda	Ntamwira Bagula	PhD	Makerere University	In progress	Improved production in banana-legume intercropping systems.
Uganda	Amos Owamani	Master	Makerere University	In progress	Soil Nutrient Balance under Different Organic Management Scenarios.
Uganda	Bonny Ongom	Master	Makerere University	In progress	Local Soil Classification Based Organic Agro-Enterprises Potential in Hoima District.
Uganda	Joseph Mulindwa	Masters	Makerere University	Completed	Evaluation of Soil and Soil Improvement Methods for Ginger Production.
Uganda	Winnie Alum	Masters	Makerere University	Completed	Analysis of Gender and Livelihood Implications of Linking Smallholder Farmers to Organic Markets.
Uganda	Flavia Asiimwe,	Masters	Makerere University	In progress	Participation of Farmers in Collective Marketing of Groundnuts in Eastern Uganda.
USA	Joseph Fulgence Mishili	PhD	Purdue University,	Completed	Grain Legumes Trade and Markets: Spatial and Temporal Analysis for Common Beans Trade in Tanzania and Its Neighbors.

V. LIST OF PARTNERS

Collaborators:

NARS: Kenyatta University, Kenya, VLIR project on food security in Central Kenya; RF soybean project; JKUAT, Kenya, RF banana project; NARO, Uganda and LZARDI, Tanzania, DfID project on striga management in the Lake Victoria Basin; NARO, Uganda, RF project on exploring soybean potential in East Africa; KARI, Kenya, DfID project on striga management in the Lake Victoria Basin; University of Zimbabwe, Zimbabwe, NSF project on soil aggregation; Soil Research Institute, Ghana, NSF project on soil aggregation; INERA, D R Congo, ISAR, Rwanda, DGDC project on legume integration in systems in Central Africa; DGDC project on banana management in Central Africa; ISABU and IRAZ, Burundi, DGDC project on banana management in Central Africa; University of Kinshasa and University of Bukavu, D R Congo, VLIR project on cassava in D R Congo; Forest Dept of CIRAD, France, Kenyan Forestry Research Institute, Kenya, FOFIFA, Madagascar INCO DEV FOREAIM on Bridging restoration and multi-functionality in degraded forest landscape of Eastern Africa and Indian Ocean islands; INERA-DPF, Burkina Faso and Forest Dept of CIRAD, France, project CORAF/Gomme Arabique on Impact de l'inoculation par les rhizobiums sur la productivite de gommeraies plantees ou naturelles et la dynamique de facteurs lies au fonctionnement biologique des sols sous-jacents ; INERA, Burkina Faso, ISRA, Senegal, FOFIFA, Madagascar, project ANR/MICROBES project on microbial observatories for the management of soil ecosystem services in the tropic; KEFRI, Kenya, Forest Dept of CIRAD, France and Grassland Research Station, Zimbabwe, project INCO DEV SAFSYS on Symbionts in agro forestry systems: what are the long-term impacts of inoculation of Calliandra calothyrsus and its intercrops; Antananarivo University, Madagascar and University of Makerere, Uganda project INCO DEV FOREAIM on Bridging restoration and multi-functionality in degraded forest landscape of Eastern Africa and Indian Ocean islands; University of Niamey, Niger and University Cheikh Anta Diop, Senegal, project CORAF/Gomme Arabique on Impact de l'inoculation par les rhizobiums sur la productivite de gommeraies plantees ou naturelles et la dynamique de facteurs lies au fonctionnement biologique des sols sous-jacents; Institut National de Recherches Agronomiques du Niger (INRAN); Niamey/Niger; Institut d'Economie Rurale (IER), Mali; ARS, Chilanga Zambia (Moses Mwale); EARO (Ethiopian Agricultural Research organization), Ethiopia; Ahmadu Bello University, Nigeria; ARI Mlingano, Tanzania; Egerton University, Kenya; LBDA (Lake Basin Development Authority), Kenya (Amos Ameya); University of Nairobi, Nairobi (Kenya) (Rosemary Atieno); Makerere University, Kampala (Uganda) (Elizabeth K. Balirwa, Jonny Mugisha, John Baptiste, Mary Silver); Lake Basin Development Authority (Kenya) (Amos Ameya); Selian Agricultural Research Institute (Tanzania) (Sossi Kweka and Festo Ngulu); Southern Regions Research Institute, Ethiopia; AREX (Department of Agriculture Research and Extension), Zimbabwe; IIAM (Instituto Nacional de Investigacao Agronomica), Mozambique; Eduardo Mondlane University, Maputo, Mozambique; Universidade Católica de Moçambique, Beira, Mozambique and DARS (Department of Agriculture Research Services), Malawi; Moi University, Kenya; Ethiopian Institute of Agricultural Research (EIAR), Ethiopia; Programme d'appui au developpement durable (PAD), DRC; Conseil Consultatif Des Femmes (COCOF), Rwanda; Programme de Development Rural Durable (DERD), Rwanda; Plate-Forme Diobass Au Kivu (Diobass), DRC; Rwanda Farmers Federation (IMBARAGA), Rwanda; Service d'Accompagnement et de Renforcement des Capacités d'Auto promotion de la Femme en sigle (SARCAF), DRC ; Ebubala Self-Help Group (Shianda Location of

Butere Division, Kenya); Tushiauriane Self Help Group (Eluche Sub-location, Kenya); Nabongo Panga Self-Help Group (Matawa Sub-Location, Nabongo Location, Kenya); Jitolee Women Group (Lukohe sublocation, North Marama location, Butere Division, Kenya); Etako Women Group (Lukohe sublocation, North Marama location, Butere Division, Kenya); Bushe Women Group (Butere Division, Kenya); Shishebu farmers' Group (Shianda location, Butere Division, Kenya); Mabole farmers' field school (Shianda location, Butere Division, Kenya); Masaa Men and Women Group; Eluche Mwangaza Community Dev't Organization (Eluche Sublocation, Mumias Division, Kenya); Uriri farmers' cooperative society (Migori District, Kenya); Suna farmers' cooperative society (Migori District); Octavio Menocal, Jellin Pavón, Oscar Poveda, José Luis Olivares and Roberto Paredes, Nicaraguan Institute for Agricultural Technology; Edgar Amézquita, Miguel Ayarza, Colombian Corporation for Agricultural Research (CORPOICA), Colombia.

Advanced Research Institutes: J Six, University of California Davis, USA, NSF project on soil aggregation; R Merckx, Catholic University of Leuven, Belgium, VLIR project on food security in Central Kenya; E Tollens, Catholic University of Leuven, Belgium, DGDC project on legume integration in systems in Central Africa; R Swennen, Catholic University of Leuven, Belgium, DGDC project on banana management in Central Africa; S Recous, INRA, France, VLIR project on food security in Central Kenya; K Giller, WUR, Netherlands, EU project on Africa NUANCES; L Brussaard, L Stroosnijder, WUR, Netherlands, WOTRO project on soil fauna and soil aggregation; Institut de Recherche pour le Developpement, France, project CORAF/Gomme Arabique on Impact de l'inoculation par les rhizobiums sur la productivite de gommeraies plantees ou naturelles et la dynamique de facteurs lies au fonctionnement biologique des sols sous-jacents; Institut de Recherche pour le Developpement, France, Centre of Ecology and Hydrology, UK' University of Norway, project INCO DEV FOREAIM on Bridging restoration and multi-functionality in degraded forest landscape of Eastern Africa and Indian Ocean islands; GSF-Munich, Germany and Institut de Recherche pour le Developpement, France project ANR/MICROBES project on microbial observatories for the management of soil ecosystem services in the tropic; Centre of Ecology and Hydrology and, Scottish Agricultural College UK, project INCO DEV SAFSYS on Symbionts in agro forestry systems: what are the long-term impacts of inoculation of Calliandra calothyrsus and its intercrops; BIOFORSK Soil, Water and Environment, Norway; JIRCAS (Japan International Research Center for Agricultural Sciences), Japan; Wye College, University of London (Colin Poulton); Kyoto University, Kyoto, Japan (Atsuyuki Asami); Ishikawa Prefectural University, Japan (Hiroshi Tsujii); University of Kiel, Kiel, Germany (Roll A.E. Mueller); Universite Catholique de Louvain (Eric F. Tollens); Swedish Univ. Agric. Sci (SLU), Uppsala, Sweden (Olof Andrén). University of Natural Resources and Applied Life Sciences (BOKU), Vienna Project on Linking Farmers to Markets; University of Hohenheim, Germany,University of Firenze, Florence, Italy; Matilde Somarriba, Bismark Mendoza, Ignacio Rodríguez, Glenda Bonilla, National University of Agriculture (UNA), Nicaragua[2]; Zoila Ávila, Oscar W. Ferreira and Oscar Ferreira Catrileo, National School of Forest Sciences (ESNACIFOR), Honduras*; José Trinidad Reyes, National University of Agriculture (UNA), Honduras*; Juan Carlos Menjívar, Edgar Madero, Carmen Rosa Bonilla, Ricardo Malagón and Martin Prager, National University of Colombia - Palmira campus (UNAL-Palmira), Colombia; Edmundo Barrios, Harvard University, USA; Arthur Conacher and Natasha Pauli, University of Western Australia (UWA), Australia; Johan Six and Steven Fonte, University of California - Davis, USA; Urs Scheidegger, Swiss College of Agriculture, Switzerland; Elisabeth Huber-

[2] as part of the MIS Consortium

The Private Sector: TSBF-Africa is also working with a wide array of private sector and farmers associations. Some of those involved include:
Western Seed Company (Kenya)– Saleem Esmail; BIDCO OIL REFINERIES LIMITED (Kenya) – Dileswar Pradhan, Ashish Mandlik; Mukwano Group of Companies (Uganda) – Ibnul Hassan Rizvi; NUTRO MANUFACTURING EPZ LIMITED – Simon Glover; Kenya). AMFRI farms (Uganda), Olivine Industries, Harare, Reapers (Pvt) Ltd, Harare; Luis Álvarez-Wélchez, Germán Flores, Carlos Zelaya and Walter Alvarenga, Food and Agriculture Organization of the United Nations (FAO), Honduras.