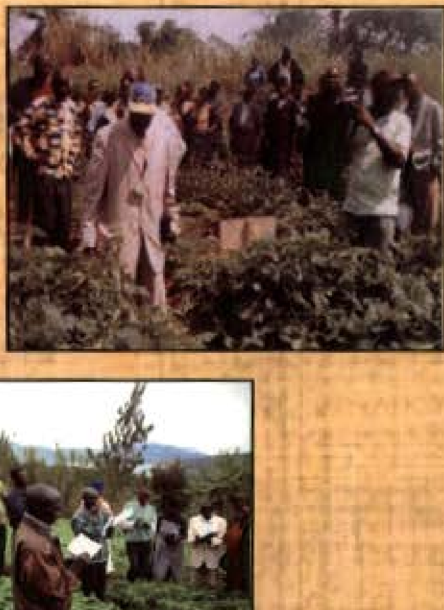
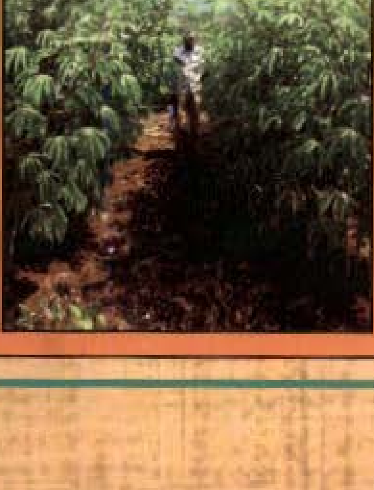
CIAT
Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

Annual Report 2008

# TSBF Institute

## Outcome line
## ISFM-BASED CROP PRODUCTION SYSTEMS FOR MAJOR IMPACT ZONES IN SUB-SAHARAN AFRICA





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

## OUTCOME LINE

## 'ISFM-BASED CROP PRODUCTION SYSTEMS FOR MAJOR IMPACT ZONES IN SUB-SAHARAN AFRICA'

Centro Internacional de Agricultura Tropical (CIAT)
Apartado Aéreo 6713
Cali, Colombia
South America

TSBF Institute: Outcome Line: 'Integrated Soil Fertility Management-based crop production systems for major impact zones in sub-Saharan Africa'

*Contact address:*
Nteranya Sanginga
Director, Tropical Soil Biology and Fertility (TSBF) Institute of CIAT

Bernard Vanlauwe
Leader, Outcome Line on 'ISFM-based crop production systems for major impact zones in sub-Saharan Africa'

ICRAF Campus
P O Box 30677-00100
Nairobi, Kenya
Tel: + 254 (20) 524766 or 524755
Fax: + 254 (20) 524764 or 524763
E-mail: tsbfinfo@cgiar.org

Tropical Soil Biology and Fertility (TSBF) Institute, Outcome Line: ISFM-based crop production systems for major impact zones in sub-Saharan Africa. 2008. Annual Report 2008. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia, 231 pp.

## TABLE OF CONTENTS

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

## Outcome line

## 'ISFM-based crop production systems for major impact zones in sub-Saharan Africa'

Centro Internacional de Agricultura Tropical (CIAT)
Apartado Aéreo 6713
Cali, Colombia
South America

TSBF Institute: Outcome Line: 'Integrated Soil Fertility Management-based crop production systems for major impact zones in sub-Saharan Africa'

*Contact address:*
Nteranya Sanginga
Director, Tropical Soil Biology and Fertility (TSBF) Institute of CIAT

Bernard Vanlauwe
Leader, Outcome Line on 'ISFM-based crop production systems for major impact zones in sub-Saharan Africa'

ICRAF Campus
P O Box 30677-00100
Nairobi, Kenya
Tel: + 254 (20) 524766 or 524755
Fax: + 254 (20) 524764 or 524763
E-mail: tsbfinfo@cgiar.org

Tropical Soil Biology and Fertility (TSBF) Institute, Outcome Line: ISFM-based crop production systems for major impact zones in sub-Saharan Africa. 2008. Annual Report 2008. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia, 231 pp.

# TABLE OF CONTENTS

# 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 current Outcome line, referred to as the ISFM Outcome line, 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 current Outcome line: (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 is expected to launch its Soil Health Program half 2008. This program has adopted ISFM as a guiding framework for improving the soil health status of African soils and the present Outcome line 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**[a] | 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**[a] | 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.

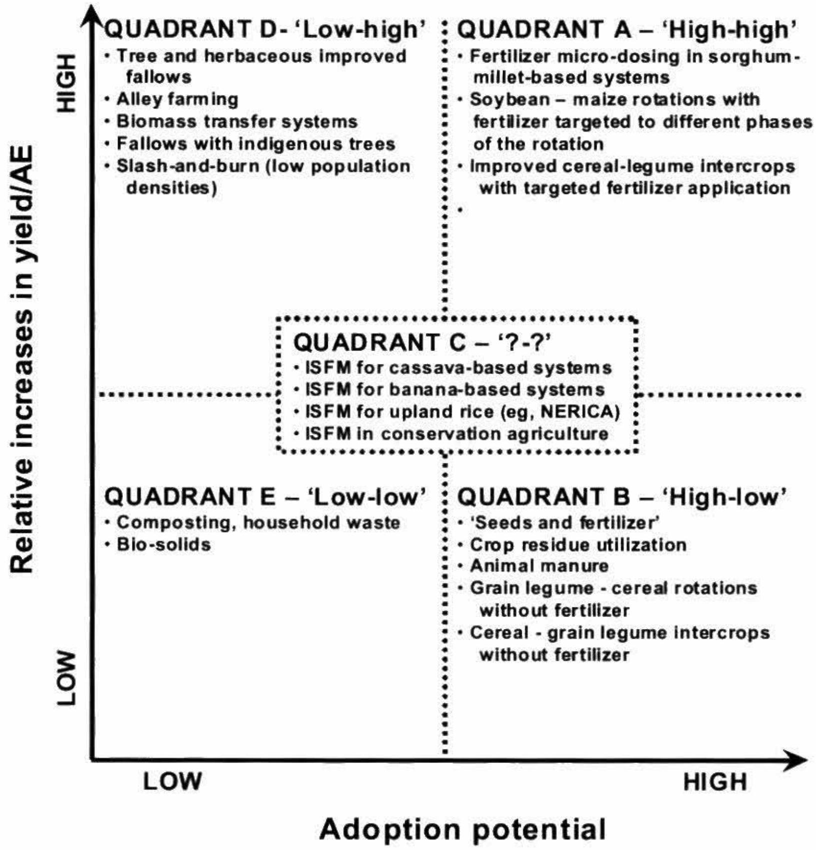



**Figure 1: The relative adoption potential and contribution to soil fertility enhancement for various tested soil fertility management interventions.**

The GOAL of the ISFM Outcome line 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 2009-2011 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 current Outcome line will require specific inputs from the **SLM OUTCOME LINE** under TSBF-CIAT and various Outcome lines 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)**.

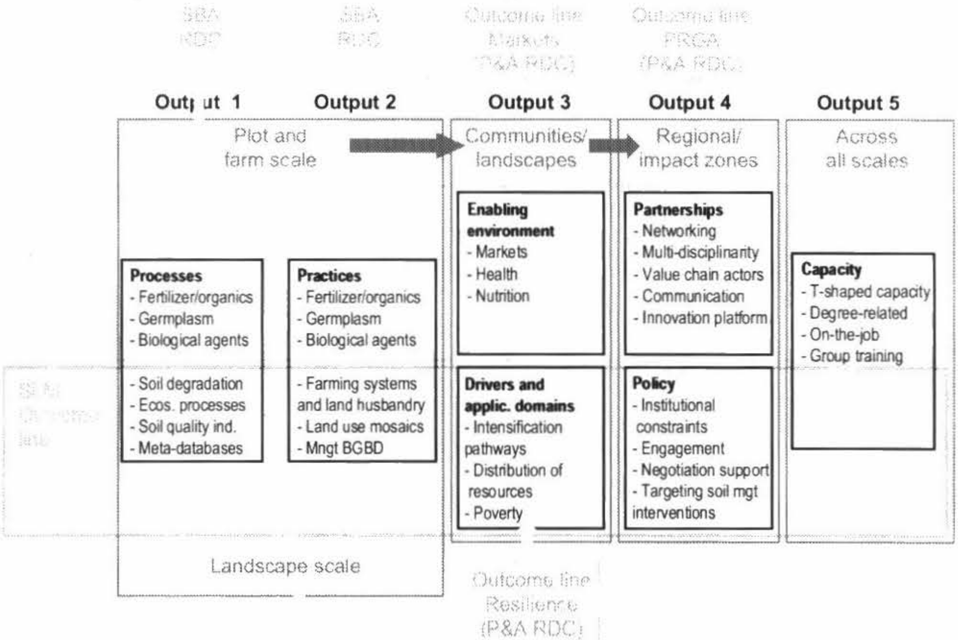



**Figure 2: Specific focus areas of the ISFM and SLM Outcome lines and potential linkages between these and the other CIAT Outcome lines under the 'Sharing the Benefits of Agro-biodiversity' (SBA) the 'People and Agroecosystems' (P&A) RDC.**

# I.2. ALIGNMENT TO CGIAR SYSTEM PRIORITIES:

The ISFM Outcome line 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 Outcome line 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 (Figure 3). 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.

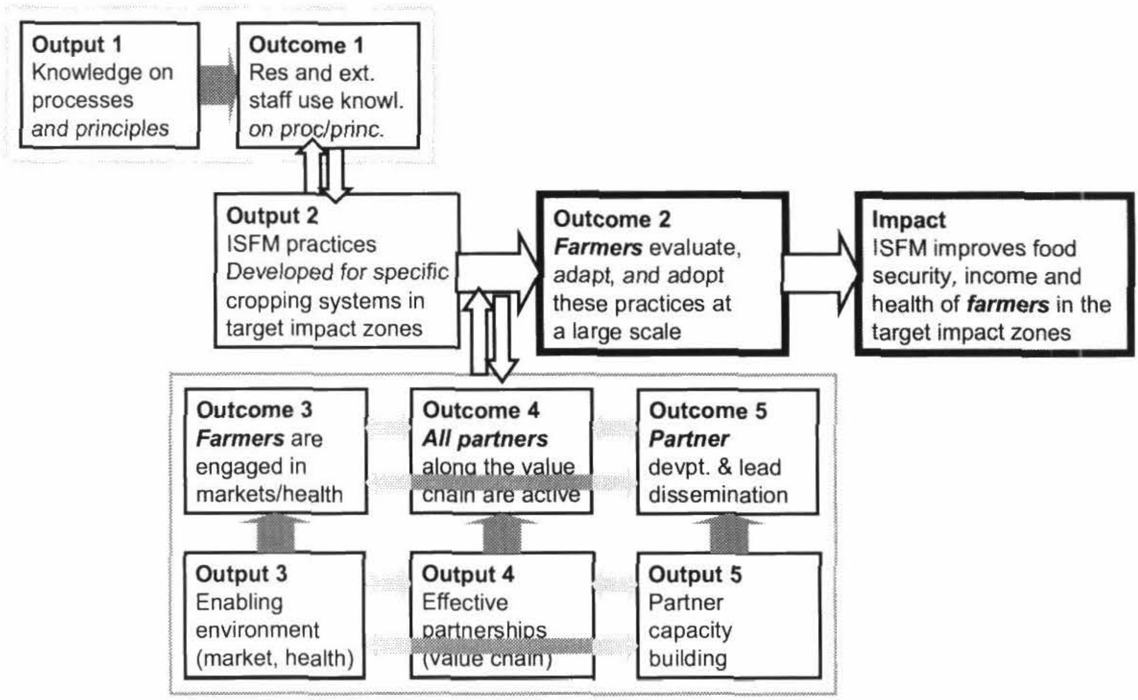



**Figure 3: Linkages between the different Outputs, resulting in Outcomes and their relation to the overall goal of the ISFM Outcome line. Light grey arrows show linkages between Outputs/Outcomes and dark grey arrows indicate the translation of Outputs into Outcomes.**

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 Outcome line 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 TSBF-CIAT 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 staffs 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 Outcome line 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 Outcome line 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 Outcome line 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) TSBF-CIAT stakeholders remain engaged and show limited staff turnover, (iv) TSBF-CIAT management continues to adapt and innovate in response to changing priorities, and (v) linkages remain maintained among research and development organizations. Other important assumptions are: (i) investments in various aspects of the 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 Outcome line 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 TSBF-CIAT 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 2008 SUMMARY

## II.1. ISFM PRODUCT LINE 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.<br>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).<br>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. |
| | 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. |

| Targets | Outputs (Intended users) | Outcome (Impact) |
| --- | --- | --- |
| | 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** | Description: Management practices that are in resonance with the resource-base and socio-economic environment of smallholder farmers.<br>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.<br>Impact: 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.<br>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.<br>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 **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 **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.<br>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.<br>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.<br>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.<br>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 2008

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

***Status:*** Fully Achieved.

***Explanation:***
The revised definition of Integrated Soil Fertility Management (ISFM) explicitly mentions the need for fertilizer, improved germplasm, organic inputs, other amendments where needed, and adaptation to local conditions with a special focus on addressing variability at the community (farm typologies) or farm (soil fertility gradients) scale. In order to develop and implement complete ISFM packages, rapid assessment methods are needed to diagnose the current soil fertility status and the various components that constitute ISFM. Most of the activities related to this target that was inherited from the earlier TSBF-CIAT strategy, before CIAT had adopted the Outcome Line structure, were implemented in legume and cereal-based systems which constitute the major cropping systems for East and Southern Africa. This target has also attracted substantial attention since 2005.

In terms of diagnosis, reports are available on approaches to determine local soil quality indicators, nutrient balances, farm typologies, and within-farm soil fertility gradients (Tittonnel et al, 2005a, Tittonnel et al, 2005b; Kathuku et al., 2007; Kimiti et al, 2007; Masvaya et al, 2007; Tittonnel et al, 2007; Vandamme et al, 2008). Tools to assess organic resource quality and its decomposition dynamics have been summarized in Shepherd et al (2005) and Vanlauwe et al (2005). Tools for assessing soil organic matter dynamics and soil P dynamics have been presented in Andren et al. (2007) and Waswa et al. (2007), respectively, Pypers et al. (2007) and Pypers et al (2009). Rhizobial diversity tools have been presented by Abaidoo et al. (2007), Faye et al. (2008), and Lesueur and Sarr (2008).

Although we report full achievement of this target, due to recent renewed interest in exploration germplasm for differential tolerance to low soil fertility and direct microbial inoculations, activities on (i) evaluation of early legume root traits for tolerance to low P and (ii) identification and deployment of best *Rhizobium* and arbuscular mycorrhizal fungi will continue.

## II.2.2. The social, gender, and livelihood constraints and priorities affecting the sustainable use of soils through at least two successful case stories using innovative methods in the African Sahel and moist savanna have been identified, characterized, and documented.

***Status:*** 75% Achieved.

***Explanation:***
The current target aims at setting the scene for ISFM interventions and is consequently never fully achieved since each new project requires specific information on the current status of the priority areas addressed by these projects. Such priorities will in most cases encompass specific livelihood dimensions, including gender and social capital. Evaluation of the status

of this target is thus related to the on-going projects, recognizing above logic. Most of the activities related to this target that was inherited from the earlier TSBF-CIAT strategy, before CIAT had adopted the Outcome Line structure, were implemented in legume and cereal-based systems which constitute the major cropping systems for East and Southern Africa. This target has also attracted substantial attention since 2005 but changes in social scientist capacity at TSBF-CIAT have hindered progress with full completion of this target.

Livelihood-related constraints encompass constraints to enhanced rural well-being at the level of human, social, natural, financial, and manufactured capital. General livelihood characterization has been presented by Pypers et al (2008). Reports on factors driving soil management and fertilizer use have been presented by Misiko (2007), Tittonnel et al. (2007a), Tittonnel et al. (2007b), and Zingore et al. (2007). Social capital and gender dimensions affecting soil management have been reported by Delve et al. (2007), Ramisch et al. (2007), Muzira (2008); Njuki et al. (2008), and Gotschi and Delve (2008). Development domains defining the boundary conditions within which certain technologies could be disseminated have developed by Farrow et al. (2006) and Risinamhodzi (2007).

Activities in the context of this target will partially continue under the 2009 Output 2 target of the ISFM outcome line 'Local diagnosis of soil fertility constraints and farmer understanding of important soil processes underlying ISFM for all impact zones'. Any other constraints analysis will take place on a routine basis whenever new projects come on line and do not require a specific log-frame target.

## II.2.3. Improved production systems having multiple benefits of food security, income, human health and environmental services identified.'

***Status:*** > 50% Achieved [100% achieved for legume cereal systems; < 50% Achieved for cassava, rice, and banana-based systems]

***Explanation:***
This target is key to the overall objectives of TSBF-CIAT and sets the scene for the development of impact pathways and any other accompanying measures that will favor dissemination and adoption of ISFM technologies. The aim is to identify production systems with multiple benefits since it is generally known that single benefit technologies usually have very limited adoption potential. Multiple benefits include benefits related to productivity increases, higher income, better nutrition and health, and improved environmental conditions. As with the other targets and due to the nature of earlier interventions of TSBF-CIAT, progress reported has been achieved in legume-cereal systems. We have scored the status of this target at 50% since the range of farming systems has broadened through the development of the ISFM Outcome Line. For the legume-cereal systems, the target has been achieved close to 100% but for the cassava, rice, and banana-based systems, the development of ISFM technologies with multiple benefits is achieved < 50%. Note that the environmental service dimension of improved production systems is covered under the SFM Outcome Line of TSBF-CIAT.

In the savannas, most of the progress under this target is related to soybean-maize rotations or intercropping systems (Vandeplas et al., 2008). Specific efforts have been made on promoting the nutritional qualities of soybean (Kamau et al, 2007; Ohiokpehai et al, 2007a; Ohiokpehai et al, 2007b; Ohiokpehai et al, 2009,) and improving their market potential (Chianu et al., 2006). Other activities in East and southern Africa focused on herbaceous legumes (Kankawatsa and Delve, 2007), technologies to deal with Striga in East Africa (Vanlauwe et al., 2008), integrated nutrient management (Zingore et al., 2008), and evaluation of soil amendments (Nekesa et al., 2007). In West-Africa, technologies based on fertilizer micro-dosing (Tabo et al., 2007) and crop-livestock integration (Chianu et al, 2007) have been developed.

# II.3. RESEARCH HIGHLIGHTS FOR 2008

| 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.<br>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).<br>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. |

## 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.

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 distinguished 18 intergenic spacer groups (IGS) I-XVIII. 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 while *B. yuanmigense* related accounted only 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.

## A modelling analysis suggests that conservation agriculture can lessen the negative effects of climatic change on maize production in Zimbabwe

There is a consensus among climate specialists that Southern African regions will become dryer with more irregular rainfall by the end of the 21st century. Conservation agriculture (CA) is seen as a new paradigm to conventional agriculture that uses soil tillage. Three practices underpin CA: (1) minimizing soil disturbance by reduced or zero-tillage; (2) retaining residues on the soil surface and (3) using crop rotations. The widely used crop growth simulation model DSSAT-CSM was adapted and tested to simulate the effect of CA practices. The model was run to simulate maize production under the present climate using 50 years of daily climatic data from Harare and under the future rainfall scenario. The simulation results show that climate change will decrease maize productivity in the study region with about 25 to 30% in the coming 50 years. CA practices have a real potential to reduce climatic risk for farmers in southern Africa. Under the current climate the probability of producing at least 3000 kg/ha grains is 40 and 65 % under, respectively, conventional tillage and CA practices. Under future climate, the probability drops to respectively 15 and

45%. The results indicate that the negative impact of climate change can be mitigated by adopting CA in the 'normal' years, but with a higher risk of lower yields in the 'good' and 'bad' years. However, the question remains how CA practices fit in the farming systems. Crop residue mulching profoundly alters the flow of resources at the farm, and there are trade-offs in the use of crop residues at farm level. Crop residues, and in particular cereal stover, is a highly-valued fodder for livestock in smallholder farming systems in Africa.

## Effects of single and dual inoculation with selected microsymbionts (rhizobia and arbuscular mycorrhizal fungi) on growth and nitrogen fixation of *Calliandra calothyrsus* Meissn under nursery and field conditions

Our results showed that plants inoculated with both microsymbionts grew better (height and root collar diameter) than plants from the three other inoculation treatments (control, inoculation with KWN35 and GE1 singly). However, the statistical analysis showed that these results were not significantly different except one and five months after planting. Results of nodule occupancy by *Rhizobium* strain KWN35 showed that strain KWN35 was largely present in the majority of nodules harvested on plants inoculated with the rhizobial strain alone and with both microsymbionts (around 60%) one year after planting. Nodule occupancy of the strain decreased two years after planting, and only around 40% of the nodules harvested on these two treatments contained the rhizobial strain. The other treatments did not show significant differences. We conclude that dual inoculation did not enhance the nodule occupancy of *C. calothyrsus*. However, it was wondering to see that even when a majority of nodules were occupied by the selected rhizobia, the growth of trees was not significantly highest compare with the growth of control plants. Several assumptions can be done for explaining these results.

## Comparative effects of different quality organic resources on soil microbial diversity under two different environments in Kenya

In soil samples collected in 2002 and 2006 from plots which had received a fresh weight condition carbon at a rate of 4.0 t C $ha^{-1}$ dry weight we assessed total bacterial communities. Different classes of organic resources: i.e. *Tithonia*, *Calliandra*, Maize stover, *Grevillea*, and goat manure were the sources of carbon. Manure treatments in both sites recorded the lowest Shannon-Weaver index value values followed by the controls. This could have been caused by high competition of Mineral N in manure between crops and soil microbes. *Grevillea* and stover with mineral N fertilizer gave the highest diversity (1.05 and 1.02) respectively. There was a decrease in diversity of bacterial communities in Embu and Machanga with application of organic resources. This could have occurred due to the fact that specific types of organic resources would restrict the microorganisms to only those which can decompose those particular materials. There was a statistical significant difference in diversity of bacteria within the sites but no statistical significant difference in diversity of bacteria across the sites. Nitrogen application had a slight significant effect on the diversity of bacterial communities in the Machanga soil but no significant effect in the Embu site. This could have been because of moderate amount of total nitrogen in the Embu soil but very low nitrogen amounts in Machanga soils. Different quality organic resources affect soil microbial communities.

| Targets | Outputs (Intended users) | Outcome (Impact) |
|---|---|---|
| **Output 2** | 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. |

## The prospects of reduced tillage in tef (Eragrostis tef Zucca) in Gare Arera, West Shawa Zone of Oromiya, Ethiopia

Soils in Ethiopia are traditionally ploughed repeatedly with an oxen-drawn plough before sowing. The oxen ploughing system exposes the soil to erosion and is expensive for farmers without oxen. In field experiments carried out on a Vertisol and a Nitisol for 2 years in Ethiopia to study the effect of zero tillage, minimum tillage, conventional tillage, and broad bed furrows (BBF) on the yield of tef (Eragrostis tef Zucca), no significant differences in tef biomass and grain yields were observed between the treatments on both soils in the first year. In Nitisol in the second year, yield was lower in the zero tillage treatment as compared to the other treatments. No difference in yield was observed between single plough, conventional, and BBF. On Vertisol, the yields were higher in BBF as compared to the other treatments. Zero tillage gave the lowest gross margin on both soils whereas BBF gave the highest gross margin. On Vertisol there were no significant difference in gross margin between minimum tillage and conventional tillage. Minimum tillage is an interesting option on Vertisols, particularly for female-headed households as it reduces the tillage cost. It may also improve overall productivity of the farming system because it allows partial replacement of oxen with cows and reduces soil erosion.

Striga hermonthica (Delile) Benth, stemborers, and declining soil fertility are serious threats to sustainable food production in the Lake Victoria zone of Kenya. To address these constraints, promising integrated crop management technologies were evaluated, using a multi-locational design for six cropping seasons. Technologies evaluated consisted of the traditional maize (Zea mays L.) – bean (Phaseolus vulgaris L.) intercrop, maize – Desmodium (Desmodium uncinatum (Jacq.) DC.) push–pull intercrop, Crotalaria (Crotalaria ochroleuca G. Don) – maize rotation, and soybean (Glycine max (L.) Merr) – maize rotation. Within each of these systems, imazapyr-coated herbicide-resistant maize (IR-maize) and fertilizer were super-imposed as sub-plot factors. The push–pull system was observed to significantly reduce Striga emergence and stemborer damage from the second season onwards. IR-maize reduced and delayed Striga emergence from the first cropping season. After five cropping seasons, the Striga seedbank was significantly higher in the maize-bean intercrop system than in the push–pull system under both maize varieties. Maize yields in the push–pull system were higher than in the maize-bean intercrop after two seasons and in the absence of mid-season drought stress. In the short term, IR-maize integrated in a push–pull system is the most promising option to reduce Striga while the rotational systems may need a longer timeframe to reduce the Striga seed bank.

## Improved cassava-legume intercropping systems for the Humid Tropics

Technologies for increased productivity in legume-cassava intercropping systems were evaluated in a series of on-farm demonstration trials, conducted in the CIALCA mandate area of Sud-Kivu, DRC. An improved system was developed that maximizes productivity by combining improved germplasm, fertilizer application, organic matter management, and adapted agronomic practices and crop spacing. In this system, the cassava is spaced at distances of 2 m between rows and 50 cm within the row. Between the cassava rows, 4 legume rows are planted at the same time as the cassava. After the harvest of the first legume, the system allows planting 2 rows of another legume during the second season. Spacing the cassava in this manner allows higher legume production, without affecting the cassava tuber yield. Productivity is maximized when fertilizer is applied: legume yields are increased by 300 % and cassava yields by 200 %, relative to the common practice (random spacing, local varieties and sole organic input application). The system can be modified following production objectives and different legumes can be intercropped. In Sud-Kivu, for example, farmers prefer intercropping with beans and soybean, while in Bas-Congo, intercropping with groundnuts or soybean is most common. The system was very positively evaluated by farmer groups and is currently being further tested in farmer adaptation trials. Some early indications of farmers experimenting and taking up the system have been recorded. In pilot studies with fertilizer credit, several farmer groups have opted to apply this system, since expected benefit-cost ratios are very favourable (varying between 1.9 and 9.0).

| 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.<br>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.<br>Impact: Improved income and health and nutrition for the farmers in the target impact zones through adoption of ISFM-based production systems. |

## Farmers and agro-input service reception in western Kenya

Agricultural productivity is critical to poverty reduction in Africa and requires that smallholder farmers increase their farm inputs use. Agro-input dealers must help to stock necessary inputs required by farmers. There are ongoing interventions to help them do this. In order to account for the contributions of these interventions, we carried out as baseline survey of 114 farm households from two districts in western Kenya. Results indicate that most of the households were not market-oriented, food insecure, lack financial ability to command inputs from shops, limited access to 'certified' crop seed, exposed to unreliable source (traders, not agro-input dealers or agricultural extension staff) of input-output market information, had poor perception of extent of degradation of their lands and high perception of agricultural output price instability (and hence that agriculture is risky). Between the male- and female headed households, there was endowment asymmetry [terms of physical and social capital assets, information, training on the use of various farm inputs and technical assistance for increased agricultural productivity] in favor of the former. The major reason for little use of input by farmers is lack of fund since their physical access is quite good, with input shops located at walking distances to most farmers. They have a low understanding of ISFM.

## Agro-input dealers and service provision in Western Kenya

The dearth of agricultural extension due to structural adjustment programs of the 1980s and early 1990s have necessitated the need to involve other players in the provision of agricultural extension service farmers in Africa. For widespread use of Integrated Soil Fertility Management (ISFM), agro-input dealers are being involved. A baseline survey to understand where we are starting from was carried out with 42 agro-input dealers from 10 districts and 31 markets. Result shows that although the agro-dealers were ready to serve farmers (even with respect to ISFM) they face key constraints including poor road infrastructure (and high transport cost), low marketing volume, travel long distance to source inputs, limited collective action, "barriers" (trade license, KEPHIS certificates, etc.) to entry into business, and limited ability to allow credit to farmers. Others include no knowledge of the use of soil test kits, limited training on how to improve service to farmers, low business capital, no training for them to become ISFM practitioners, and unstable agro-input policy environment. Most of the agro-input dealers did not know what is meant by ISFM. This means agro-input dealers must be further empowered in various direct and indirect ways in order for them to serve farmers better.

| Targets | Outputs (Intended users) | Outcome (Impact) |
|---|---|---|
| **Output 4** | Description: Effective partnerships along each step of the value chain for innovative, effective and efficient dissemination and impact.<br>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.<br>Impact: Improved ISFM-based production systems contribute to food and nutrition security and income and health of farmers in the target impact zones. |

## Determinants of the decision to adopt integrated soil fertility management practices by smallholder farmers in the central highlands of Kenya

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.

## Bridging the gap between farmers and researchers through collaborative experimentation cost and labour reduction in soybean production in South-Nyanza

TSBF- CIAT introduced dual purpose soybean varieties in south-west Kenya both to improve soil fertility by nitrogen fixation and to provide a source of better food and income. We started a Collaborative Experiment (CE) Approach in March 2006 to make soybean production more accessible to farmers. The approach consisted of four stages: 1) information sessions; 2) participatory rural appraisal; 3) collaboration in the whole process of experimentation, from problem identification, to the design and analysis; 4) handing over to farmers. Treatments were chosen that addressed labour and input use constraints. Statistic analysis of the yields show a significant increase in yields from 586 kg/ha to 756-1047 kg/ha when applying inputs, but no significant differences between the local or mineral inputs. The farmers' preferences amongst the labour treatments, were planting in trenches with one or two weeding, or broadcasting with one weeding, depending on labour availability in their household. The results and discussions with farmers during the field days, and short term impact analysis allowed demonstrating that the CE approach had been successful on two main aspects. First, CE was successful in defining problems and yield enhancing treatments which are accessible to deprived people. The second main success of the CE process was the increased awareness and interest about soybean. Several farmers started their own experiments to further adapt the recommendations to their own needs. The CE approach was thus successful in bridging the power-relations and knowledge gap between researchers and farmers and in designing appropriate technologies.

| Targets | Outputs (Intended users) | Outcome (Impact) |
|---|---|---|
| Output 5 | Description: Stakeholder capacity to advance the development and adaptation of above outcomes.<br>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.<br>Impact: Large-scale impact of ISFM practices in the target impact zones. |

## Report of the Agro-dealer training workshop on Integrated Soil Fertility Management, Kisumu, Western Kenya

In the context of the collaboration between TSBF-CIAT and AGMARK aiming at enhancing the capacity of agro-dealers in western Kenya to give advice to farmers on Integrated Soil Fertility Management (ISFM), a Training Workshop in Integrated Soil Fertility Management was organized between 13 and 15 November 2008. A total of 56 people attended. The Training workshop consisted of a one-day session on Integrated Soil Fertility Management (ISFM). The second day consisted of an exchange visit to 4 demonstration trials while the third day consisted of sessions on Striga management and pest and disease management. In the concluding section, participants were invited to evaluate the training workshop. The most frequently mentioned positive aspects of the training workshop include: the exposure to training on soil fertility management, to fertilizer use and management, to Striga control, and to crop nutrient requirements. Some important observations made during the workshop include: (i) the current knowledge on soil and fertilizer management is variable and generally limited, (ii) linkages between input suppliers (seed, fertilizer) are weak and driven by the suppliers with little negotiation power on the side of the agro-dealers, and (iii) there is a genuine interest for agro-dealers to give better advice to farmers.

## Concepts of soil quality indicator analysis

The development of soil quality indicators was the main thrust and output of the statistical analysis and training seminar held in Bondy, Paris, France to tease out and analyze data that informs the definition and understanding of soil quality. The conventional definition of soil quality is "the fitness of a specific kind of soil to function within its capacity and within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation". A more holistic concept of soil quality is a holistic concept that recognizes soil as part of a dynamic and diverse production system with biological, organic, chemical and physical properties that relate to the inherent properties of the soil. Soil Quality Indicators (SQI) were generated from a combination of sub indicators developed from the PCA analysis of soil organics, soil chemical, soil biological properties (soil fauna & species richness) and soil physical proprieties.

# II.4. PROJECT OUTCOME FOR 2008

Activities under this target will continue under the Output 2 targets of the ISFM Outcome Line, still including the legume-cereal systems (2009 target) but with special attention given to the cassava (2010 target), rice (2010 target), and banana-based (2011 target) systems.

As of today, at least 11,900 households (with an average size of seven persons) belonging to over 250 farmer associations and cooperatives are growing soybean for improved soil fertility, higher income, and better nutrition in western Kenya. The current outcome was first identified in the 2003-2005 MTP and is the results of various outputs having been achieved simultaneously. Outputs related to germplasm evaluation, adaptive agronomy, soybean value chain evaluation, and soybean processing and utilization were delivered within the same timeframe and target areas. Various documents detail components of this achievement (see supporting references below). The use of the various outputs was driven by interested farmer groups and cooperatives in western Kenya. There has been a substantial increase in soybean production, processing, utilization, and marketing, as evidenced by several small and medium-scale enterprises (e.g., Soybean Resource Centers in Migori, Mumias, and Butere districts; a soybean snack bar in Mumias district). Other development organizations and micro-credit agencies have stepped in to help to scale up the soybean success story (e.g., Kenya Women Trust Fund, Equity Bank, Bukura Agricultural Development Training Center in Kakamega district). At the agronomy level, adopting farmers integrated dual purpose soybean varieties in various ways in existing systems based on maize or sugarcane. As a result, regular cash income of participating farmers has improved. For instance, between December 2008 and February 2009, farmers in Mumias and Butere districts have realized over 8,000 USD from the sale of soybean seeds. Beneficial nutritional and health effects as a result of increased soybean consumption are being reported (Mr. Aruaya, Butere district; Mr. Omondi, Migori district, personal communication). The outcome has potential to spread throughout the initially envisaged recommendation domain, encompassing the Nyanza, Western, and part of the Rift Valley provinces of western Kenya and beyond. In the Alliance for a Green Revolution in Africa strategy, the dual purpose soybean – maize cropping system was anticipated to have potential impact with 150 million people on 30 million hectares. The interdisciplinary approach used to deliver the outputs, covering aspects of germplasm, agronomy, seed systems, markets, and nutrition could serve as a model to move other ISFM technologies in other impact zones.

# II.5. PUBLICATIONS FOR 2008

**Refereed Journal Articles**


Anyanzwa, H., Okalebo, J.R., Othieno, C.O., Bationo, A., Waswa, B.S. and Kihara, J. (2008) Effects of conservation tillage, crop residue and cropping systems on changes in soil organic matter and maize–legume production: a case study in Teso District. *Nutrient cycling in Agroecosystems Journal*. (Published online)

Aune, B.J. and Bationo, A. (2008) Agricultural intensification in the Sahel – The ladder approach. *Agricultural systems, Vol. 98, Issue 2, pp 119-125.*

Chianu, J., Huising, E.J. Danso, S.K., Sanginga, N., and Okoth P. Economic Value of Nitrogen Fixation in Soybean in Africa: Improving benefits for smallholder farmers. *(Submitted to Ecological Economics)*

Chianu, J.N., Adesina, A., Sanginga, P., Bationo A., Chianu J. and Sanginga N. (2008). Structural change in fertilizer procurement method assessment of impact in Sub-Saharan Africa. *African Journal of Business Management Vol. 2 (3), pp. 065-071.*

Chianu, Jonas N., Adesina, A., Sanginga, P., Bationo, A., Chianu, Justina N. and Sanginga, N. (2008) Structural change in fertilizer procurement methods: assessment of impact in Sub-Saharan Africa. *African Journal of Business Management 2 (3): 065–071.*

Chianu, Jonas N., Mairura, F., Ekise I. and Chianu, Justina N. (2008) Farm input marketing in western Kenya: Challenges and opportunities. *Africa Journal of Agricultural Research 3 (3): 167–173.*

Chianu, Justina N., Ajani, O.I.Y., and Chianu, Jonas N. (2008) Livelihoods and rural wealth distribution among farm households in western Kenya: Implications for rural development, poverty alleviation interventions and peace. *African Journal of Agricultural Research 3 (7): 455–464.*

Chikowo, R., Corbeels, M., Tittonell, P., Vanlauwe, B., Whitbread, A. and Giller, K.E. (2008) Aggregating field-scale knowledge into farm-scale models of African smallholder systems: Summary functions to simulate crop production using APSIM. *Agricultural Systems 97, 151-166.*

Fofana, B., Wopereis, M.C.S., Bationo, A., Breman, H. and Mando, A. (2008) Millet nutrient use efficiency as affected by natural soil fertility, mineral fertilizer use and rainfall in the West African Sahel. *Nutrient cycling in Agroecosystems Journal Vol. 81, No. 1, pp 25-36.*

Gentile, R., Vanlauwe, B., Chivenge, P. and Six, J. (2008) Interactive effects from combining fertilizer and organic residue inputs on nitrogen transformations. *Soil Biology and Biochemistry (In Press)*

Gentile, R., Vanlauwe, B., Chivenge, P. and Six, J. 2008 Residue quality and N fertilizer do not influence aggregate stabilization of C and N in two tropical soils with contrasting texture. *Nutrient Cycling in Agroecosystems (in Press)*

Hayashi, K., Abdoulaye, T., Gerard, B. and Bationo, A. (2008). Evaluation of application timing in fertilizer micro-dosing technology on millet production in Niger, West Africa. *Nutrient cycling in Agroecosystems Journal Vol. 80, No. 3, pp 257-265.*

Kamau Joyce, Ohiokpehai O., Kimiywe Judith, and Oteba Lawrence (2008) Nutrition and Health Status of Orphaned and Vulnerable School Children Aged 6-9 Years In Suba District, Kenya. *Applied Biosciences 4: 45-53.*

Mairura, F.S., Mugendi, D.N., Mwenje, J.I., Ramisch, J.J., Mbugua, P.K. and J.N. Chianu. (2008) Scientific evaluation of smallholder land use knowledge in Central Kenya. *Land Degradation & Development 19: 77–90.*

Masvaya, E.N., Nyamangara, J., Nyawasha, R.W, Zingore, S., Delve, R.J. and Giller, K.E. (2008) 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 (In press)*

Mucheru-Muna, M., Pypers, P., Mugwe, J., Kung'u, J., Vanlauwe, B., Mugendi, D. and Merckx, R. Enhancing productivity by integrating grain legumes in maize cropping systems in the highlands of Central Kenya (*In preparation)*

Njuki, J., Mapila, M., Zingore, S. and Delve, R.J. (2008) The Dynamics of Social Capital in Influencing Use of Soil Management Options in the Chinyanja Triangle of Southern Africa. *Ecology and Society 13: 1-9*

Ohiokpehai, O., Mbithe, D. and Kamau, J. (2009) (2009) Serum Zinc Levels Of School Children On A Corn Soy Blend Feeding Trial In Primary Schools In Suba District, Kenya *(submitted to Applied Biosciences)*

Ohiokpehai, O., Mbithe, D. and Kamau, J. (2009) the Effects of Soybean (Glycine Max) and Pigeon Pea (Cajanus Cajan) Food Mixtures on the Nutritional Status of School Children in Suba District, Kenya. *(Accepted for JFAE V.7 number 2)*

Pypers, P., Sanginga, J.M., Merckx, R. and Vanlauwe, B. Genotype by environment effects on Fe and Zn content of biofortified bean varieties in Central Africa (*in preparation).*

Pypers, P., Vandamme, E., Sanginga, J.M., Walangululu, M., Merckx, R. and Vanlauwe, B. Soil fertility constraints for maize and bean production in the highlands of Sud-Kivu, Democratic Republic of Congo. *(In preparation)*

Pypers, P., Wangechi, H. and Vanlauwe, B. A long-term evaluation of various P fertilizer application strategies: comparison of maize grain yields and recovery of applied P using an adjusted model to calculate residual effects. *Soil Science Society of America Journal – in press.*

Pypers, P., Wangechi, H., De Groote, H., Chianu, J. and Vanlauwe, B. A long-term evaluation of various P fertilizer application strategies: II. Cost-benefit analysis and risk evaluation. *Agronomy Journal* (*In preparation*)

Tabi, F.O., Diels, J., Ogunkunle, A.O., Iwuafor, E.N.O, Vanlauwe, B. and Sanginga, N., (2008) Potential nutrient supply capacity, nutrient utilization efficiencies, fertilizer recovery rates and maize grain yield in the northern Nigeria. *Nutrient Cycling in Agroecosystems, 80, 161-172.*

Tittonell, P., Corbeels, M., van Wijk, M.T., Vanlauwe, B. and Giller, K.E. (2008) Targeting nutrient resources for integrated soil fertility management in smallholder farming systems of Kenya. *Agronomy Journal* (*In Press)*

Tittonell, P., Vanlauwe, B., Corbeels, M. and Giller, K.E. (2008) Yield gaps, nutrient use efficiencies and response to fertilizers by maize across heterogeneous smallholder farms of western Kenya. *Plant and Soil (in Press)*

Tulema, B., Aune, J.B., Johnsen, F.H. and Vanlauwe, B. (2008) The prospects of reduced tillage in tef (Eragrostis tef Zucca) in Gare Arera, West Shawa Zone of Oromiya, Ethiopia. *Soil and Tillage Research (In Press)*

Vanlauwe, B., Idrissa, A., Diels, J., Sanginga, N. and Merckx, R. (2008) Plant age and rock phosphate effects on organic resource quality of herbaceous legume residues and their N and P release dynamics. *Agronomy for Sustainable Development (In Press)*

Vanlauwe, B., Kanampiu, F., Odhiambo, G.D., De Groote, H., Wadhams, L. and Khan, Z.R. (2008) Integrated management of Striga hermonthica, stemborers, and declining soil fertility in Western Kenya. *Field Crops Research (In Press*)

Veldwisch, G.J.A. and Spoor, M. (2008) Contesting rural resources: Emerging 'forms' of agrarian production in Uzbekistan. *Journal of Peasant Studies 35 (3): 424–451.*

Veldwisch, G.J.A.; Bolding, A., and Wester, Ph. (2009) Sand in the Engine: The Travails of an Irrigated Rice Scheme in Bwanje Valley, Malawi. *Journal of Development Studies 45 (2): 197-226.*

Were, G., Ohiokpehai, O., Mbagaya, G., Okeyo, O., Kimiywe, J. and Kamau, J. (2008) Underweight, Stunting and Wasting Among HIV Affected Children Aged 6-9 in Suba District, Kenya. *JFAE 6 (2): 68-73.*

Zingore, S., Gonzalez-Estrada, E., Delve, R.J., Dimes, J., Herrero, M. and Giller, K.E. (2008) An integrated evaluation of resource use options for smallholder farms in Zimbabwe. *Agricultural Systems (In press)*

Zingore, S., Murwira, H.K., Delve, R.J. and Giller, K.E. (2008) Variable grain legume yields, responses to phosphorus and rotational effects on maize across soil fertility gradients on African smallholder farms. *Nutrient Cycling in Agroecosystems 80: 1-18*

Zingore, S., Nyamangara, J., Delve, R.J. and Giller, K.E. (2008) Multiple benefits of manure: The key to maintenance of soil fertility and restoration of depleted sandy soils on African smallholder farms gradients on African smallholder farms. *Nutrient Cycling in Agroecosystems 80: 267-282.*

**Books and monographs**

Bationo, A. (2008) Integrated Soil Fertility Management Options for Agricultural Intensification in the Sudano-Saherian Zone of West Africa. *Academy Science Publishers, Nairobi*

Bationo, A., Tabo, R., Waswa, B., Okeyo, J., Kihara, J., Fosu, M. and S. Kabore (eds) (2008) Synthesis of Soil, Water and Nutrient Management Research in the Volta Basin. *Ecomedia Ltd, Nairobi.*

Moreira, F.M.S., Huising, E.J. and Bignell, D.E. (eds), (2008) A Handbook of Tropical Soil Biology: Sampling and Characterization of Below-ground Biodiversity. *Earthscan, London*

**Book chapters and workshop proceedings**

Bado B.V., Bationo A., Lompo F., Sedogo M.P. Cescus M.P. Sewadogo A. et B. Thio (2008). Role des legumineuses sur la fertilite des sols et la productivite des systemes de cultures. In: Bationo A., Tabo R., Waswa B., Okeyo J., Kihara J., Fosu M., and S. Kabore (eds.). Synthesis of Soil, Water and Nutrient Management Research in the Volta Basin, *Ecomedia Ltd, Nairobi.*

Bationo A., Tabo R., Okeyo J., Kihara J., Maina F., Traore P.C.S. and Waswa B. (2008). General characteristics of the Volta Basin. In: Bationo A., Tabo R., Waswa B., Okeyo J., Kihara J., Fosu M., and S. Kabore (eds.). Synthesis of Soil, Water and Nutrient Management Research in the Volta Basin, *Ecomedia Ltd, Nairobi.*

Chianu, J.N., Njuki, J., Birachi, E., Alonso, G., Lundy, M., Kirkby, R., Buruchara, R., Ohiokpehai, O., Vanlauwe, B., Sanginga, N. (2008) Agricultural Market Development: A synthesis of CIAT 's approach, priorities, experiences and case studies for AGRA, Towards priority actions for market development for African farmers.

Hood-Nowotny, R., Zapata, F.and Vanlauwe, B. (2008) Use of tracer technology for the management of organic sources In: Guidelines on Nitrogen Management in Agricultural Systems. *International Atomic Energy Agency, Vienna, Austria, pp. 181-203.*

Huising, E.J. (2008). Description and classification of land use at sampling locations for the inventory of below-ground biodiversity. In: Moreira, F.M., Huising E.J. and Bignell D.E. (eds), A Handbook of Tropical Soil Biology: Sampling and Characterization of Below-ground Biodiversity, *Earthscan, London*

Huising, E.J., Coe, R. Van Noordwijk, M., Huang, S.P., Cares, J., Louzada, J., Zanetti, R., Moreira, F.M.S., Susilo, F. and Konate S. (2008). Sampling strategy and design to evaluate below-ground biodiversity. In: Moreira, F.M. Huising, E.J. and Bignell, D.E. (eds), A Handbook of Tropical Soil Biology: Sampling and Characterization of Below-ground Biodiversity, *Earthscan, London*

Moussa A. S., Rensburg, L. V., Kellner K. and Bationo A. (2008). Soil Indicators of Rangeland Degradation in a Semi-Arid Communal District in South Africa. In: Lee, C., and Schaaf, T., The Future of Drylands, *Springer, The Netherlands.*

Okoth, P., Chianu, J., Ohiokpehai, O., Vanlauwe, B., Sanginga, N. and Bationo, A. (2008) Milk from beans benefiting the rural poor, CGIAR news release by Burness story.

Swift, M.J., Bignell, D.E., Moreira F.M.S. and Huising, E.J. (2008). The inventory of soil biological diversity: concepts and general guidelines. In: Moreira, F.M.S., Huising, E.J., and Bignell, D.E. (eds), A Handbook of Tropical Soil Biology: Sampling and Characterization of Below-ground Biodiversity, Earthscan, London

Tabo R., Bationo A., Hassane O., Fatondji D., Abdou A., and S. Koala (2008). Way forward and future perspectives. In: Bationo A., Tabo R., Waswa B., Okeyo J., Kihara J., Fosu M., and S. Kabore (eds.). Synthesis of Soil, Water and Nutrient Management Research in the Volta Basin, *Ecomedia Ltd, Nairobi.*

Van Cleemput, O., Zapata, F., Vanlauwe., B. (2008) Use of tracer technology in mineral fertilizer N management. In: Guidelines on Nitrogen Management in Agricultural Systems. *International Atomic Energy Agency, Vienna, Austria, pp. 19-125.*

Vandeplas, I., Vanlauwe, B., Sagwa, A.M., Asimba, J.A., Merckx, R. and Deckers, J. (2008) Bridging the gap between farmers and researchers through collaborative experimentation. Workshop on Rethinking Impact: Understanding the complexity of poverty and change March 26–28, 2008, Cali, Colombia.

Veldwisch, G.J.A. (2008). Authoritarianism, validity, and security: Researching water distribution in Khorezm, Uzbekistan', in: C.R.L. Wall and P.P. Mollinga (Eds), Field Work in Difficult Environments: Methodology as Boundary Work in Development Research. *Lit Verlag pp.161–181, Berlin*

Yeboah, E. (2008) How can sustainable land management contribute to mitigating climate change? *Natural Resources Forum 32: 252-256.*

Yeboah, E., Abekoe, M.K. Dowuona G.N.N, Sohi S.P, Vanlauwe, B and Six, J.W. (2008) Understanding soil carbon dynamics for sustainable land management. CarboAfrica. Open Science Conference. Africa and carbon cycle. The CarboAfrica Project. Accra. Ghana 25-27 Nov. www.carboafrica.net

Yeboah, E. (2008) Smallholder agriculture; Factors generating a change. Learning, Producing and Sharing Innovations. Burkina Faso 21-24 October. *(http://APPRI2008.cirad.en)*

Zundel, C., Musyoka, M., Baruah, R., Mader, P., Kilchere, L., Muriuki, A., Vanlauwe, B. and Mucheru, M. (2009) Langzeit-Systemvergleiche in Kenia und Indien: Konventionelle und biologische Ertrage aus dem ersten Versuchsjahr. 10th Scientific Conference on Organic Agriculture, Zurich, Switzerland.

**Other Publications (posters and internal seminars)**

Chianu J., Muthoni, R., Douthwaite, B., White, D. and Holmann, F. (2008) "Future Focus of Economics (E) and Impact Assessment (IA) Studies in CIAT: Suggestions", PowerPoint presentation during the CIAT's Knowledge Sharing Week, Cali, Colombia, 7 – 12 April.

Chianu, J. (2008) "Socio-eonomics and soil fertility: TSBF-CIAT experience". Power Point presentation at an International Workshop at the Swedish Agricultural University (SLU), Uppsala, on 17 September 2008.

Chianu, J. and Chirasha, M. (2008) "Linking research to identification of market opportunities and enterprise selection". PowerPoint presentation at the AfNet Workshop on Participatory Approaches and Scaling Up held at Gigiri, United Nations Office in Nairobi (UNON) 21 April to 2 May.

Chianu, J., Alene, A., Coulibaly, O., Odendo, M., Manyama, A., Tefera, H., Boahen, S., Chikoye, D., Kanthiti, G. and Kananji, G. (2008) "Progress in Targeting Impact: Soybean in East and Southern Africa". Power Point presentation at the TL II First Annual Meeting 28 September – 04 October.

Chianu, J., Odendo, M. and Manyama, A. (2008) Progress in socio-economics in Kenya and Tanzania. PowerPoint presentation at the TL II Sub-Regional Annual Review Meeting held at Lilongwe, Malawi 20 – 22 August.

Chianu, J.N and Nkonya, E.M. (2008) "Socioeconomic and policy constraints to inoculants production and use in Africa". Power Point presentation at the Rhizobium Inoculation workshop held at Impala Hotel, Arusha, Tanzania: 17 – 21 March.

Chianu, J.N. (2008) "Ex-ante impact assessment of technologies for agricultural intensification". Power Point presentation to the consultants hired by AGRA to carry out the in-country studies that would feed into AGRA's Soil Health Business Plans Development, 19 June.

Chianu, J.N. and Chirasha, M, (2008) "Marketing and agriculture in SSA". PowerPoint presentation at the AfNet Workshop on Participatory Approaches to Research and Scaling Up held at Gigiri, United Nations Office in Nairobi (UNON) 21 April to 2 May.

Chianu, J.N. and Chirasha, M. (2008) "Market-led hypothesis on investment in NRM". PowerPoint presentation at the AfNet Workshop on Participatory Approaches to Research and Scaling Up held at Gigiri, United Nations Office in Nairobi (UNON) 21 April to 2 May.

Chianu, J.N. and Chirasha, M. (2008) "Meaningful farmer recommendations based on agronomic data". Power Point presentation at the AfNet Workshop on Participatory Approaches to Research and Scaling Up held at Gigiri, United Nations Office in Nairobi (UNON) 21 April to 2 May.

Chianu, J.N. and Chirasha, M. (2008) "Structural change in fertilizer procurement method: Assessment of impact in SSA". PowerPoint presentation at the AfNet Workshop on Participatory Approaches to Research and Scaling Up held at Gigiri, United Nations Office in Nairobi (UNON) 21 April to 2 May.

Fandika, I.R. and Zingore, S. (2008) The potential impact and adaptation to climate change on smallholder farms and food security in Shire Valley, Malawi. 2008. Proceedings of the CTA conference on Implications of climate change for sustainability of agricultural production systems, Ouagadougou, Burkina Faso October 2008.

Huising, J. (2008) Conservation and Management of Soil Resources for Sustainable Agricultural Production Landscapes, presentation given during the KSW 7-11 April 2008.

Kihara, J. Bationo, A. Waswa, B. and Okeyo, J. (2008) Tillage, rotation and surface residue effects on crop water productivity in Nyabeda, western Kenya, as modeled using DSSAT. Presented during CPWF workshop in Tamale, Ghana in September.

Kihara, J., Vlek, P., Martius, C., Amelung, W. and Bationo, A. (2008). Influence of conservation tillage on soil microbial diversity, structure and crop yields in sub-humid and semi-arid environments in Kenya. Proceeding paper presented during Tropentag November 2008, Stuttgart, Germany. Available online at http://www.tropentag.de/2008/proceedings/node408.html

Mairura, F.S. and Chianu, J.N. (2008) "Agricultural Markets and Improved Livelihoods in SSA". Power Point presentation at the AfNet Workshop on Participatory Approaches to

Research and Scaling Up held at Gigiri, United Nations Office in Nairobi (UNON) 21 April to 2 May.

Njuki, J. and Chianu, J. (2008) "Creation of markets for agricultural commodities". Power Point presentation during the CIAT's Knowledge Sharing Week, Cali, Colombia, 7 – 12 April.

Ohiokpehai, O. (2008) School Feeding: The role of processed legumes and nutrition. Presented at the Kenya College of Communication Technology, Mbagathi Campus, Nairobi, Kenya 29 June -1 July, 2008.

Ohiokpehai, O. (2008) Soybean Processing and Nutrition-GATES FOUNDATION - Tropical Legumes Project- Soybeans-East and Southern Africa sub regional annual meeting, Lilongwe, Malawi 20-22 August 2008.

Ohiokpehai, O. and Maina, A. (2008) The Effect of Climate Change on Food Processing and Packaging in smallholder Household. Presented at the IGBP Congress, Cape Town International Convention Center, South Africa, 5-9 May

Ohiokpehai, O., Maina, A. and Sanginga, N. (2008) Dolichos lablab: Soil and food potential and challenges. Presented at the International Dolichos (Lablab Purpureus) meeting and the International Symposium 'Underutilized Plants for Food, Nutrition, Income and Sustainable Development'. Arusha, Tanzania 2-7 March 2008.

Okoth, P., Huising, J., Ichami, S. and Mung'atu, J. (2008) Do forests preserve soil biodiversity? The case of five soil organisms in seven tropical countries. Poster presented during the SBSTTA meeting, 18-22 February 2008 in Rome. The same poster was presented during the KSW of CIAT.

# II.6. PROJECTS OPERATIONAL IN 2008

| ACTIVE TSBF BUDGET CODES – 2008 | | | | |
|---|---|---|---|---|
| | **Budget Code** | **Project title** | **Donor** | **Budget in 2008 (USD)** |
| 1 | TS01 | Integration CIAT-TSBF Holdback | CIAT | 30,000 |
| 2 | TS02 | CIDA-Funds to Africa | CIDA | 230,000 |
| 3 | TS10 | USAID's Funds to TSBF | USAID | 50,000 |
| 4 | TS15 | Bridging funds | CIAT | 79,000 |
| 5 | TSA25 | France CIRAD Scientist | MOFA - France | 30,000 |
| 6 | TSA30 | ICRISAT- Desert Margins Programme with GEF Local Areas on Biological Diversity with Relevance to Climate Change and the Reduction of Land Degradation in the desert Margin Areas | ICRISAT | 15,303 |
| 7 | TSA34 | Accelerating Prosperity of Rural Communities in the Umatara Province in Rwanda | IFAD | 15,958 |
| 8 | TSA36 | IDRC - Community-Based Interactive Learning and its Application to Soil Fertility Management (Kenya) Phase II | IDRC | 78,315 |
| 9 | TSA39 | Rural livelihood Diversified soil fertility | Sub-contract from CNFA | 75,325 |
| 10 | TSA42 | Scaling up livelihood impacts through farmer organization and access to market | KILIMO | 227,329 |
| 11 | 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 |
| 12 | TSA58 | IFDC - Combating Soil Fertility Decline to Implement smallholder Agricultural Intensification in Sub-Saharan Africa | Sub-contract from IFDC | 153,877 |
| 13 | TSA63 | WOTRO-More Cropping Per Dropping: Optimizing the Water and Nitrogen use efficiency $ Crop Residue Management for Water Conservation Agriculture | WOTRO | 17,308 |
| 14 | TSA67 | Increasing Total Farm Productivity in Vulnerable Production Systems in Mozambique through Improved Germplasm Water and Nutrient use efficiencies | AUSTRIA | 253,867 |
| 15 | 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 |
| 16 | TSA81 | RF - Exploring the multiple potentials of soybeans in enhancing rural livelihoods and small Industry in East Africa | Rockefeller Foundation | 226,243 |
| 17 | TSA83 | Building adaptive capacity to cope with increasing vulnerability due to climate change | Sub-contract | 31,200 |

| | | | | |
|---|---|---|---|---|
| | | | from ICRISAT | |
| 18 | TSA90 | DGDC - Enhancing the resilience of agro-ecosystems in Central Africa: A strategy to revitalize agriculture through the integration of natural resource management coupled to resilient germplasm and marketing approaches | DGDC | 1,039,605 |
| 19 | 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 |
| 20 | TSA96 | IDRC -Strengthening the capacity for research and development to enhance natural resources management and improve rural livelihoods in Sub-Saharan Africa | IDRC | 191,408 |
| 21 | TSA97 | Exploring measures to enhance the adaptive capacity of local communities to pressures of climate change | Sub-contract from UZ | 36,209 |
| 22 | TSA99 | Going to scale: Developing strategies for scaling out market-oriented organic from farmer group to associate level | Austria | 240,889 |
| 23 | 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 |
| 24 | TSB35 | Publishing of Books by the African Network for Soil Biology and Fertility (AfNet) | FARA | 20,000 |
| 25 | 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 | 6,786 |
| 26 | TSB39 | Increased understanding and application of Integrated Soil Fertility Management in Africa: Publication of a Reference Manual | Bill & Melinda Gates Foundation | 268,556 |
| 27 | TSB47 | Promoting Conservation Agriculture to Improve Land Productivity and Profitability among Smallholder Farmers in Western Kenya | KILIMO TRUST | 61,359 |
| 28 | TSB54 | A Globally Integrated African Soil Information Service (AFSIS) | Bill & Melinda Gates Foundation | |
| 29 | TSB57 | Building Impact Pathways for Improving Livelihoods in Musa-based Systems in Central Africa | Sub-contract from Bioversity-International | 203,000 |
| 30 | TSB59 | Strengthening Agrodealers Technical Capacity in Integrated Soil Fertility Management (ISFM):A case of Siaya and Mumias Districts in Western Kenya a Proposed activity of the Kenya Agrodealer Strengthening Project (KASP) | Sub-contract from CNFA | 104,650 |
| 31 | TSB63 | AGRA - Publishing of Book by The African Network for Soil Biology and Fertility (AfNet) for Use in the Development of the Soil Health Program of The Alliance for a Green Revolution in Africa | AGRA | 79,750 |
| 32 | TSB68 | Kano-Katsina-Maradi Pilot Learning Site KKM PLS | Sub-contract from INRAN | 20,000 |

| | | | | |
|---|---|---|---|---|
| 33 | TSB74 | Participatory Approaches to Research and Scaling up | CTA | 54,516 |
| 34 | TSB76 | Tropical Soil Biology Fertility Institute-Operations | IDRC | 47,876 |
| 35 | 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 |
| 36 | TSB82 | Efficient water and nutrient use in cereal grains systems in market based conservation agriculture systems | Sub-contract from IITA SSA-CP | 411,840 |
| 37 | 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 |
| 38 | TSB92 | Improving Farmers Livelihoods through the Adoption of Legume Based Soil Fertility Restoration Technologies in Kenya, Uganda and Tanzania | OPEC | 28,899 |
| 39 | TSB94 | Improving and Strengthening Rural Community Access to Agricultural and Soil Fertility Information in Korogwe District, Tanzania | CTA | 59,417 |
| 40 | TSB96 | Effects of Soil Fertility Interventions on Soil Aggregation and Organic Matter Incorporation and Stabilization: The Role of Soil Macrofauna | Sub-contract from UCLA | 11,590 |
| 41 | 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 |
| | | **TOTAL** | | **5,498,668** |

# II.7. STAFF LIST

**TSBF Institute – Africa Staff**

TSBF Institute -Director
Sanginga, Nteranya (Soil Microbiologist) (50%)

Senior Staff
Bationo, André (African Network Coordinator (Soil Scientist)) (50%)
Chianu, Jonas (Socio Economist) (75%)
Corbeels Marc (Soil scientist, modeler) (75%)
[1]Delve, Robert (Soil Fertility Management) (75%)
Huising, Jeroen (BGBD Coordinator (GIS Scientist)) (25%)
Jefwa, Joyce (Microbiologist) (100%)
Lesueur, Didier (Microbiologist) (100%)
Ohiokpehai, Omo (Food & Nutrition Scientist) (100%)
Pypers, Peter (Soil scientist) (100%)
Misiko, Michael (Social Scientist) (75%)
Roing, Kristina (Agronomist) (50%)
Thierfelder, Christian (Soil and Water management) (50%)
Vanlauwe, Bernard (Soil Scientist) (75%)
Gert Jan Veldwisch (Soil Scientist) (25%)
Zingore Shamie (Soil Scientist) (50%)

Consultants
Woomer, Paul (Soil Scientist. ISFM project) (100%)

Research Assistants
Akech, Caren (Research Asst) (50%)
Kankwatsa, Peace (Research Asst, Kampala) (100%)
Kasareka, Bashikwabo (Research Asst, DR Congo) (100%)
Lodi-Lama, Jean-Paul (Agronomist, DR Congo) (100%)
Lunzihirwa, Julie (Research Asst, DR Congo) (100%)
Maina, Fredah (Asst Scientific Officer) (50%)
Mairula, Franklin (Data Analyst)
Magreta, Ruth (Research Asst, Lilongwe) (50%)
Mapila, Mariam A.T.J. (Research Fellow, Lilongwe) (100)
Mombeyarara, Talkmore (Research Asst, Harare) (50%)

Technical Staff
Chibole, Livingstone (Field Technician) (100%)
Dzvene, M (Field Asst, Harare) (50%)
Kadzere, Chengetai (Field worker, Harare) (50%)
Kingolla, Brenda (Field Asst-Food Nutrition) (100%)
Kimathi, Martin (Laboratory Assistant) (75%)
Mburu, Harrison (Lab Assistant-Microbiology) (100%)
Mugadi, Doreen (Lab Technician-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%)
Muranganwa, Francis (Field worker Harare) (50%)

Administrative Staff
Agalo, Henry (Driver / Field Assistant) (50%)
Akuro, Elly (Driver / Field Assistant) (50%)

[1] Left during the year

Mukalama, John (Snr Scientific Assistant) (100%)
Okeyo, Jeremiah (Research Asst) (50%)
Rusinamhodzi, Leonard (Research Asst, Harare) (50%)
Sanginga, Jean-Marie (Research Asst., DR Congo) (100%)
Waswa, Boaz (Asst Scientific Officer) (50%)
[1]Speciose Kantengwa (CIALCA Coordinator, Rwanda) (100%)

Chisvino, Stephen (Driver/OA, Harare) (50%)
Kareri, Alice (Administrator) (50%)
Kuya, Sebastien (Driver/Technician, DR Congo) (100%)
Meyo, Rosemary (Administrative Assistant) (50%)
Mulogoli, Caleb (Finance/IT Asst) (50%)
Mutende, Oscar (Finance Assistant) (50%)
Mary Nderitu (Finance Assistant) (50%)
Ngwira, Evelyn (Accounts Asst, Lilongwe) (50%)
[1]Ngutu, Charles (Finance/Admin. Officer) (50%)
Nomsa Nhaoinesu (Admin Asst., Harare) (50%)
Nyamhingura, Isabella (Admin. Asst, Harare) (50%)
Odongo, Jacqueline (Administrative Asst.) (50%)
Ogola, Juliet (Snr Administrative Asst.) (50%)
Sambo, Margaret (Admininistrative Asst) (50%)

## II.8. SUMMARY BUDGET

| SOURCE | AMOUNT (US$) | PROPORTION (%) |
|---|---|---|
| Unrestricted Core | 389,000 | 7% |
| Restricted Core | 0 | 0% |
| **Sub-total Core** | **389,000** | **7%** |
| **Restricted** | | |
| Special projects | 3,635,329 | 66% |
| Sub Sahara Africa Challenge Program- | 417,349 | 8% |
| Water and Food Challenge Program | 52,425 | 1% |
| **Sub Total Restricted** | **4,105,103** | **75%** |
| **Direct Expenditures** | **4,494,103** | **82%** |
| Non Research Cost | 986,511 | 18% |
| **Total Expenditures** | **5,480,614** | **100%** |

# III. Progress against output targets 2008 – 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.<br>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).<br>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 **(Figure 3)**.

*Major research questions are:*

→ *Which quick, cheap, and widely applicable approaches can be used to diagnose soil fertility-related constraints to enhanced productivity?*

→ *Which interventions that increase resource use efficiencies are available for evaluation?*

→ *What is the role of improved germplasm in regarding the soil fertility status, relative to the use of mineral and organic inputs?*

→ *Which are the mechanisms underlying interactions between various growth factors (water, fertilizer, organic resources, etc) resulting in enhanced use efficiencies of each of those factors?*

→ *Which food quality indicators are sensitive enough to assess yield quality?*

| 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. |

## COMPLETED WORK

### 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.

**Wasike[1,2,3], V.W., Lesueur[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.**
*[1]Kenya Agriculture Research Institute, Kenya; [2]CIAT-TSBF, Kenya; [3]Egerton University, Kenya; [4]CIRAD and [5]TSBF - CIAT, Kenya*

**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

### Genetic diversity and effectiveness of indigenous Bradyrhizobium strains and their potential to fix nitrogen under greenhouse conditions.

**V. Wasike[1], D. Lesueur[1], B. Vanlauwe[1]**
*[1] TSBF - CIAT, Kenya*

## Introduction

Currently in Kenya, the cost of Diamomnium Phosphate (DAP), an inorganic N and P source commonly used in crop production in the country is in excess of $ 1000 per ton at farm level. Hence the need to use promiscuous soybean in Kenya due to their capacity to nodulate and fix N with a population of indigenous bradyrhizobia. In Brazil, benefits resulting from the use of inoculants with selected superior indigenous strains are equivalent to about $ 3 billion per cropping season that would otherwise go to purchase, transportation and application of nitrogenous fertilizers (Hungria et al. 2005). Farmers generally cannot afford or access inorganic sources of N or inoculants respectively, identification of effective locally adapted Bradyrhizobia strains which nodulate promiscuous soybean could be useful in the development of inoculant strains which survive longer in the soil and hence reduce the need for inoculant application each growing season. From a previous activity of this project, genetic diversity and phylogeny of indigenous Bradyrhizobia strains nodulating seven introduced promiscuous soybean varieties grown in two sites differing in agro-ecological zones and soil chemical characteristics in Kenya using PCR RFLP of the 16S-23S rDNA intergenic spacer region and 16S rRNA gene sequencing revealed considerable (18 IGS groups) genetic diversity. When tested in sand on promiscuous soybean varieties, an elite sample from this diverse population of strains produced significantly more biomass when tested on TGx 1895-33F and TGx 1740-2F, than the control strains USDA 110 currently used in Kenyan inoculants. These strains need to be further tested in soil to determine their effectiveness and competitiveness against background rhizobia and against each other in order to recommend them or not as suitable for use in inoculants. The objective of this experiment was to determine the effectiveness and competitiveness of elite indigenous *Bradyrhizobium strains* in soil.

## Materials and methods

Two elite strains (TSBF 442, TSBF 531) and a control strain (USDA 110) previously reported to be to be more effective and belonging to different IGS groups were selected **(Table 4)**.

**Table 4: Selected strains as described by IGS groups and phylogeny based on partial 16S rRNA gene sequence analysis.**

| Trt | Code | Site* | Cluster** | Species affiliation | IGS group |
|---|---|---|---|---|---|
| 1 | TSBF-531 | 1 | C | *Bradyrhizobium sp.* | I |
| | TSBF-442 | 2 | A | *B. elkanii* | III |
| | USDA 110 | - | - | *Bradyrhizobium japonicum* | - |
| 2 | - ve control | - | - | - | - |
| 3 | + ve control (70 ppm N) | - | - | - | - |

*1= Mitunguu, 2 = Bungoma

**= These were the major clusters of strains isolated from the Bungoma and Mitunguu sites)

A both mixture of these strains was then inoculated on three varieties' seedlings, TGx 1895-33F) and TGx 1740-2F and Nyala, planted in autoclaved and non autoclaved soil. Before planting, seed was surface sterilized by immersion in 3.3% Calcium hypochlorite solution for 3-5 minutes and then washed with six changes of double distilled water to remove excess disinfectant. These were then pre-germinated in 75 % water agar for 5 days. Autoclaving was done at 121 $^{0}$C or 20 minute to soils sampled from Bungoma, Mitunguuu and Nakuru sites.

Cultures of various indigenous bradyrhizobia cultured from nodule suspension was serially streaked to obtain respective pure cultures. The control strain (USDA 110) obtained from KEFRI was included. These were then individually grown in broth culture until logarithmic phase mixed in equal proportions. 5 day old seedlings were each inoculated with 3ml/plant of the mixed broth culture in 2 kg polythene bags arranged. A negative and positive (70ppm N) control and strain (USDA 110) were included for comparison in a strip-plot design replicated four times in the greenhouse. These bags were kept at field capacity by alternate day watering with double distilled water and brought on solution until harvest. Harvesting was done at flowering stage for each variety. At harvesting all the plants (3/bag) were cut at ground level, nodules counts recorded from roots and fresh biomass weighed. Data on nodule number (NN), nodule dry weight (NDW), biomass shoot dry weight (BDW) were recorded. All samples were dried to constant weight for 48 hrs of at 70$^{o}$ C. Biomass shoot dry weight produced in this nitrogen free growth system was used as a proxy for nitrogen fixation.

**Preliminary results**

There was a significant interaction between strain treatments and varieties on nodulation and nodule dry weights **(Figure 4 and 5)** in general, strains produced significantly more nodules on SB 19 than Nyala **(Figure 4)**.
There was a significant interaction between soil treatment (autoclaved versus non autoclaved) and varieties on shoot dry weights. Overall, varieties inoculated with strains in non autoclaved soil produced significantly more biomass than in autoclaved soil **(Figure 7)**. This may be due to altered soil chemistry occasioned by autoclaving soil.
The interaction of strain treatments and variety was significant at (P=0.07) indicating that "elite" were more effective on some varieties (Nyala) but not others **(Figure 6)**. Since the "elite" was applied as broth composed in equal proportions of three different strains (TSBF 531, TSBF 442 and USDA 110). It is possible that some of these constituent strains had more competitive nodulation in soil on certain varieties than others. Besides, it is necessary to determine which strains constitute nodules in Nyala, a variety with north American genetic background bred to nodulate with specific (*B. japonicum*) bradyrhizobia.

**Preliminary conclusions**

The tendency for elite strains to produce more biomass on Nyala than promiscuous soybean varieties may suggest a better competitive ability of USDA 100 than indigenous bradyrhizobia. This needs to be confirmed by analysis of these nodules to determine nodule occupancy in different varieties.

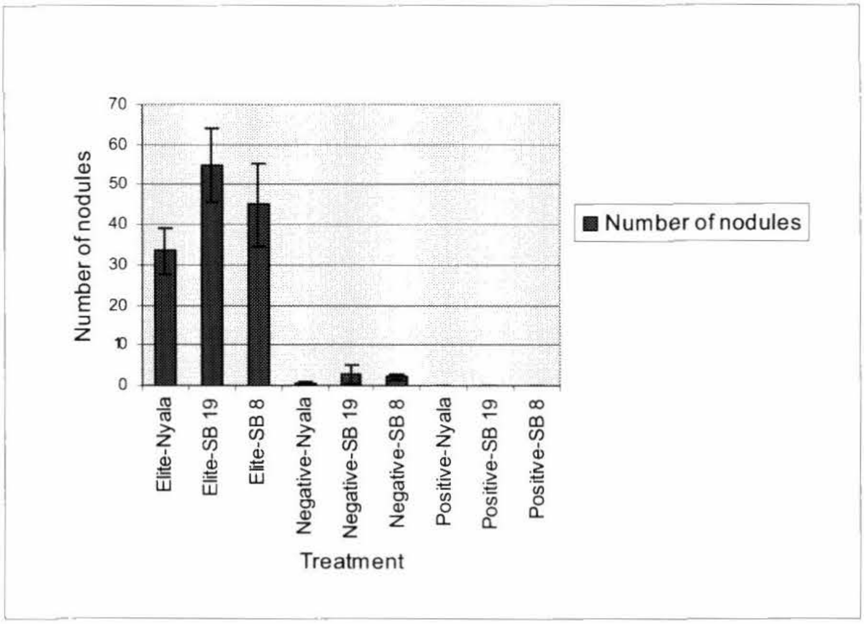



**Figure 4: Interaction between strain treatments and varieties on nodulation across soil treatments and sites. Elite: A combination of three strains (TSBF-531, TSBF-442 and control strain USDA 110); Positive: 400 mg $NH_4NO_3$ applied to 2 kg in soil (70 ppm); Negative: No applied nutrients; SB 8 and SB 19 are promiscuous soybean varieties while Nyala is a specific variety).**

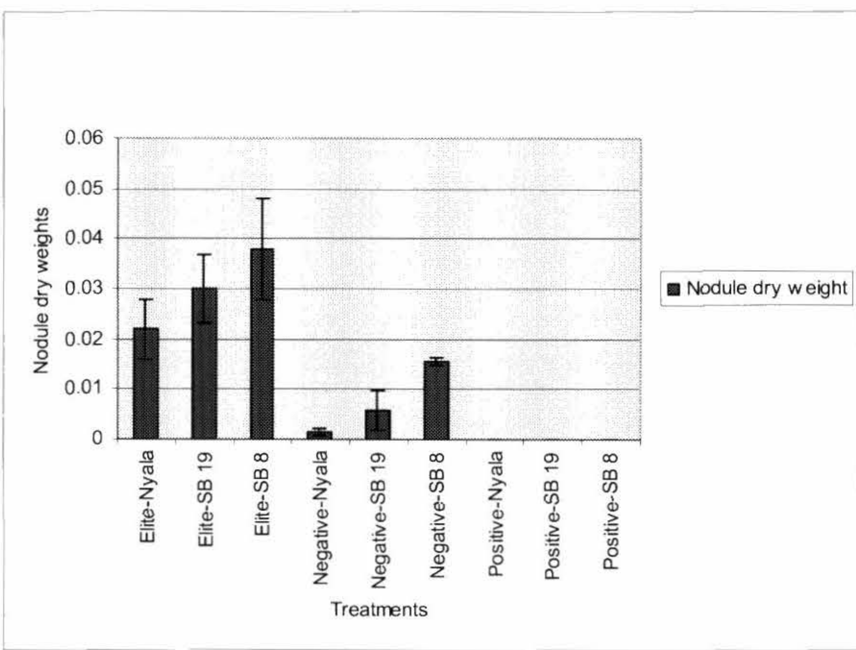



**Figure 5: Interaction between strain treatments and varieties on nodule dry weights across soil treatments and sites. Elite: A combination of three strains (TSBF-531, TSBF-442 and control strain USDA 110); Positive: 400 mg $NH_4NO_3$ applied to 2 kg in soil (70ppm); Negative: No applied nutrients; SB 8 and SB 19 are promiscuous soybean varieties while Nyala is a specific variety).**

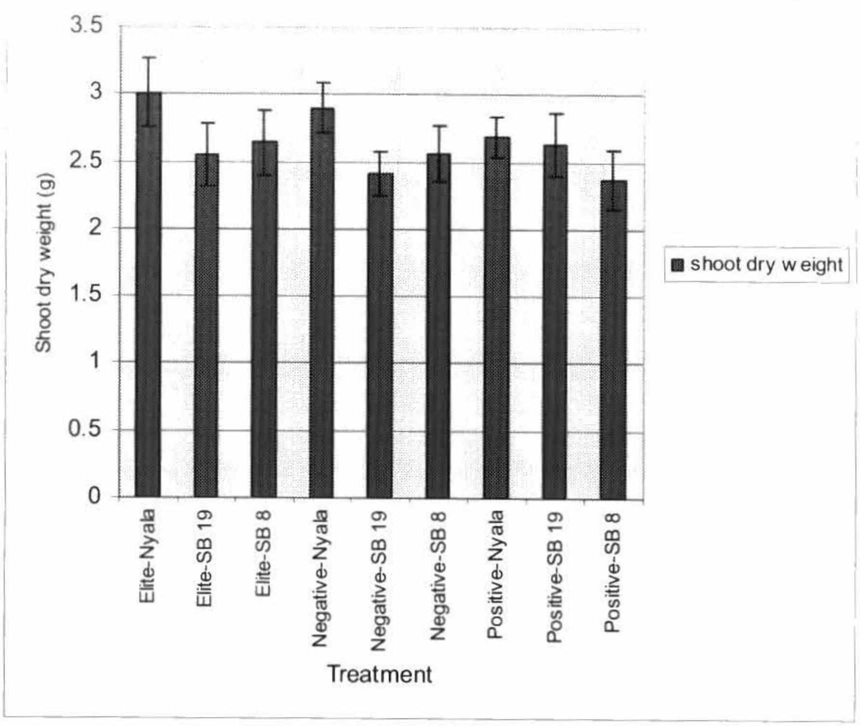



**Figure 6: Interaction between strain treatments and varieties on nodule shoot dry weights across soil treatments and sites. Elite: A combination of three strains (TSBF-531, TSBF-442 and control strain USDA 110); Positive: 400 mg $NH_4NO_3$ applied to 2 kg in soil (70ppm); Negative: No applied nutrients; SB 8 and SB 19 are promiscuous soybean varieties while Nyala is a specific variety).**

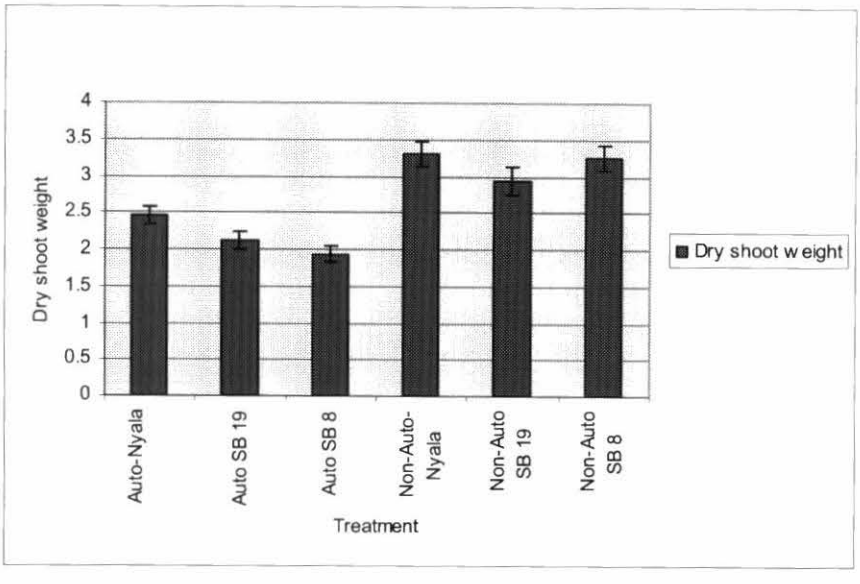



**Figure 7: Interaction between soil treatments and varieties on shoot dry weights across sites. Auto connotes soils that were autoclaved at 121 ° C for 30 minutes while Non-Auto represents soils which are not autoclaved; SB 8 and SB 19 are promiscuous soybean varieties while Nyala is a specific variety).**

## Evaluation of status of AMF in banana farms and the effect of AMF in establishment of TC banana plantlets in Rwanda.

**J. Jefwa[1], E. Rurangwa[2], B. Vanlauwe[1]**
*[1]CIAT – TSBF, Kenya; [2]ISAR, Rwanda*

### Introduction

Arbuscular mycorrhizal fungi have potential to improve the performance of tissue cultured bananas in poor soils. The magnitude of response may vary between species and within species. This was confirmed by a greenhouse experiment set up to determine dependency of different tissue culture cultivars on different AMF isolates. Inoculation trials on TC banana cultivars and AMF use exotic species. There is no information on AMF the performance of TC bananas inoculated with AMF associated with bananas neither has there been field trials on banana and indigenous AMF species. AMF species associated with banana may be more efficient than introduced AMF species. This project will use AMF inoculum (mixed and single) isolated from banana plantations

*Survey (year 1)*
Soil samples and banana roots samples from Kibungo and Rubona were evaluated for AMF composition and colonization.
A total of 8 AMF species were isolated from two soil samples from the rhizosphere of bananas in Rwanda comprising of two *Acaulospora* species, three *Glomus* species one of which is sporocarpic and three *Scutellospora* species. Assessment of AMF composition in all banana study sites (TSBF/IITA) is still in progress.
Mycorrhizae colonization of banana roots was established under natural field conditions. Entry points were evident indicating fungal point of entry at the surface of the roots **(Figure. 8a)**. The presence of entry points signifies that AMF propagules are viable and active. The most dominant characteristic of colonization was arbuscules, clearly indicating active phase of nutrient uptake of AMF **(Figure. 8b).** Banana roots were also infested by nematodes **(Figure 8c)** under field conditions. There is some indication of exclusion of nematodes by AMF and vise versa as shown on **(Figure 8b and 8c).**

**a** **b** **c**

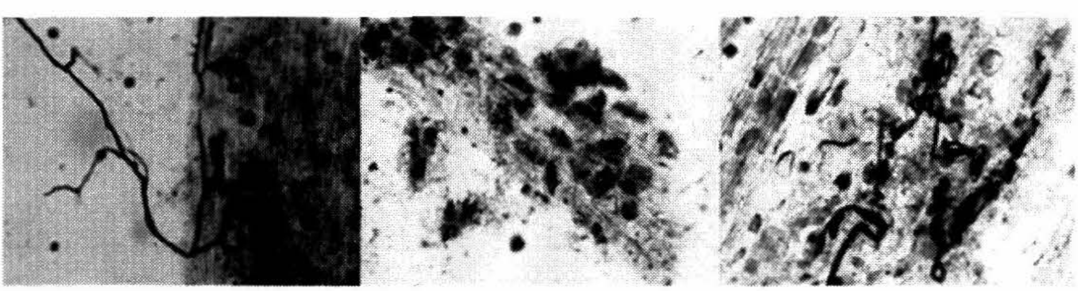


**Figure 8 a, b and c: AMF Colonization with (8a) entry point into the root by hyphae and the initial spread of AMF hyphae into the root and (8b) arbuscules confined in the cell characterized by deep blue staining in plant cells and (8c) root infestation by nematodes.**

## Materials and methods

*Multiplication of AMF (year 1 + year 2 + year 3)*

Trap cultures were initiated with soils collected from the rhizosphere of banana farms in Kibungo and Rubona. The mixed cultures were initiated at the National Museums of Kenya (NMK) and bulked up at Jomo Kenyatta university of Agriculture and Technology (JKUAT) and the single culture was prepared in Belgium. *Sorghum bicolor* was used as the trap plant for the two soils a period of four months. This was followed by bulking/multiplication of AMF inoculum with *Allum sepa* (leek) used as the host plant to bulk-up and sustain the cultures for two months before inoculation. Approximately 100 g of soils from the Sorghum traps, containing infected root fragments, mycelia and spores, was used as a sandwich layer on a 4:1 mixture of sand: cotton black soil (soil analysis still in progress). Trap cultures were also set up to generate fresh spores and also recover from the soils spores of AMF species that had not sporulated at the time of sampling from the field. Percentage AMF colonization was between 50-70% in sorghum and 70-90 % in leek. Young spores, mycelia and infected root fragments were recovered during inoculation. Trap cultures for evaluation of AMF species were left longer to allow for sporulation. This process is still in progress.

The Inoculum for use in the Tissue culture banana experiment was obtained after two months as mixed inoculum of soils with young spores, mycelia and infected root fragments. The inoculum potential of the two mixed inoculants was evaluated in an infectivity test experiment where a comparison was made with single spore cultures of *Glomus mosseae* generated from Katholieke University Leuven and fresh soils from sites where the field experiment was to be established (Kibungo and Rubona).

*Screen house activities*

*Testing of AMF (year 2 + year 3)*

Experiment was established to test the indigenous AMF inoculants. Two tissue cultured banana cultivars, Mpolongoma (cooking) and Kamaramasenge (desert) were selected for evaluation of AMF. The plantlets were purchased from AGROGENETICS lab Uganda. Inoculation of the TC bananas was done at hardening stage and plants maintained under high humidity polythene structure for a period of 8 weeks. At the time of inoculation, banana plantlets were stressed due to transportation and prolonged storage. Four weeks later the banana plantlets had recovered and were much better in appearance.

*Evaluation of the Inoculum Potential (IP) or Infectivity of three inoculants (single spore, and Mixed inoculants with origin from Kibungo and Rubona.*

*Evaluation of the infectivity of three AMF species in two different soil types*

The objective was to evaluate the mycorrhizal inoculum potential of inoculants and soils from sites where inoculation trial will be established. This experiment was to establish whether there is need to inoculate banana plantlets prior to field establishment. Two banana cultivars (Kamaramasenge and Mpolongoma) were used as test plants. This was to verify whether some banana cultivars would differ in their requirements for inoculation.
This experiment comprised of 5 test soils (three inoculants and two non-sterile field soils) at three levels of dilutions (full dose, half dose) and two banana cultivars. To guarantee uniformity, sand was used as the diluent. Plantlets were established in basins of approximately 15 cm diameter with each containing 10 plants (five per cultivar).
Treatments included three AMF (single species and 2 mixtures) and two non-sterilized soils; 2 banana cultivars at three dilutions. The total volume of soils per basin was 1200ml. The

Amount of inoculum was: full strength (1200ml), half strength (600ml) and quarter strength (300ml). Sterilized Sand was used as diluent added at 0,600 and 900 ml respectively.
This experiment was terminated 8weeks after inoculation,

*Characteristics of Inoculants*

AMF mixed inoculants Kibungo and Rubona were derived from soils collected Kibungo and Rubona and inoculum prepared and bulked up at the National Museums of Kenya (NMK) and Jomo Kenyatta University of Agriculture and Technology (JKUAT). In this experiment, they are referred to as Kibungo and Rubona. *Glomus mosseae* was single species also derived from Rwanda but prepared at KU Leuven.

The Inoculum potential of the inoculants was evaluated using the two banana cultivars to establish the strength. Alongside the inoculants, the inoculum potential of soils from selected sites for field trial establishment of the TC banana plantlets was also evaluated.

There were significant differences between the AMF innoculum potential ($P<0.001$ and LSD value of 7.93) **(Figure 9).** Mixed inoculum Kibungo and Mixed inoculum Rubona had higher infectivity compared to single spore culture *Glomus mosseae*. The fresh soils from the two sites (Kibungo original and Rubona original) had low infectivity.

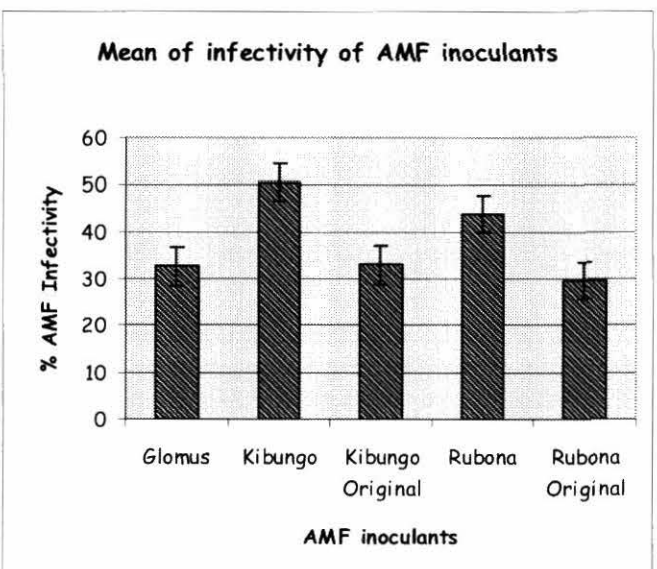



**Figure 9: AMF infectivity of three inoculants (Glomus, Kibungo and Rubona) and two freshly collected soils (Kibungo original and Rubona original) from banana growing sites.**

To further determine the strength of each inoculum, the dilution (Mycorrhizal soil infectivity (MSI) test) experiment was conducted with the soils concentrations comprised of full, half and quarter dose diluted into half and quarter strength, hence concentrations comprised. Main effects showed full, half and quarter not to differ significantly ($p= 0.722$, LSD 6.86) in infectivity **(Figure 10).** Further dilutions of the inoculants to more concentrations are therefore necessary to capture the differences in infectivity. In this experiment, the limiting factor to evaluating more dilutions was availability of banana plantlets. A comparison of the inoculum potential of the AMF treatments at three different concentrations showed mixed inoculants (Kibungo and Rubona) to still maintain higher soil infectivity and the decline in soil infectivity with dilution to be more pronounced in single spore culture (Glomus) **(Figure**

**13)**. Soils fresh from the sites of banana growth (Kibungo original and Rubona original), though low in infectivity, were less affected by dilution. The low infectivity is however, indicative that banana plantlets may be inoculated prior to establishment at these sites.

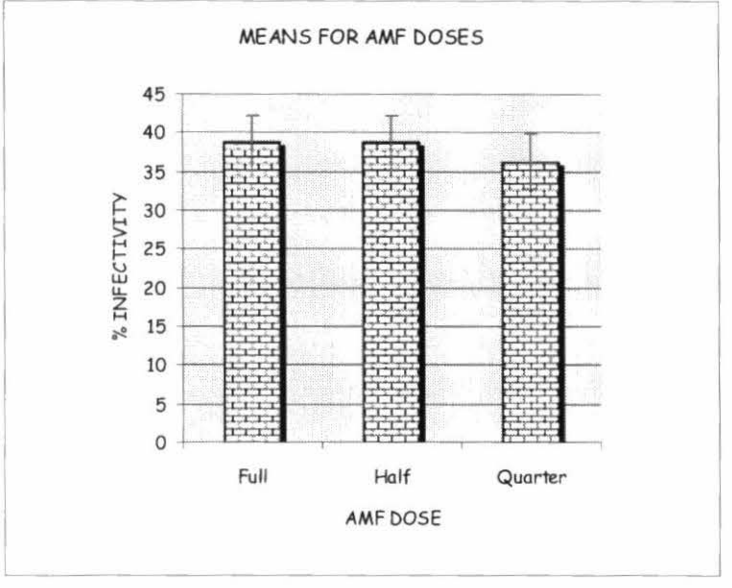



**Figure 10: Summary of infectivity of the three strengths (full, half, quarter dose concentration)**

The main effects of the doses was not significant, this was however not the case when Individual inoculants were evaluated. The infectivity of a dose was dependent on the type of inoculum and soils. There were differences in infectivity with dilutions, with trends showing some inoculants not affected (Kubungo original and Rubona original) while some declined and one increased in infectivity with dilutions **(Figure 11 ).** Single spore inoculum was the most affected by dilution indicating lowest AMF infectivity, whereas fresh soils from banana growing sites were least affected. Although the infectivity of mixed inoculum prepared from soils collected from Kibungo declined with dilution, it still retained higher infective potential than single spore inoculum. For some reasons, the infectivity of mixed inoculum originating from Rubona increased with dilution. A slight increase in infectivity was also noted in fresh soils from Rubona.

Evaluation of inoculum potential of the three inoculants and field soils as detected by the two banana cultivars showed the banana cultivars not to differ in infectivity ($p = 0.26$ and LSD = 7.89) **(Figure12).** Mixed inoculum prepared from soils collected from Kibungo followed by mixed inoculum prepared from soils collected from Rubona maintained the highest infectivity in both banana cultivars while the fresh soils from the same sites (Kibungo original and Rubona original) and *Glomul mosseae* had the least infectivity detected by the two banana cultivars. Except for original soils from Rubona, Mpolongoma detected higher infectivity than Kamaramasenge.

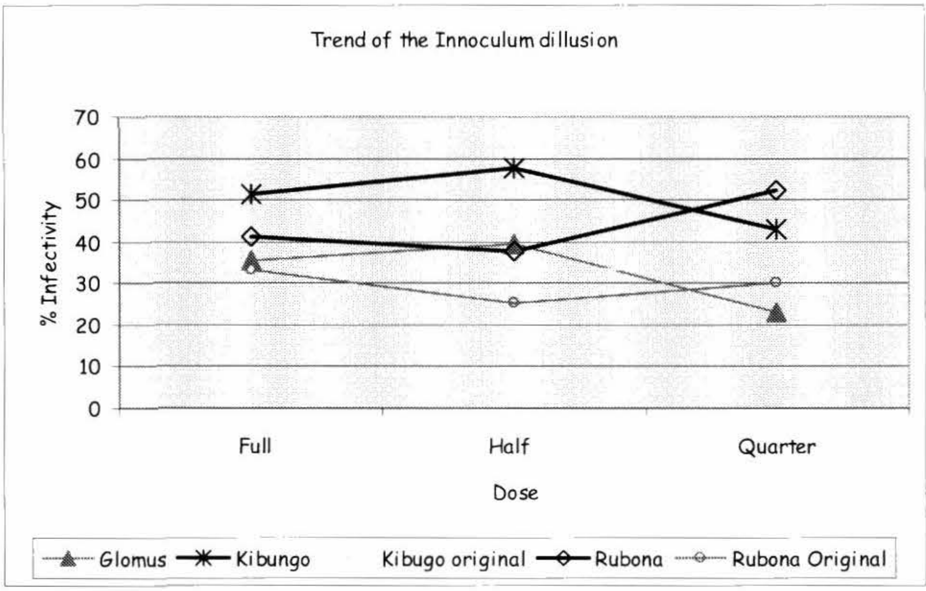



**Figure 11: Trends in inoculum potential of one sigle inoculum (Glomus), two mixed inoculants (Kibungo and Rubona) compare with fresh soils from two banana growing regions (Kibungo original and Rubona original).**

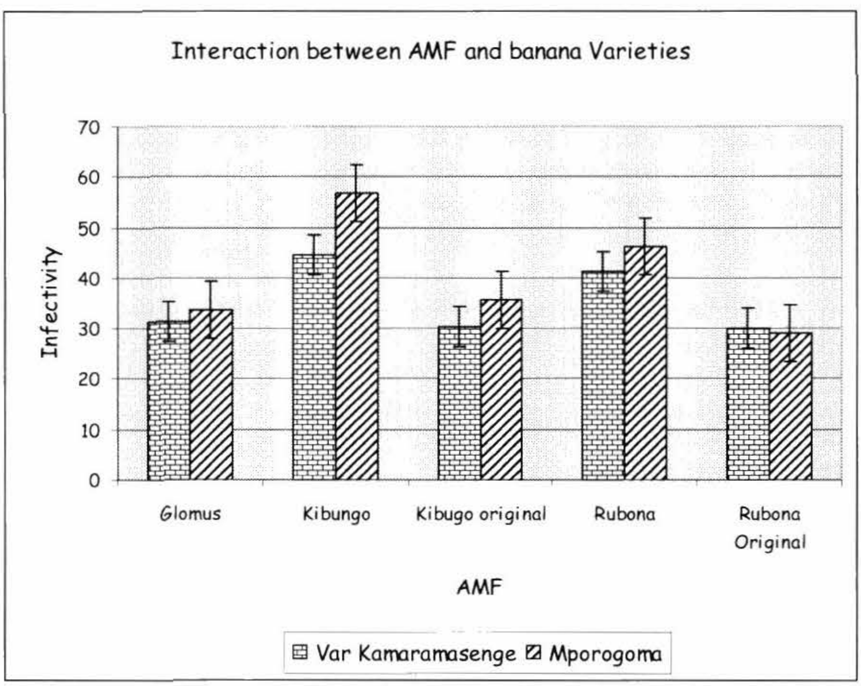



**Figure 12: Mycorrhizal soil infectivity of three inoculants and two field soils detected by two banana cultivars.**

effect of AMF inoculants on growth performance was dependent on the banana cultivar **(Figure 16a-d).**

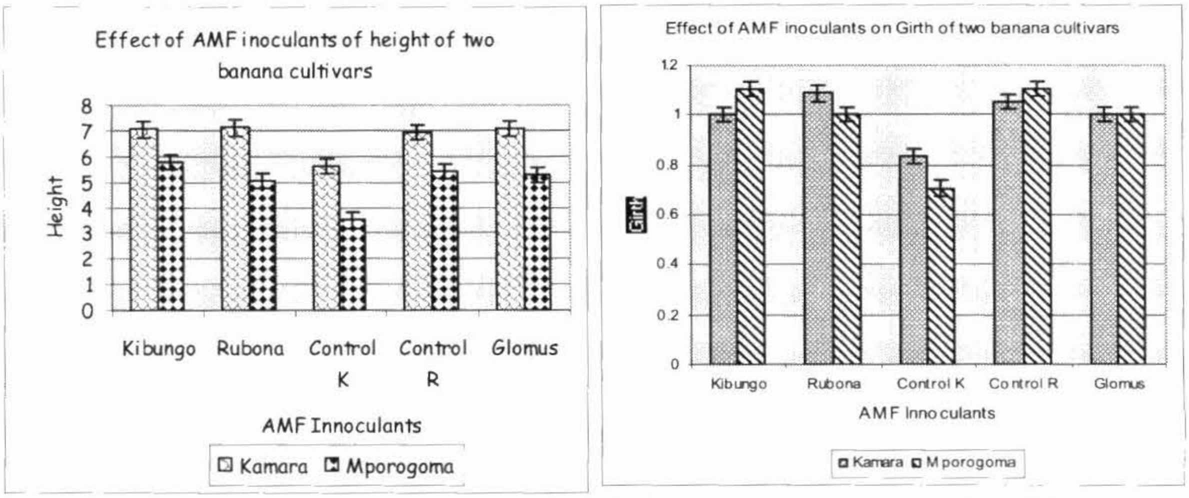



**Figure 15: Effect of AMF inoculants on height, girth, leaf surface area and leaf number of the two banana ciltivars.**

Evaluation of trends shown on (**Figure 16**) on the performance of banana cultivars from 8 weeks after planting to 18 weeks after planting showed fresh soils from Kibungo to consistently have the least effect on height, girth, leaf surface area and number of leaves of the banana cultivar Mpolongoma. Mixed inocullants from Rubona and Kibungo were more effective at improving one or more plant growth parameters. The single species inoculum, *Glomus* was at the lower end of the growth curves for all the four parameters evaluated. Establishment of the banana cultivar Mpolongoma in Kibungo soils seemed to perform better when inoculated as is evident with inoculation with mixed inoculum Kibungo. Mpolongoma seemed to establish better without inoculation in fresh soils from Rubona than soils from Kibungo whereas Kamaramasenge performed well without inoculation but much better with inoculation with the mixed inoculants.

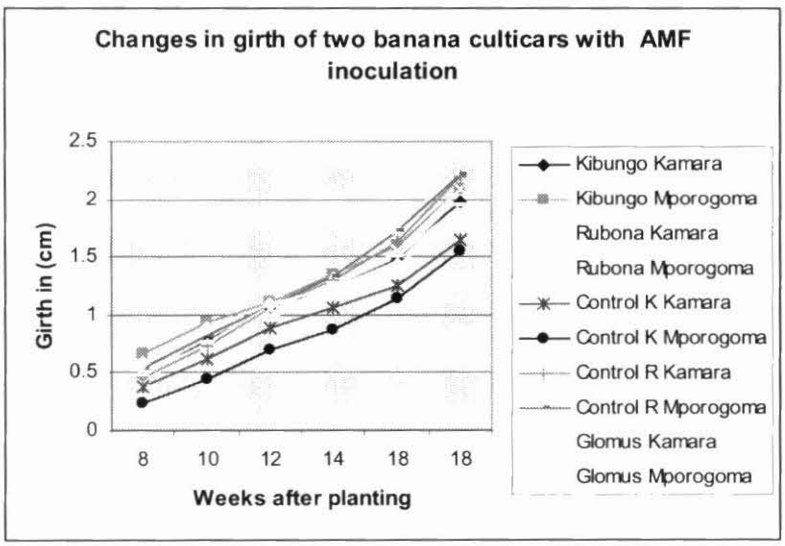



**Figure 16a: Trends in girth of two banana cultivars inoculated with AMF inoculants.**

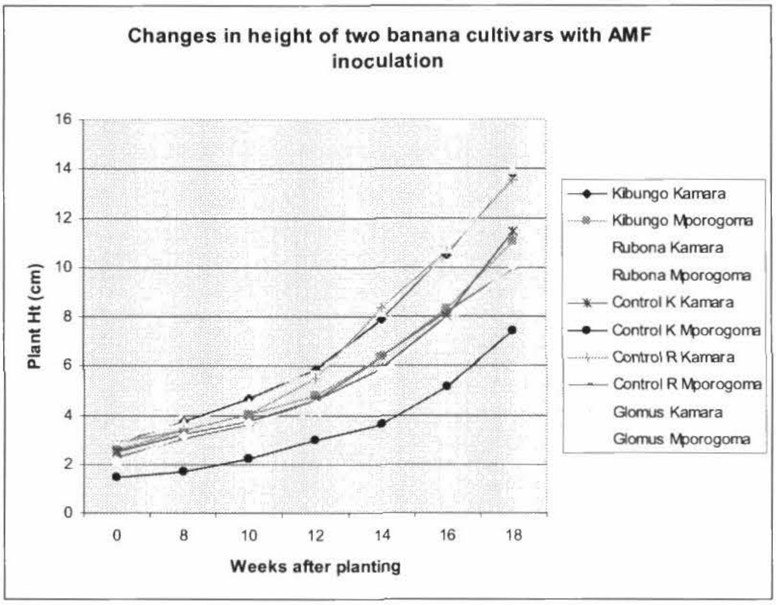



**Figure 16b: Trends in height of two banana cultivars inoculated with AMF inoculants.**

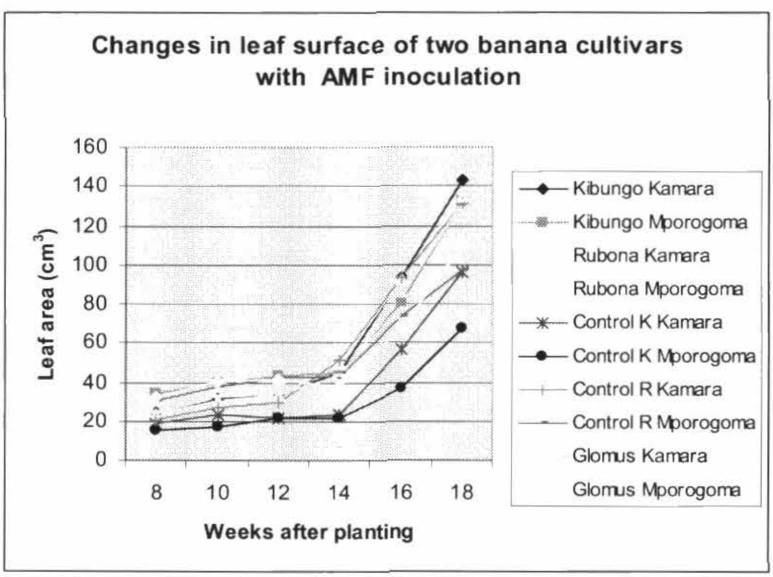



**Figure 16c: Trends in leaf surface area of two banana cultivars inoculated with AMF inoculants.**

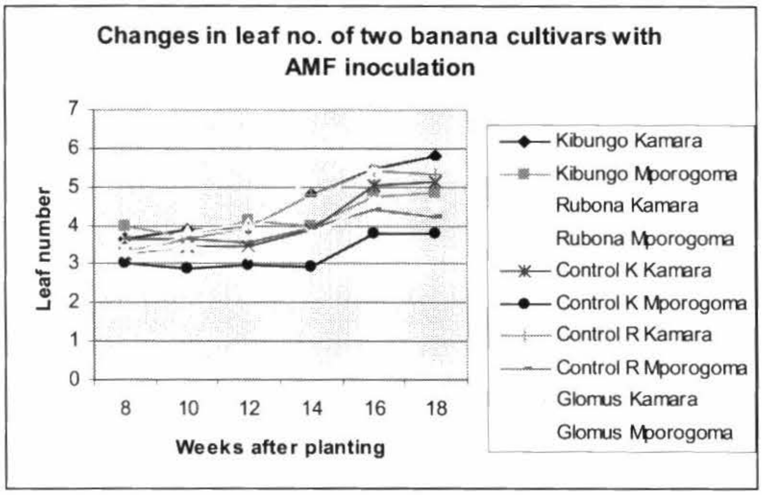



**Figure 16d: Trends in leaf number of two banana cultivars inoculated with AMF inoculants.**

**Preliminary results**

Indigenous mixed AMF inoculum was more infective than indigenous single culture inoculum. The potential of single spore inoculum was comparatively less than the mixed culture inoculum. Soils from Kibungo seemed to be less responsive to inoculation irrespective of the banana cultivar whereas soils from Kibungo responded mor to inoculation. This was more evident with the cooking banana cultivar Mpolongoma than the desert banana cultivar Kamaramsenge.
The experiment is still in progress and plants have been established in the field at ISAR field stations in Rubona and Kibungo. Monitoring of survival upon establishment, performance and resistance to pests and diseases is being evaluated.

## Test existing soybean varieties and lines for their drought tolerance, promiscuity, disease resistance, low P tolerance, and processing/nutritional quality

**B. Vanlauwe[1], J. Mukalama[1], and V. Wasike[1]**
*[1]TSBF - CIAT, Kenya*

**Introduction**

Twenty elite, early to medium maturity, soybean lines evaluated for drought tolerance, promiscuity, disease resistance, low P tolerance, and processing/ nutritional quality, using farmer participatory approaches (Nov 07- Nov 09)

*Select existing varieties*
Existing varieties and elite lines were selected for evaluation in on-station mother trials in Kenya (**Table 3**). The categories of these genotypes are (i) varieties and elite lines from IITA, (ii) varieties and promising lines developed by the NARS, (iii) varieties and/or lines that had been tested and found best during earlier work in Kenya, led by CIAT – TSBF and KARI, and (iv) widely available 'local' materials. The basis of selection of test genotypes from the IITA soybean breeding program was based on a prior superior performance in West-Africa.

**Table 3: Soybean varieties and elite lines selected for on-station (mother) trials in Kenya.**

| | |
|---|---|
| Promiscuous varieties | TGx 1440-1E |
| | TGx 1448-2E |
| | TGx 1485-1D |
| | TGx 1740-2F |
| | TGx 1835-10E |
| | TGx 1871-12E |
| | TGx 1889-12F |
| | TGx 1893-10F |
| | TGx 1895-33F |
| | TGx 1895-49F |
| | TGx 1903-1F |
| | TGx 1908-8F |
| | TGx 1910-14F |
| | TGx 1951-4F |
| | TGm 1420 |
| | TGm 1360 |
| Other varieties | 931/5/34 |
| | 915/5/12 |
| | 917/5/16 |
| Local checks | Sable |
| | Nyala |
| | Gazelle |

*Develop detailed protocols for researcher managed trials*

A research protocol for the researcher-managed field trials was developed in collaboration with all partners to be followed in all trial sites. The protocol describes details related to the layout, observations, and farmer evaluation. The protocol also contains a standardized data reporting template. The detailed protocol was included as an annex to an earlier progress report.

*Implementation of the researcher-managed trials*

In Kenya the trial was implemented in Nyabeda (1200 masl, 1400 mm annual rainfall), western Kenya on the 30$^{th}$ March 2008 (with the 'late planting' treatments established on 12 May 2008).

*Results*

Information on the germination and time to flowering was presented in an earlier report. In this report, the focus is on grain yield, biomass accumulation, nodulation properties, and disease scoring.

*Grain yield*

In absence of P and with optimal planting, soybean grain yield of the local varieties (Gazelle, Nyala, Sable) varied between 715 and 1094 kg/ha **(Figure 17)**. Application of P increased the yields to between 1033 and 1523 kg/ha. The varieties developed by KARI (931/5/34; 915/5/12; 917/5/16) performed within similar ranges while the dual purpose varieties produced, on average slightly below above levels. Obviously, grain yield of the varieties that were planted late was negligible due to drought stress **(Figure 17)**.

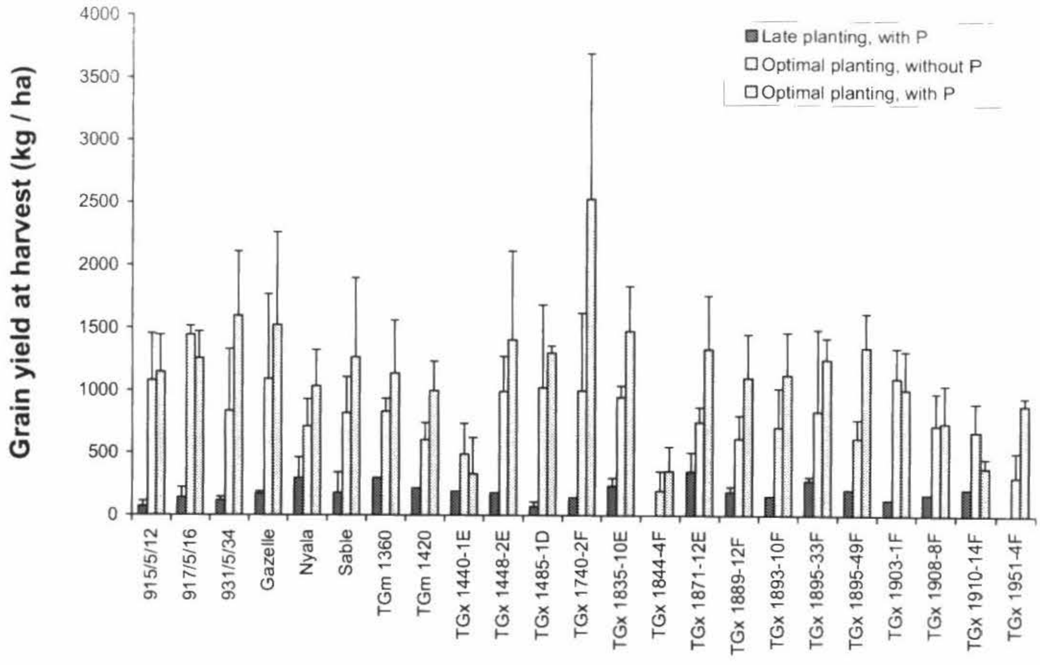



**Figure 17: Soybean grain yield during the long rainy season of 2008 as affected by the imposed treatments for the varieties retained in the Sidada trial, western Kenya. Error bars are standard deviations.**

To evaluate the tolerance of varieties to low soil P, **(Figure 18)** depicts grain yield with P application against grain yield without P application for the Kenya trial. It is important to note that ideal varieties are those that produce relatively high yields under low P conditions and that still respond to fertilizer P application. Varieties that occur in the top right side of the graph are those that score best against tolerance to low P and that can also show further response to P application, depending on the distance above the 1:1 line depicted in **(Figure 18)**. The 3 KARI varieties occured in this part of the graph and only 1 of these also showed response to P. Of all promiscuous varieties, only TGx 1448-2E and TGx 1835-10E showed relatively high grain yields without P and a further response to P. TGx 1903-1F showed only tolerance to low soil P **(Figure 18).**

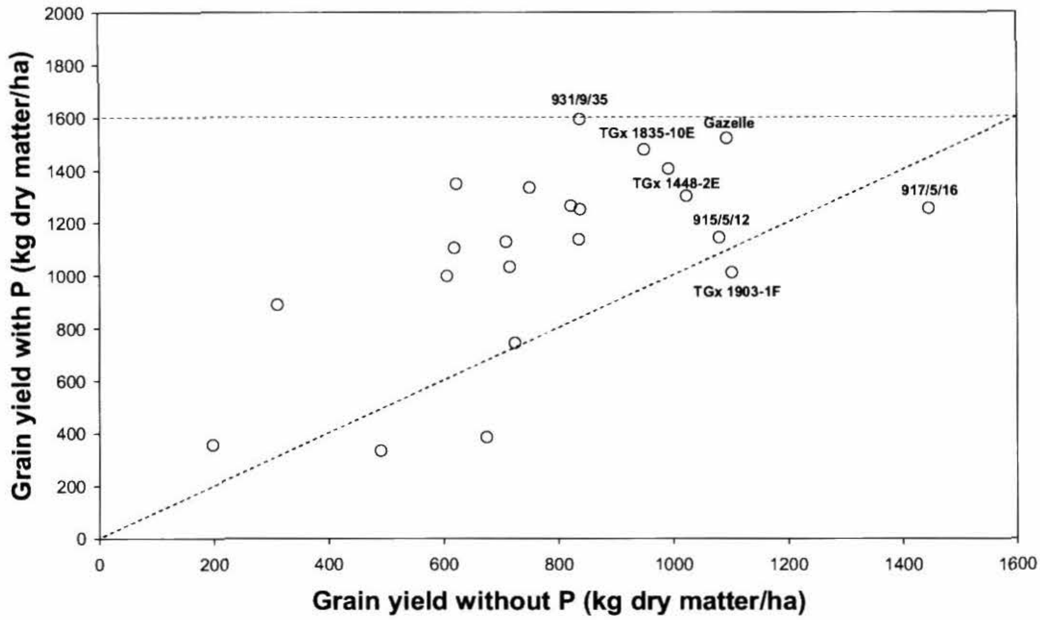



**Figure 18: Relationship between soybean grain yield with P and without P application during the long rainy season of 2008. Both treatments were planted with optimal timing. The dashed line indicates the 1:1 line or the line where yields with and without P application are similar.**

*Biomass production*

In absence of P and with optimal planting, soybean total biomass accumulation of the local varieties (Gazelle, Nyala, Sable) varied between 406 and 610 kg/ha **(Figure 19)**. Application of P increased the yields to between 464 and 863 kg/ha. The varieties developed by KARI (931/5/34; 915/5/12; 917/5/16) slightly higher amounts of total aboveground biomass. The dual purpose varieties, on the other hand, produced between 661 and 1648 kg biomass/ha without P and between 1129 and 3273 kg biomass/ha with P application. Total biomass accumulation of the varieties that were planted late was more similar for the local, the KARI, and the dual purpose varieties **(Figure 19).**

When focusing on tolerance to low soil P in terms of biomass accumulation, all varieties that occurred in the top right area of the graph depicting biomass accumulation with P vs biomass accumulation without P were dual purpose varieties **(Figure 20).** Of the 3 dual purpose varieties that showed relatively good grain yields with and/or without P application, only TGx 1448-2E and TGx 1835-10E accumulated relatively high amounts of biomass in contrast with TGx 1903-1F which only produced slightly over 1000 kg/ha with P applied **(Figure 20).**

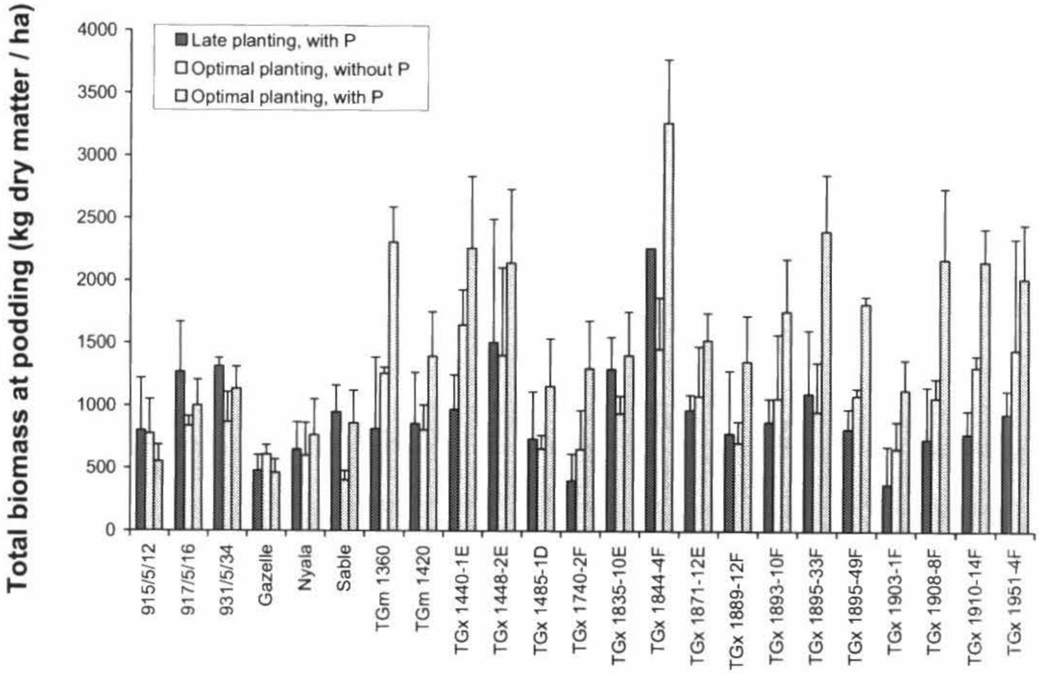



**Figure 19: Soybean total biomass accumulation at podding during the long rainy season of 2008 as affected by the imposed treatments for the varieties retained in the Sidada trial, western Kenya. Error bars are standard deviations**

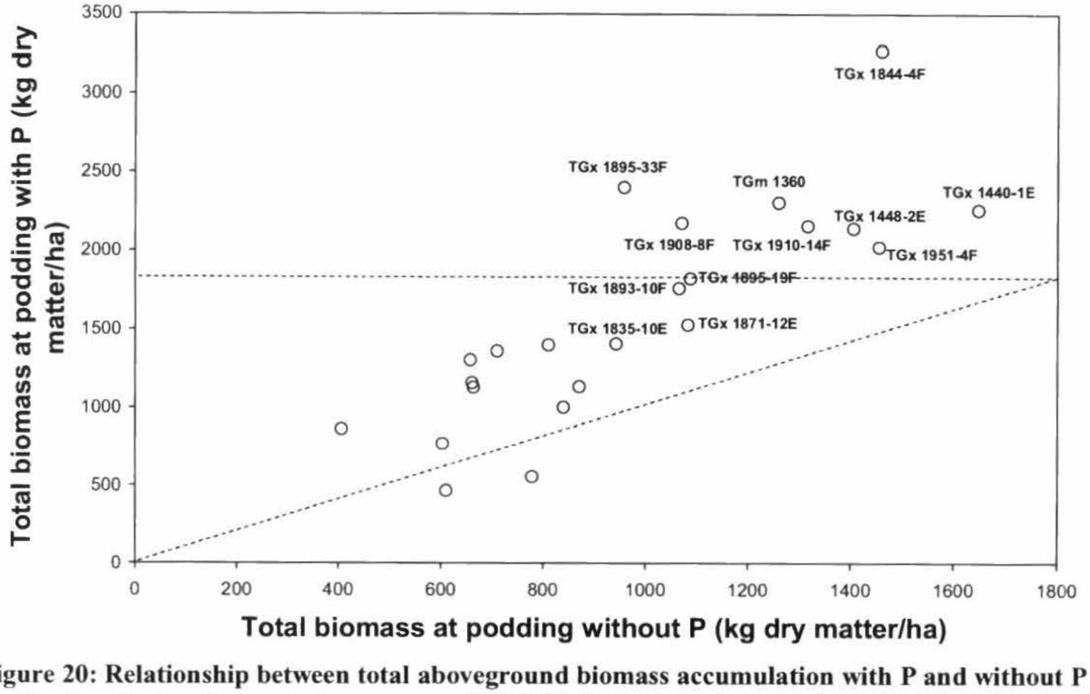



**Figure 20: Relationship between total aboveground biomass accumulation with P and without P application during the long rainy season of 2008. Both treatments were planted with optimal timing. The dashed line indicates the 1:1 line or the line where yields with and without P application are similar.**

*Nodulation*

Both the local and the KARI varieties had a low number of nodules with minimal impact of the imposed treatments **(Figure 21).** Most of the promiscuous varieties, on the other hand, showed relatively high nodulation in absence of P with substantial increases in nodulation after P application. Varieties that were planted late showed substantially reduced nodule formation **(Figure 21).**

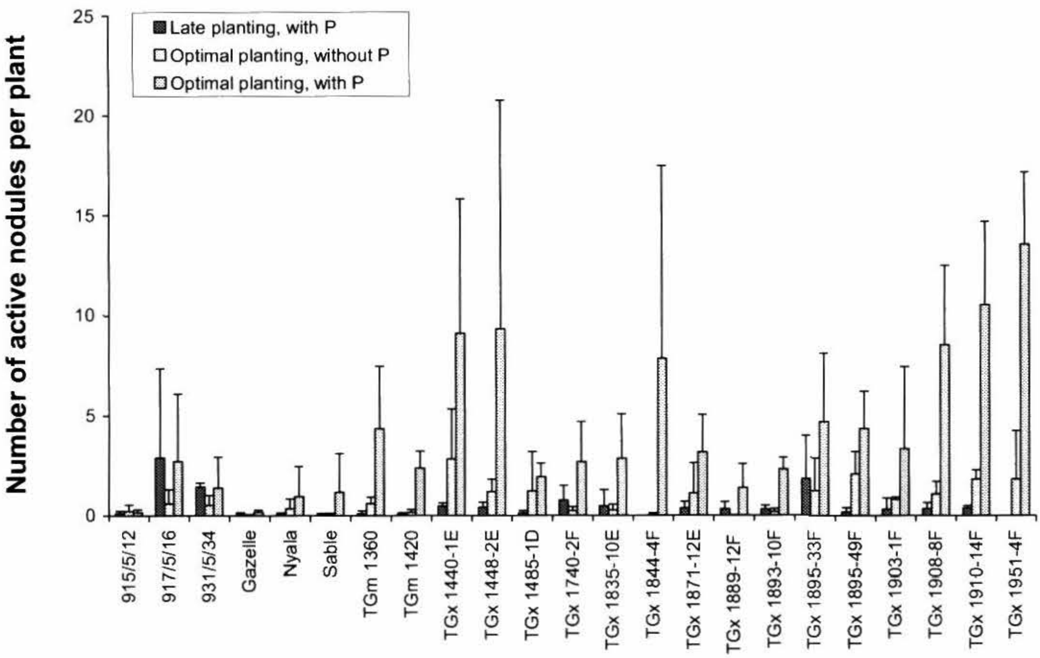



**Figure 21: Presence of active nodules on the various soybean varieties at podding during the long rainy season of 2008 as affected by the imposed treatments for the varieties retained in the Sidada trial, western Kenya. Error bars are standard deviations.**

*Disease scoring*

All plots were scored for presence of rust, bacterial pustules, and frogeye leaf spot, following the scoring technique explained in the detailed protocol. Only the first two diseases were observed to occur during the growing season. Although some variation between varieties could be observed, occurrence of rust was minimal with all varieties showing less than 5% lesions **(Figure 22).**

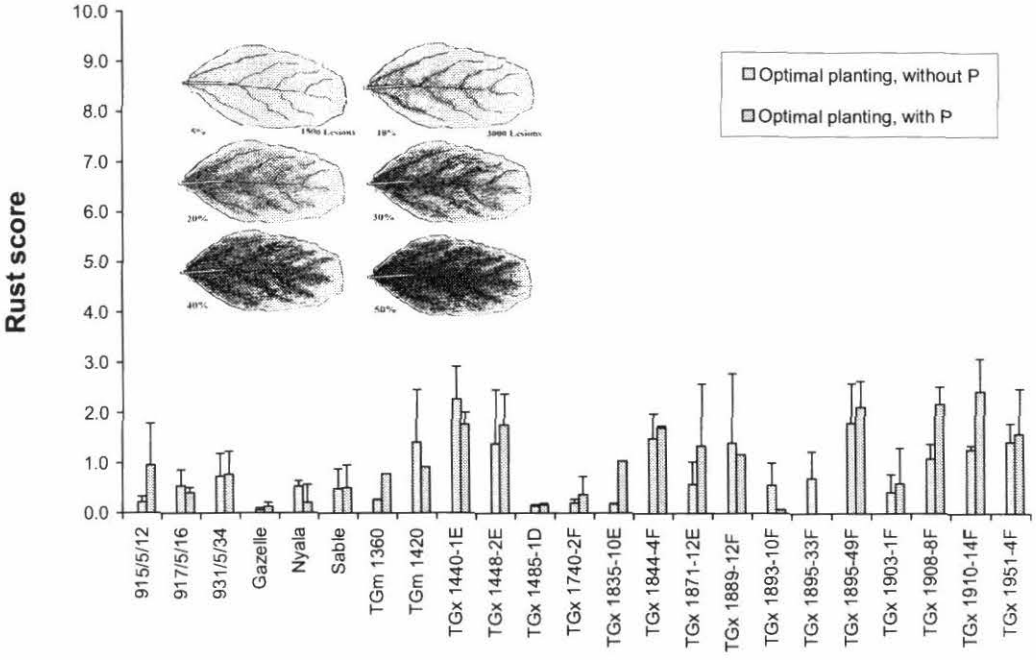



**Figure 22: Occurrence of rust on the different varieties, as affected by P application during the long rainy season of 2008 in Sidada, western Kenya. Error bars are standard deviations. Data for variety TGx 1895-33F with P applied are missing.**

**Preliminary conclusions**

Two batches of varieties could be identified, one batch, referred to as the 'grain soybean' which produces a relatively high amount of grains in a relatively short time with minimal biomass accumulation. These varieties also tend to be specific and show little nodulation with indigenous Rhizobia. These varieties were developed through the KARI soybean breeding program and are unlikely going to benefit the soil fertility status. The 'dual purpose soybean' varieties, mostly developed by IITA through their breeding program focusing partly on promiscuity and low N harvest index, show similar grain yields as the 'grain soybeans', but produce a larger amount of aboveground biomass and show better nodulating with indigenous populations, with potential benefits to the soil N status when put in rotations with cereals. These added benefits, however, go at a cost of longer periods to maturity.

In terms of tolerance to low soil P, above batches respond according to their major traits: the 'grain soybeans' show higher tolerance to low P in terms of grain production while the dual purpose varieties show relatively higher tolerance to low soil P when considering biomass production. At least 2 dual purpose varieties showed a relatively high tolerance for both grain and biomass production (TGx 1448-2E and TGx 1835-10E). Occurrence of pests and diseases was minimal. Despite low values, some variation in presence of rust was observed for different soybean varieties, while all varieties were equally affected by bacterial pustules.

## Evaluation of the Striga suicidal triggering potential of soybean

**GD. Odhiambo[1], I. Tabu[1], B. Vanlauwe[2]**
[1]*Egerton University, Kenya;* [2]*CIAT-TSBF, Kenya*

### Introduction

Conditioned *Striga* seeds will only germinate when exposed to synthetic germination stimulant or natural stimulants. Once germinated, the *Striga* seedling must attach to a host root within 3-5 days or the seedling dies. Hence a sustainable control option to reduce *Striga* parasitism is the use of trap crops, particularly legumes that stimulate germination of the parasite seeds but are non-hosts in rotation or intercropping with cereals. Since the ability of leguminous trap crops to stimulate *Striga* seed germination, both between and within species, is variable, the objective of this study was to identify and select soybean accessions with high ability to stimulate germination of *Striga* seeds, starting with an in-vitro technique with a lot of accessions, followed by a greenhouse bio-assay study with a selected number of accessions, and ending with a multi-locational field trials with a few logically-selected accessions. This work aims at achieving deliverable (ii) a set of best-bet legume species/varieties for triggering suicidal Striga germination.

### Materials and methods

Roots from thirty-two soybean accessions were tested in laboratory for their ability to stimulate *Striga* seed germination. For reasons of comparison, roots of *Desmodium*, *Mucuna*, and three maize varieties were included. Strigol and distilled water were used as baseline and control, respectively. Seeds treated with strigol displayed high germination, which was not significantly different from stimulation due to soybean accessions like TGm 1039 and TGx 1876-4E (**Figure 23**). Seeds treated with distilled water did not show any significant germination (germination % of 0.1%). Soybean accessions were significantly different in their ability to stimulate *Striga* seed germination with some soybean accessions showing a higher germination potential than *Desmodium* and *Mucuna*.

To confirm above observations, a selection of soybean varieties with differing *Striga* suicidal germination potential was grown in greenhouse pots with soils inoculated with *Striga* seeds (7500 viable seeds per pot) together with or in rotation with maize. *Desmodium* and *Mucuna* were also included, together with a pot with non-infested soil. In the intercropping bio-assay study, maize was planted together with various legumes in the same *Striga*-free soil, inoculated with *Striga* seeds at a rate of 0.075g of *Striga* seeds (whose percent viability and germination had been determined earlier) per 4 kg of soil and above and belowground legume and maize biomass was harvested after 7 weeks. *Striga* seedlings and *Striga* seeds attached to the maize roots were also measured when harvesting the pots. In the rotation bio-assay study, Eplee bags were inserted in the pots during the legume phase and after determination and incorporation of the legume biomass, maize was planted in the same pots. Again, *Striga* seedlings and *Striga* seeds attached to the maize roots were measured when harvesting the maize phase.

**Preliminary results**

While both the legume and maize aboveground biomass was rather similar for both the intercrop and the rotational bio-assay study, the shoot, root ratio was larger in the rotational than in the intercrop study, probably related to the lack of competition between the legume and the maize crop in the rotational bio-assay study (**Figure 24**). In the intercrop trial, a highly significant negative relationship between maize and legume shoot weight was observed (**Figure 25**), indicating substantial competition between the maize and the legume when grown in association.

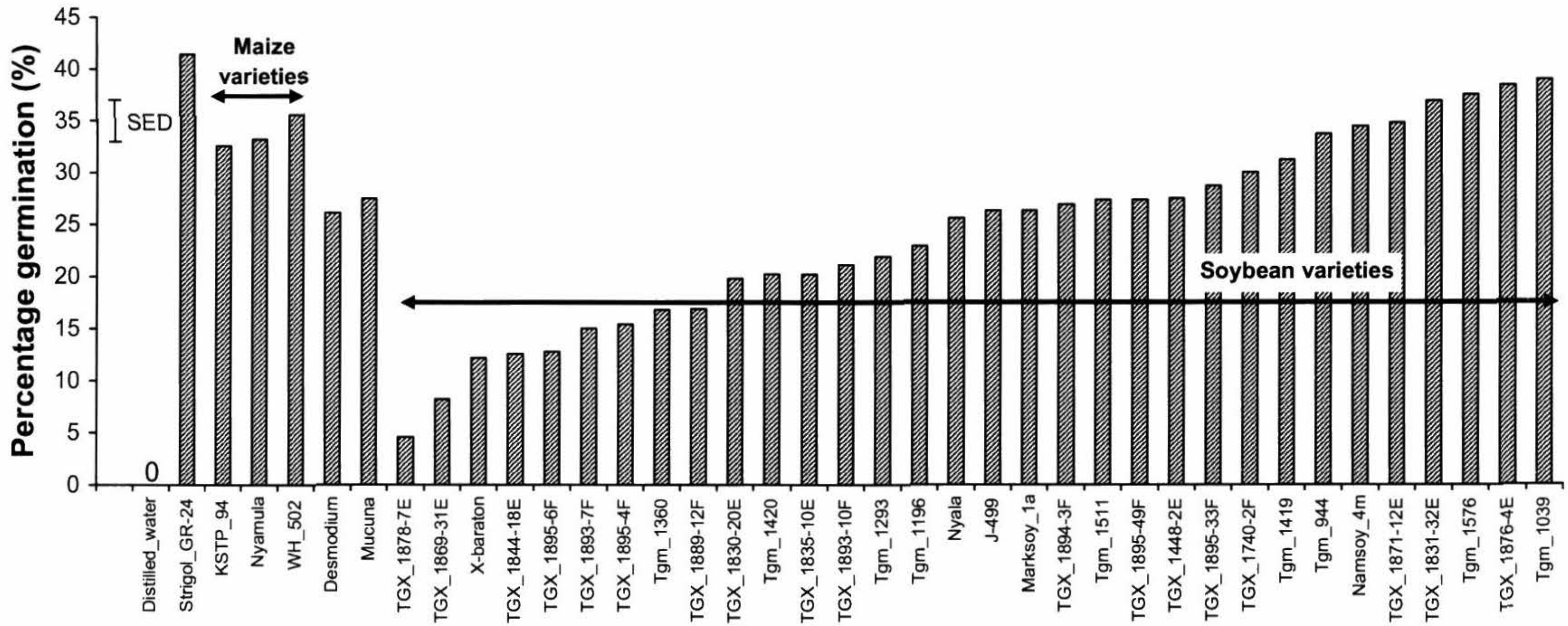



**Figure 23: Striga germination percentage caused by roots from 21 days old seedlings in descending order, relative to strigol.**

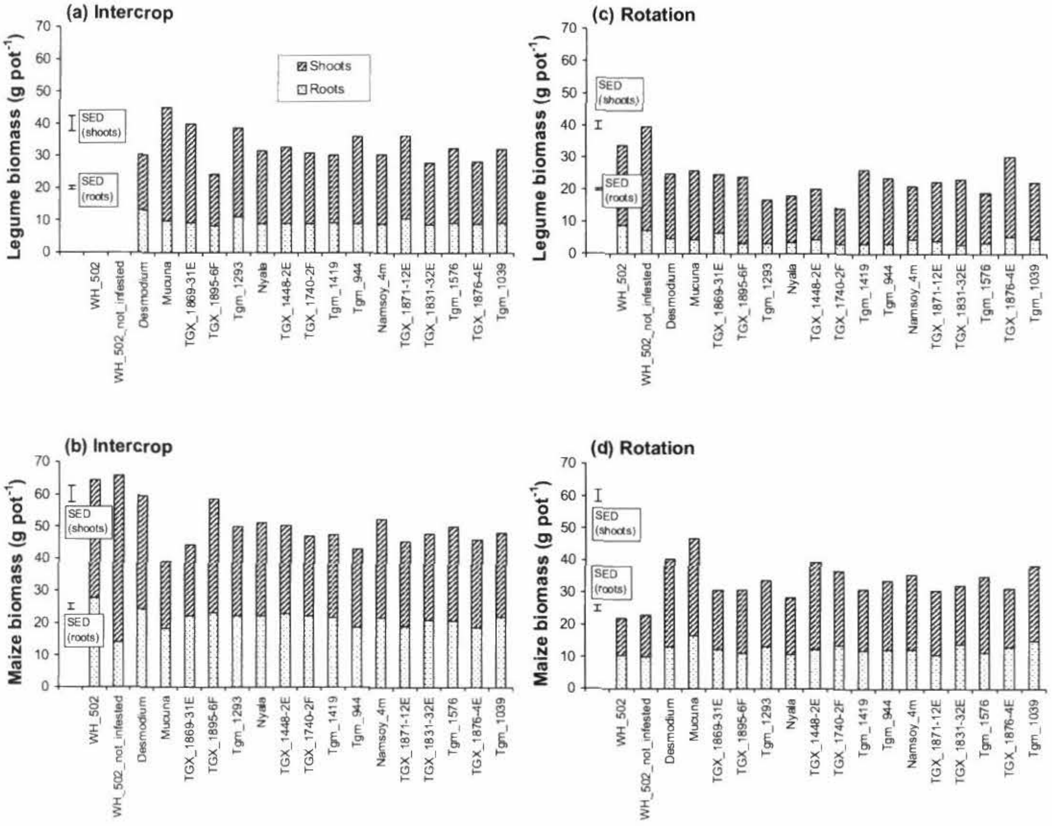



**Figure 24: Legumes and maize above and belowground biomass in the intercrop and rotational greenhouse bio-assay studies.**

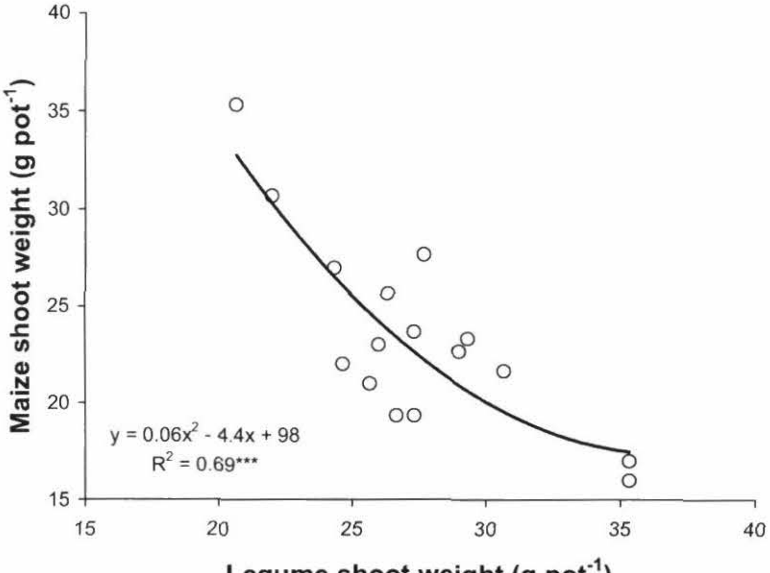



**Figure 25: Relationship between maize shoot weight and legume shoot weight in the intercropping bio-assay study.**

As for the rotational bio-assay study, a significant negative relationship was also observed between aboveground soybean biomass production and aboveground biomass of a following maize plant (**Figure 26**). Maize following *Desmodium* and *Mucuna* had greater aboveground biomass values. This is likely caused by the relatively high C/N ratio of the soybean residues that may have resulted in temporary N immobilization and lack of mineral N for optimal maize growth. Organic residues from *Desmodium* and *Mucuna* likely had a higher quality (or quicker N mineralization potential).

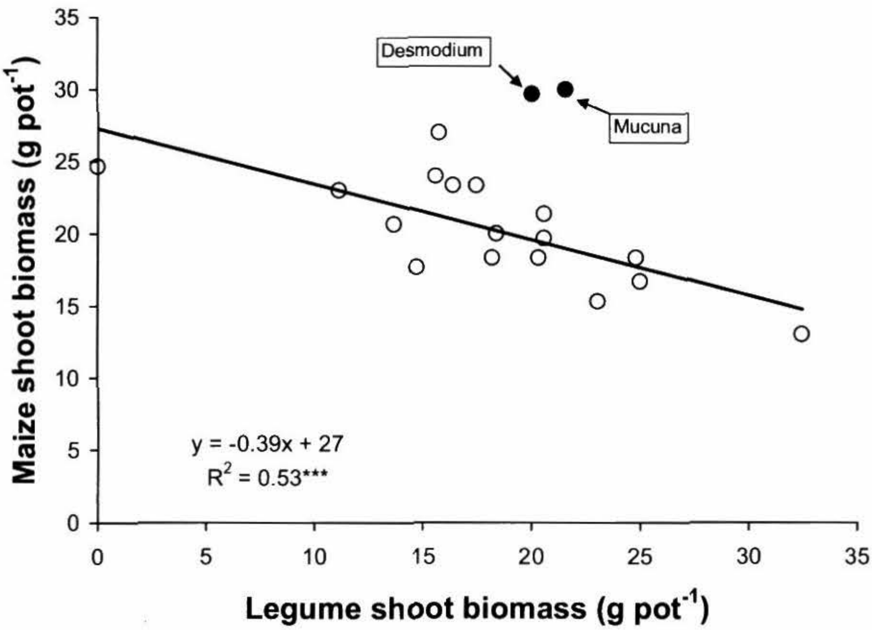



**Figure 26: Relationship between maize shoot weight and legume shoot weight in the rotational bio-assay study.**

In the intercropping bio-assay, 6 of the 10 soybean varieties with high suicidal germination potential, as determined in the laboratory incubation, showed larger *Striga* germination values than the maize mono-cropped pot, while those varieties with low to medium suicidal germination potential showed *Striga* germination data not larger than the maize monocropped pot (except for 1 variety – TGX1895-6F) (**Figure 27**). In the rotational pot trial, half of the maize following soybean varieties with high suicidal germination potential showed larger germination percentages of *Striga* seeds than the maize mono-cropped pot while of those varieties with low to medium suicidal germination potential, 2 accessions of the 4 showed *Striga* germination percentages that were equal to those in the maize mono-cropped (**Figure 27**). In the rotational systems, after the legume phase, only 3 of the 10 soybean accessions with high suicidal triggering potential show higher *Striga* germination values compared with the maize baseline values. Of those with low potential, none had *Striga* germination values exceeding those of the maize baseline (**Figure 28**).

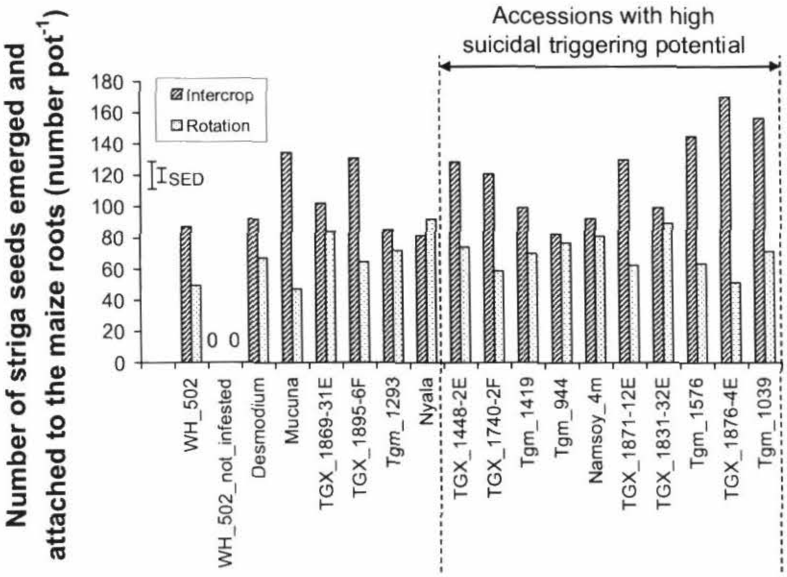



**Figure 27: Total *Striga* seeds emerged and attached to maize in intercropping and rotational bio-assay studies with different soybean accessions with high, medium, and low Striga suicidal germination potential as observed in Figure 8 and with *Desmodium* and *Mucuna*, relative to a maize mono-crop (indicated with 'WH502'). The pots were artificially infested with viable Striga seeds, except for one pot ('WH502_not_infested'). Error bars are Standard Deviations (*n*=3).**

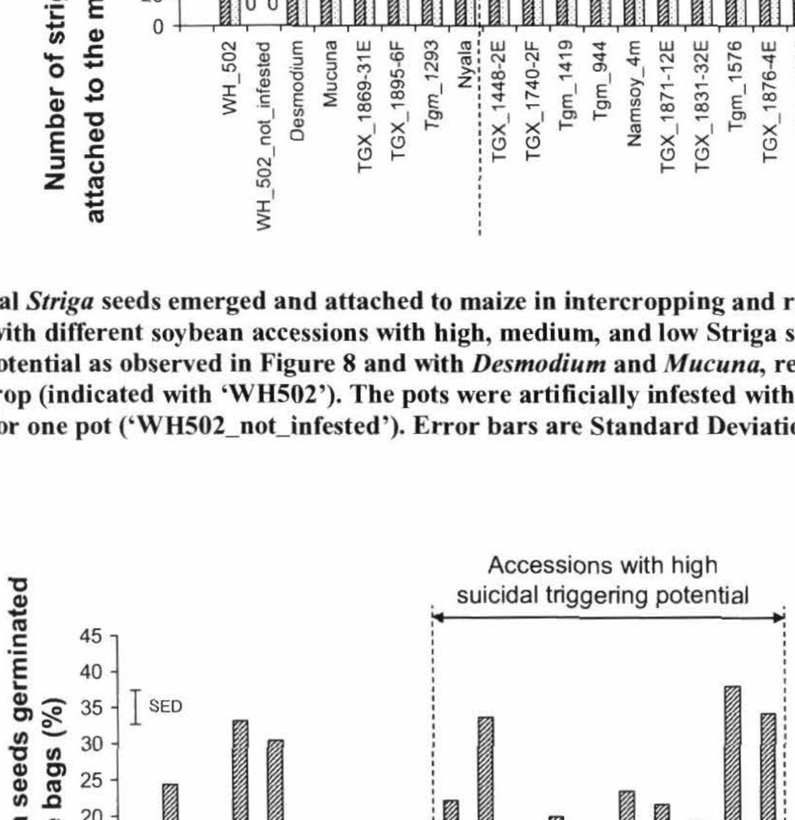



**Figure 28: Total *Striga* seeds germinated in Eplee bags in greenhouse pots, cropped with different soybean accessions with high, medium, and low Striga suicidal germination potential as observed in Figure 8 and with *Desmodium* and *Mucuna*, relative to a maize mono-crop (indicated with 'WH502'). The pots were artificially infested with viable Striga seeds, except for one pot ('WH502_not_infested'). Error bars are Standard Deviations.**

Bio-assay data were more consistent between the intercrop and rotation (**Figure 29**). *Striga* germination data in the intercrop bio-assay study were positive related to Eplee data, indicating that the Eplee data and the intercropping trial yielded similar relative results. *Striga* germination data in the rotation bio-assay were negatively related to Eplee data, indicating that large *Striga* germination values during the legume phase or the Eplee phase resulted in lower *Striga* germination during the subsequent maize phase.

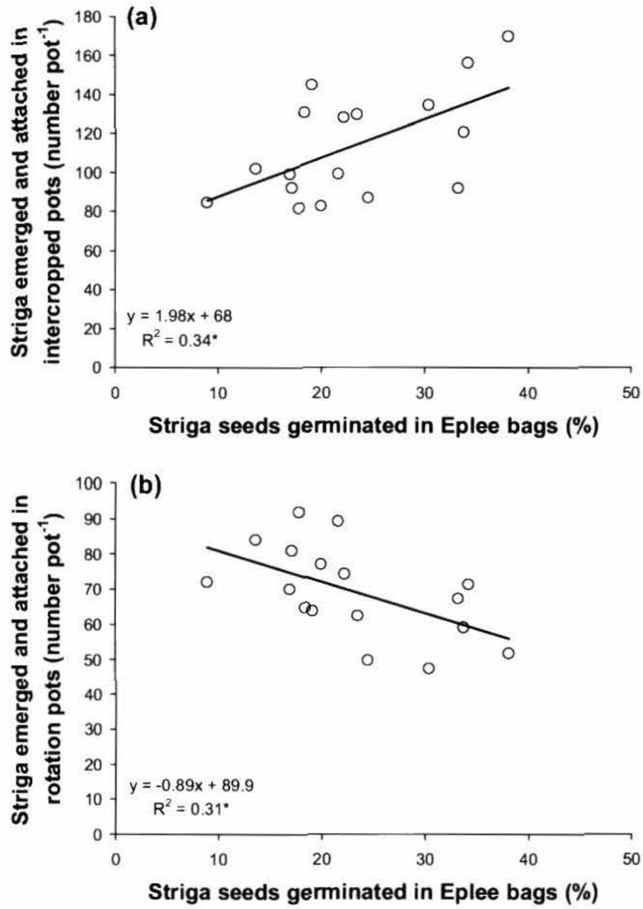



**Figure 29: Relationships between *Striga* germination data in the rotation and intercrop bio-assay studies.**

## Evaluation of early root traits for P acquisition efficiency


**E. Vandamme[1], P. Pypers[2] and R. Merckx[1]**
*[1]KULEUVEN, Belgium; [2]TSBF - CIAT, Kenya*


An experiment is currently on-going to determine early root trait indicators for P acquisition efficiency (the ability of the plant to acquire P from the growth medium) in soybean. In particular, root traits related to root morphology and architecture (shallow root proliferation, root angles, total root length and root hair length and density) are targeted. These traits are well known to be related to enhanced P uptake under low-P conditions (Bates and Lynch, 2001; Liao et al., 2001; Lynch and Brown, 2001; Gahoonia and Nielsen, 2004a, b; Yan et al., 2004). The screening technique takes into account different external P concentration and speciation regimes, since these may affect the expression of root traits related to P acquisition efficiency. Observations will be related to the performance of the varieties under field conditions in order to identify the key traits for P uptake in low-P soils.

Differences in P acquisition efficiency between varieties have been demonstrated in different species (e.g., Beebe et al., 1997; Zoysa, 1999; Sanginga et al., 2000; Akhtar et al., 2008). It is highly probable to find contrasting root characteristics in soybean, provided that the genetic basis in the set of varieties selected for testing is sufficiently large. Therefore, a large set of varieties (currently, 110 varieties) were collected from breeding programs or locally produced varieties from legume programs in Nigeria, Kenya, Uganda, Tanzania, Rwanda, Burundi, DR Congo, Malawi, Zimbabwe, Brazil, Vietnam, Indonesia, Thailand, and China.

To allow a detailed study of the root system of young soybean plants and their response to different P treatments, seedlings are studied in gel observation chambers as described by Bengough et al. (2004) **(Figure 30)**, modified to mimic a soil environment in which P availability is constrained by sorption processes. Gel observation chambers are constructed of two plastic plates covered with layers of sterile gel, which are clipped together with gel layers facing inside while allowing a small air layer of approximately 2.5mm width between the plates. Seedling roots are then grown within this air layer. One side of the gel chamber consists of a transparent plastic plate which allows repeated monitoring during growth. This technique allows for simple, rapid, and cost-effective screening of root traits in an unimpeded environment and is therefore suitable for large-scale screening of seedling root traits in crop improvement programs.

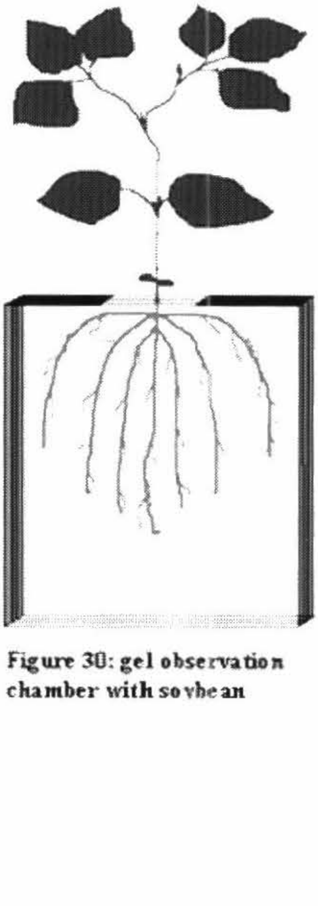


**Figure 30: gel observation chamber with soybean**

The expected outcomes of this activity are two-fold. Firstly, a valuable tool for further extensive screening and breeding of P-efficient soybean varieties will be delivered. Key traits for P acquisition efficiency in soybean will be identified, which can be evaluated at early growth stages. Secondly, varieties will be identified with high P acquisition efficiency, which can be utilized as parent lines to produce crosses and recombine the desired root traits in new soybean populations.

| **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

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

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

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

### Livelihood activities and wealth ranking among rural households in the farming systems of Western Kenya African. *(2008) Journal of Livestock Extension 5: 43 – 52*

**Ajani[1], O.I.Y., Justina[1], N.C., Chianu[2], J. N. and Olayide[1], O.E.**
*[1]University of Ibadan, Nigeria; [2]TSBF - CIAT, Kenya*

**Abstract:** The study examined the relationship between the livelihood activities of rural households in the farming systems of Western Kenya in relation to their wealth. A stratified random sampling procedure was used to select 252 farm households from eight districts in three provinces. Focus group discussions (FGD) were used to collect community-level data which complemented household data. Primary data were collected using structured questionnaire. Results indicate that average household size was seven persons across survey districts. As expected, agriculture (crop and livestock) was the main activity of the farmers. Maize and common beans are the most important staple food crops and traded food crops. Livestock enterprises are dominated by poultry production. For purposes of diversification for better livelihoods, some farm households engaged in small businesses (especially fish trading), employment and artisanal work. The cropping system is mainly mixed cropping. Lack of cash and limited land availability were the most important factors that constrain agricultural development in Western Kenya. Although most households preferred selling their farm produce in the markets or places where prices were better, many of them not only sold their farm produce but also purchased their farm inputs from the nearest towns due to

problems and costs associated with going to where produce prices were better. Our results show a high wealth inequality among farm households in Western Kenya. This was in terms of both household wealth (with a *Gini*-coefficient of 0.52) and per capita wealth (with a *Gini*-coefficient of 0.55). The high level of inequality calls for more attention on proper targeting of development activities to ensure even distribution of resources and economic growth and development.

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

**Chianu[1], J.N., Adesina[2], A., Sanginga[3], P., Bationo[1], A., Justina[1], N.C., and Sanginga[1], N.**
*[1]TSBF - CIAT, Kenya; [2]The Rockefeller Foundation, Kenya; [3]CIAT-Africa, Kawanda, Uganda.*

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

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

**Mairura[1], F.S., Mugendi[2], D.N., Mwanje[2], J.I., Ramisch[1], J.J., Mbugua[3], P.K., and Chianu[1], J.N.**
*[1]TSBF - CIAT, Kenya; [2]Kenyatta University, Kenya; [3]Department of Botany, Kenyatta University, Kenya*

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

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

**Wachira[1], P.M., Kimenju[1], J.W., Okoth[1], S., Mibey[2], R.K., and J. Mung'atu[3]**
*[1]University of Nairobi, Kenya [2]Moi University, Kenya; [3]Jomo Kenyatta University of Agriculture and Technology, Kenya*

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

## Plant age and rock phosphate effects on the organic resource quality of herbaceous legume residues and their N and P release dynamics. *(2008) Agronomy for Sustainable Development 28: 429-437*

**Vanlauwe[1], B., Idrissa[2], A., Diels[3], J., Sanginga[1], N., Merckx[3], R.**
*[1]TSBF - CIAT, Kenya, [2]INRAN, Niger; [3]KU Leuven, Belgium*

**Abstract:** Many tropical agro-ecosystems rely on organic resources for nutrient provision. Various factors affect the nutrient release dynamics of organic resources, including application of external nutrients during their growth and their age or physiological stage at the time of harvest. Understanding relationships between organic resource management factors and the resulting nutrient release dynamics is important for optimizing nutrient recovery by crops and minimizing nutrient losses to the environment. Here, *Mucuna pruriens* and *Lablab purpureus* legumes were grown on a 'slope' and 'plateau' field, treated or not with rock phosphate, and sampled from 12 to 30 weeks after planting. These plant residues were then incubated in a sandy soil under laboratory conditions and mineral N and Olsen-extractable P dynamics were measured for 28 days. Our results showed that plant age had an impact on N,

P and polyphenol contents. Application of rock phosphate only altered the P content of the legumes on the 'plateau' field, which had a lower soil-available P content. We also observed that mineral N dynamics of the organic resources varied between –62% of the added N released after 28 days, indicating net immobilization, and +23%, indicating net mineralization, with most organic resources showing an initial N immobilization phase. N release was negatively related to the lignin-to-N and (lignin+polyphenol)-to-N ratios of the organic resources. Lastly, we observed that the net release of Olsen P relative to the control soil varied between 0.4 and 4.9 mg kg−1 and that net P release was positively related to the P content of the organic resources. In summary, legume age was the parameter that most strongly influenced the quality of the legume residues, and consequently its N and P release dynamics, with potentially significant consequences for N and P uptake recovery and losses and, ultimately, cropping system sustainability.

## WORK IN PROGRESS

### Increasing water and nutrient use efficiencies: Improved Irrigation scheduling for organic and inorganic fertilized maize

**I. Fandika[1], and S. Zingore[2]**
*[1]Department of Agricultural Research Services, Malawi; [2]CIAT-TSBF, Malawi*

Irrigation scheduling is a viable practice to enhance crop productivity and profitability for smallholder farmers. It can also lead to significant water saving, reduced environmental impact of irrigation and improved sustainability of irrigated agriculture. In order to define appropriate irrigation scheduling for optional water management and maize production, research was conducted to evaluate irrigation scheduling options and organic and inorganic fertilizer management for maize at Kasinthula Research Station. Irrigation practices comprised of: Daily Water balance scheduling at 40% depletion and three fixed irrigation scenarios, 40 mm every 3-4 days, 7 days and 14 days. The maize crop had 120 kg N ha$^{-1}$ supplied as N fertilizer, or 110-140 kg N ha-1 applied as 10 t ha$^{-1}$ of manure or compost. (i) urea (U); (ii) 10 t ha$^{-1}$ compost (C); (iii) 10 t ha$^{-1}$cattle manure (CM); (iv) 80 kg ha$^{-1}$ N Urea + 3.3 t ha$^{-1}$ compost; (v) 40 kg ha$^{-1}$ N Urea + 6.6 t ha$^{-1}$ compost; (vi) 80 kg ha$^{-1}$ N Urea + 3.3 t ha$^{-1}$ manure; and (vii) 40 kg ha$^{-1}$ N Urea + 6.6 t ha$^{-1}$ manure. The data from the field experiment was used to validate the Cropwat 4 model. This model simulates soil water balance and crop water requirements for different irrigation intervals and application depths. Experimental results showed positive ($P<0.01$) and highly significant interactions between maize grain yields, crop water productivity (CWP) and Nitrogen use efficiency (NUE). The daily water balance irrigation scheduling had greater grain yields (6.42 t ha$^{-1}$) CWP (9.5 kg grain mm$^{-1}$ ha$^{-1}$) and NUE (53.5 kg grain kg$^{-1}$ N ha$^{-1}$) followed by irrigation with 40 mm every 3-4 days. The lowest NUE was observed in CM treatments irrigated every 14 days. The results also showed that long intervals of 14 days led to significant reduction in yields, water application and its associated deep percolation losses. For fertilizer treatments, maize and gross margins were highest in U and 2U: CM treatments. Maize fertilized with sole organic N sources was lowest in CWP and NUE in all irrigation regimes, and exhibited high water dependencies. The most efficient practices are (i) use of 40% allowable soil water deficit and 680 mm net irrigation water requirement for irrigated maize production; (ii) daily soil water irrigation scheduling; (iii) integrated inorganic-organic soil fertility management with 80 kg N ha$^{-1}$ applied as compost.

## Assessment of irrigation water use, crop productivity and soil quality at Nkhate Irrigation Scheme, southern Malawi

**I. Fandika[1], R. Magreta[2], S. Zingore[3], J. Nyamangara[4], A. Senzanje[4], R.J. Delve[2].**
*[1]Department of Agricultural Research Services, Malawi; [2]TSBF - CIAT, Zimbabwe; [3]TSBF - CIAT, Malawi; [4]University of Zimbabwe, Zimbabwe*

As land pressure and climate change-induced droughts intensify, there is need to increase and better manage irrigated agriculture in sub Saharan Africa to increase crop productivity. Sustained high crop productivity in smallholder irrigation schemes depends on appropriate and efficient use of water and nutrient resources. We assessed the effects of water and nutrient management practices on crop productivity and soil quality at Nkhate irrigation scheme (420 ha; 1165 rural households) in Chikwawa District, southern Malawi. The farmers irrigate 0.2 ha each and grow dryland rice (*Oryza sativa*), maize (*Zea mays* L.) and pigeon pea in summer, and irrigated maize, sweet potato and bean in winter. The scheme is operated by farmers, with technical support from government extension officers. The grain yield of rice since 1979/80 to 2006/07 ranged from 2500-4250 kg ha$^{-1}$, which is lower than results from research plots (>5000 kg ha$^{-1}$). The major factors limiting crop productivity include irrigation water shortage in winter, poor irrigation water delivery, irregular irrigation scheduling, soil salinity and suboptimal and inappropriate fertilizer rates. It was found that the average discharge from the river of 1.95 m$^3$ s$^{-1}$ during the wet season goes down to 0.16 m$^3$ s$^{-1}$ during the dry season and fails to meet the irrigation scheme designed requirement of 0.669 m$^3$ s$^{-1}$ flow for adequate water distribution. There is therefore a shortfall in water flow for irrigation during the dry season, which explains the limitation of the area under irrigation during winter to less than 50% of the total land area. Drought is leading to low river discharge and has drastic effects on crop productivity and water management mechanism. The soil quality (N, P and pH) for the scheme is low; hence yields achieved by farmers (2-5 t ha$^{-1}$) are below the attainable yields achieved with optimal fertilizer application rates, particularly on the upper and mid-slope position. The lower position, covering about 40 ha is not suitable for winter crop production due to high salinity when water supply is limited. Climatic change and variability, government policies and HIV/AIDS are among the pressures on productivity, soil and water quality and quantity at Nkhate irrigation scheme.

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

**P. Chivenge[1], B. Vanlauwe[2], Gentile[1], R. and J. Six[1]**
*[1]University of California, Davis, USA; [2]TSBF - CIAT, Kenya*

### Introduction

Stabilization of added organic matter in soils is a function of clay content, mineralogy, and aggregation. Generally, soil organic matter (SOM) stabilization increases with increasing clay content due to greater reactive surface area of clay particles, providing greater capacity to physically protect SOM by incorporation within aggregates. Together with soil texture, management practices influence the amount of organic C and its distribution among aggregate fractions. The addition of organic resources (ORs) leads to the formation and stabilization of aggregates, which in turn protect SOM from decomposition and thus further protect and stabilize aggregates. Macroaggregate formation and breakdown, i.e. macroaggregate turnover, occurs as ORs decompose and influences short-term nutrient cycling and long-term stabilization of soil C.

The quality of added ORs influences the rate of macroaggregate turnover where high quality ORs may induce a fast macroaggregate turnover, associated with faster mineralization of C and nutrients and potentially their enhanced loss from the system. However, lower aggregation in sandy soils thus 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 addition of N-fertilizer has been shown to enhance macroaggregate turnover due to enhanced decomposition of the C-rich binding agents by microbes. The objectives of this study were to quantify organic C and N dynamics in aggregate- associated SOM fractions as affected by OR quality, N-fertilizer addition, texture and climate on these dynamics.

**Materials and methods**

A mesocosm study was carried out at two sites in the Central Highlands of Kenya: Machanga (0°47' S, 37°40' E; 1022 m above sea level) and Embu (0°30' S, 37°27' E; 1380 m above sea level). Machanga is on a sandy soil (80% sand) derived from granitic gneisses and is classified as *Ferric Alisols* (FAO, 1998). Embu is on a clay soil (65% clay) derived from basic volcanic rocks and is classified as *Humic Nitisol.* Mesocosms made of polyvinylchloride (pvc) with a diameter of 15 cm were installed to a depth of 15 cm, leaving 10 cm above the soil surface. Soil collected from an ongoing experiment was passed through an 8-mm sieve by gently breaking the soil along the planes of weakness, air-dried and thoroughly mixed with three ORs of differing quality: *Tithonia* (high quality), *Calliandra* (intermediate quality) and maize (low quality). The three ORs were applied at an equivalent rate of 4 Mg C $ha^{-1}$, with or without 120 kg fertilizer-N $ha^{-1}$ (urea) enriched with 7.8 atom % $^{15}N$. Soil samples were collected by destructive sampling of the mesocosms at installation (start) and after eight months (end).

Aggregates were separated by wet sieving the air-dried soil two sieves to isolate three aggregate size fractions: i) > 250-µm (macroaggregates), ii) 53-250-µm (microaggregates), and iii) < 53-µm (silt + clay). Macroaggregates were separated further to isolate microaggregates occluded in the macroaggregates.

**Preliminary results**

Contrary to our hypothesis, low quality OR did not result in greater total SOC and N than higher quality ORs in both soils. While there were no differences in whole SOC and N among OR quality in the clayey soil, in the sandy soil greater concentrations of whole SOC and N were observed under the high quality OR, (i.e. *Tithonia*) and the other ORs were not different from the control **(Table 4)**. This was probably because of the combined effects of dry climate and sandy soils in Machanga such that the readily decomposable OR was incorporated in the soil faster than other OR. While *Tithonia* resulted in the greatest concentrations of total organic C and N in the sandy soil, for the clayey soil, there were no differences among OR qualities but all ORs resulted in greater soil C and N than the control **(Table 4)**. Greater concentrations of organic C and N were observed in the clayey soil than the sandy soil. At both sites, across ORs there were no differences in whole SOC and N due to the addition of N-fertilizer **(Table 4)**.

In Machanga, *Tithonia* had greater concentrations of N in the macroaggregate fractions than other *Calliandra*, maize and the control **(Table 5)**. There were however, no differences among different OR qualities in N in the aggregate fractions in Embu. Although there were generally no differences in soil organic N between *Tithonia* and *Calliandra* in the aggregate-associated SOM fractions of the sandy soil **(Table 5)**, Calliandra generally had greater $N_{new}$ proportions than other ORs in the silt and clay and cPOM (data not shown). This implies that decomposition was slower with *Calliandra* compared to *Tithonia*. In contrast, however, in the clayey soil there were no differences in $N_{new}$ in aggregate associated SOM fractions of soil treated with *Tithonia* and *Calliandra* (data not shown), nor were there differences in whole SOC and N among all ORs **(Table 6)**. This implies that polyphenol content, i.e. biochemical recalcitrance, influences OR decomposition in sandy soils but not clayey soils. Since macroaggregate formation and stabilization is strongly dependent on soil texture, the importance of aggregate stabilization of SOM would be greater in a clayey than sandy soils. While there were greater concentrations of both total N and $N_{new}$ when maize was applied alone than when applied with N-fertilizer in the clayey soil, in other ORs and all ORs in the sandy soil there were no differences in $N_{new}$ when ORs were applied together with N-fertilizer versus without N fertilizer **(Table 6)**. This implies that the addition of N-fertilizer with ORs does not influence the incorporation and stabilization of added ORs in sandy soils while the addition of N-fertilizer with low quality ORs will influence their decomposition and stabilization into aggregate-associated SOM fractions in clayey soils.

**Preliminary conclusions**

While OR quality clearly influences C and N in whole soil and aggregate associated SOM fractions in both sandy and clayey soils, the nature of the effects differ. In the clayey soils, the addition of low quality OR results in slower aggregate turnover associated with greater stabilization of SOC and N, specifically in the macroaggregates. Moreover, 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. In sandy soils, on the other hand, chemical recalcitrance, i.e. polyphenol concentration, is crucial for the preservation of SOC and N.

**Table 4: 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) and Embu (clayey), Kenya. Soils were sampled at installation of the experiment and eight months after residue incorporation. Soils used for the experiment were collected from a field which had received four and three years of the same treatments in Machanga and Embu, respectively.**

| Organic resource | N fertilizer (kg ha$^{-1}$) | Organic C (g C kg$^{-1}$ dry soil) | | Organic N (g N kg$^{-1}$ soil) | |
|---|---|---|---|---|---|
| | | Machanga | Embu | Machanga | Embu |
| 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 | 10.25 | 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 | | 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 | | | |
| OR | | ns | * | ns | * |
| N | | * | ns | ns | ns |
| OR*N | | * | ns | ns | ns |
| Time | | ns | ns | *** | * |

†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 and SED Time represent standard error of the difference between paired means with organic resource (OR), N-fertilizer (N), and sampling time, respectively.

**Table 5: Organic N distribution in aggregate size fractions of a sandy soil amended with organic resources (OR) of different quality applied at 4 Mg C ha$^{-1}$, alone or in combination with 120 kg N ha$^{-1}$ as mineral N fertilizer at Machanga (sandy), Kenya. Soils were sampled at installation of the experiment and eight months after residue incorporation. Soils used for the experiment were collected from a field which had received four years of the same treatments.**

| Organic resource | N fertilizer (kg ha$^{-1}$) | †Whole soil fractions | | | ‡Macroaggregate fractions | | |
|---|---|---|---|---|---|---|---|
| | | M | m | s+c | cPOM | mM | s+cM |
| | | | | (g N kg$^{-1}$ dry soil) | | | |
| Control | 0 | 0.074 | 0.197 | 0.196 | 0.019 | 0.028 | 0.020 |
| | 120 | 0.067 | 0.214 | 0.190 | 0.020 | 0.026 | 0.024 |
| *Tithonia* | 0 | 0.173 | 0.413 | 0.227 | 0.037 | 0.052 | 0.032 |
| | 120 | 0.160 | 0.317 | 0.236 | 0.065 | 0.035 | 0.025 |
| *Calliandra* | 0 | 0.097 | 0.211 | 0.157 | 0.051 | 0.020 | 0.018 |
| | 120 | 0.132 | 0.242 | 0.198 | 0.060 | 0.029 | 0.021 |
| Maize | 0 | 0.059 | 0.186 | 0.168 | 0.019 | 0.016 | 0.016 |
| | 120 | 0.085 | 0.205 | 0.172 | 0.019 | 0.022 | 0.021 |
| SED OR | | 0.033 | 0.071 | 0.033 | 0.016 | 0.014 | 0.006 |
| SED N | | 0.022 | 0.040 | 0.015 | 0.011 | 0.007 | 0.003 |
| | | | | | | | |
| Time | | | | | | | |
| Start | | 0.121 | 0.284 | 0.187 | 0.024 | 0.035 | 0.024 |
| End | | 0.090 | 0.212 | 0.199 | 0.048 | 0.022 | 0.020 |
| SED Time | | 0.011 | 0.020 | 0.032 | 0.006 | 0.003 | 0.001 |
| | | | | ¶Statistical significance | | | |
| OR | | * | ns | ns | * | ns | ns |
| N | | ns | ns | ns | ns | ns | ns |
| OR*N | | ns | ns | ns | ns | * | * |
| Time | | ** | *** | ns | *** | *** | ** |

† Aggregate fractions separated from whole soil: M, macroaggregates; m, microaggregates; s+c, silt and clay. ‡ Fractions separated from macroaggregates: cPOM, coarse particulate organic matter; mM, microaggregates within macroaggregates; s+cM, silt and clay within macroaggregates. ¶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 and SED Time represent standard error of the difference between paired means with organic resource (OR), N-fertilizer (N), and sampling time, respectively.

**Table 6: Organic N distribution in aggregate size fractions of a clayey soil amended with organic resources (OR) of different quality applied at 4 Mg C ha$^{-1}$, alone or in combination with 120 kg N ha$^{-1}$ as mineral N fertilizer at Embu (clayey), Kenya. Soils were sampled at installation of the experiment and eight months after residue incorporation. Soils used for the experiment were collected from a field which had received three years of the same.**

| Organic resource | N fertilizer (kg ha$^{-1}$) | †Whole soil fractions | | | ‡Macroaggregate fractions | | |
|---|---|---|---|---|---|---|---|
| | | M | m | s+c | cPOM | mM | s+cM |
| | | (g N kg$^{-1}$ dry soil) | | | | | |
| Control | 0 | 1.42 | 0.62 | 0.16 | 0.025 | 1.20 | 0.42 |
| | 120 | 1.43 | 0.69 | 0.19 | 0.041 | 1.18 | 0.40 |
| *Tithonia* | 0 | 1.98 | 0.69 | 0.16 | 0.058 | 1.46 | 0.60 |
| | 120 | 2.09 | 0.68 | 0.18 | 0.058 | 1.57 | 0.58 |
| *Calliandra* | 0 | 2.01 | 0.66 | 0.17 | 0.068 | 1.45 | 0.55 |
| | 120 | 1.06 | 0.70 | 0.19 | 0.078 | 1.44 | 0.58 |
| Maize | 0 | 2.30 | 0.57 | 0.15 | 0.054 | 1.55 | 0.74 |
| | 120 | 1.94 | 0.66 | 0.16 | 0.049 | 1.42 | 0.57 |
| SED OR | | 0.17 | 0.06 | 0.011 | 0.011 | 0.10 | 0.06 |
| SED N | | 0.13 | 0.05 | 0.011 | 0.009 | 0.09 | 0.06 |
| | | | | | | | |
| Time | | | | | | | |
| Start | | 1.87 | 0.69 | 0.18 | 0.005 | 1.40 | 0.57 |
| End | | 1.94 | 0.63 | 0.15 | 0.006 | 1.42 | 0.55 |
| SED Time | | 0.065 | 0.027 | 0.006 | 0.005 | 0.05 | 0.03 |
| | | ¶Statistical significance | | | | | |
| OR | | ** | ns | ns | * | * | ** |
| N | | ns | ns | ** | ns | ns | ns |
| OR*N | | * | ns | ns | ns | ns | * |
| Time | | ns | * | *** | ns | ns | ns |

† Aggregate fractions separated from whole soil: M, macroaggregates; m, microaggregates; s+c, silt and clay. ‡ Fractions separated from macroaggregates: cPOM, coarse particulate organic matter; mM, microaggregates within macroaggregates; s+cM, silt and clay within macroaggregates. ¶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 and SED Time represent standard error of the difference between paired means with organic resource (OR), N-fertilizer (N), and sampling time, respectively.

| 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

### Effect of farmer management strategies on spatial variability of soil fertility and crop nutrient uptake in contrasting agro-ecological zones in Zimbabwe. *(2008) Nutrient Cycling in Agroecosystems, in press*

**Masvaya[1], E.N., Nyamangara[1], J., Nyawasha[1], R.W., Zingore[2], S., Delve[3], R.J., and Giller[4], K.E.**
*[1]University of Zimbabwe, Zimbabwe; [2]TSBF - CIAT, Malawi [3]TSBF - CIAT, Zimbabwe; [4]Wageningen university, The Netherlands*

Variability of soil fertility within, and across farms, poses a major challenge for increasing crop productivity in smallholder systems of sub-Saharan Africa (SSA). 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 $yr^{-1}$; 16.3 persons $km^{-2}$) and Murewa (average rainfall ~850 mm $yr^{-1}$; 44.1 persons $km^{-2}$) districts, Zimbabwe. In Murewa, resource-endowed farmers applied manure (>3.5 t $ha^{-1}$ $yr^{-1}$) on fields closest to their homesteads (homefields) 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 has declined, but homefields were continually cultivated. Soil available P was more concentrated on homefields (8-13 mg $kg^{-1}$) of resource-endowed farmers than on outfields and all fields on poor 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 nutrient uptake showed deficiency in 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.

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

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

**Abstract:** Social capital has become a critical issue in agricultural development as it plays an important role in collective action, such as, management of common resources and collective marketing. Whilst literature exists on the role of social capital in the use and adoption of improved agricultural technology, such literature is fraught with issues of the measurement of social capital beyond membership of farmers in groups. We hypothesized that different types of social capital influence the adoption of soil management options differently. This study

looked at the measurement of social capital, differentiating between the main types of social capital and employed factor analysis to aggregate indicators of social capital into bonding, bridging, and linking social capital. Using logit analysis, the role of these types of capitals on influencing use of different soil management options was analyzed. The study found that bonding, bridging, and linking social capital all influence the adoption and use of different soil management options differently, a trend that might be similar for other agricultural technologies as well. The study recommends more research investments in understanding the differentiated outcomes of these forms of social capital on use and adoption of technologies to further guide agricultural interventions.

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

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

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

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

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

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

## Gender analysis in socioeconomic and soil fertility management of communities under different farmer-market links in the highlands of southwestern Uganda

**R. Muzira[1], W. Chiuri[2], and B. Vanlauwe[3]**
*[1]Makerere University, Uganda; [2]CIAT, Kigali; [3]CIAT-TSBF, Kenya*

### Introduction

The increasing interest in the market orientation and special programs like African Growth and Opportunity Act (AGOA) and New Partnership for Africa Development (NEPAD) offers new opportunities for smallholder farmers in developing countries to alleviate poverty. This is great opportunity for the poor, and especially for poor women producers who rely on the intensification of subsistence and cash cropping on the land they cultivate. To increase household incomes and rural livelihoods, Uganda Government started special programs such as 'plan for agricultural modernization' and 'prosperity for all'. In these programs farmers are urged to embrace new technologies and produce commodities for market. For this cause, International Centre for Tropical Agriculture (CIAT) in partnership with Africare-Uganda trained farmers in three parishes in *Kamuganguzi* sub County, Kabale district in southwestern Uganda in potato production and Natural Resource Management (NRM) using Farmer Field School (FFS) approach. These farmers were later linked to profitable urban market (urban fast food restaurant) which they supply potato every fortnight under agreeable terms.

This report examines the influence of farmer-market links to socio economic characterization, NRM and level of potato production among the Female Headed Households (FHHs) and Male Headed Households (MHHs) in two communities with and without FFS.

### Materials and methods

The study was conducted in *Kamuganguzi* Sub County in six parishes - *Katenga, Buranga* and *Kicumbi* with FFS and *Mayengo, Kasheregyenyi* and *Kyasano* without FFS. A total of 90 and 50 households were used in rapid and detailed farm surveys in communities with and without FFS. The selected plots under potato production and their corresponding households were visited periodically during the growing period to follow up the management aspects of the selected farmers. The details about the plot history, soil conservation measures and what was going on were discussed together with the farmer. The data collected was expressed as average values for socio economic indicators (e.g. mean number of plots under cultivation in different households) and percentage distribution (Distribution of plots under potato) by tallying and using ANOVA table. Table of variance was used to calculate the mean value of potato production under the different household typologies. Statistics were done using Genstat Release 6 computer package

### Preliminary results

*Broad socio economic characterization of FFS and Non FFS communities*
During FGDs, it was found that there were 242 and 288 households in community with and without FFS respectively. It was observed that there are more MHHs in community without FFS (77.8%) as compared to the community with FFS (69.8%) in *Kamuganguzi* sub County **(Table 7)**. This is because community without FFS is at *Katuna* boarder with Rwanda and

men are more engaged in cross boarder business than agricultural production and commute from homes. This kind of business restricts members in their movements and men prefer working within their community and homes. Community with FFS is off the *Katuna* boarder and the majority of household rely exclusively on agriculture for their livelihoods. Some men in community with FFS tend to move away in search for more paying jobs in neighboring communities and distant urban centers leaving their wives to manage households for long periods. Therefore high proportion of FHHs is found in community with FFS (30.2%).

Majority of households are found in WC III with 47.5% and 58.7% households in communities with and without FFS respectively. Big portion of households is composed of non potato growers with 58.7% and 52.1% in communities with and without FFS respectively. This is attributed to the high costs involved in potato production coupled with high incidences of diseases such as bacterial wilt widely observed in farmers' fields. High costs occur in purchase of seed potato (US$ 29-88 per 80 kg bag), fertilizers (US $ 77-88 for 50 kg bag of NPK) and fungicides (US$ 21- 41). The FHHs are for widows, single mothers, wives with husbands working far away from community, or wives who were abandoned by their husbands. Most of these households are in WC III and IV **(Table 8)**. There is big portion of FHHs in WC III and IV (56% and 20.4%; 60% and 28.1%) respectively in community with and without FFS as compared to MHHs in the same WCs. On the other hand, high proportion of households in WC I (4.1% and 3.5% in FFS and FFS community) and WC II (28.5% and 18.1% in FFS and Non FFS communities) are MHHs. The FHHs in these two categories in both communities thrive on their children working in urban centers sending remittances back home.

**Table 7: Broad characteristics of households in the study area**

| Characteristics (%) | FFS community (n=242) | Non FFS community (n=288) |
|---|---|---|
| Male headed households | 69.8 | 77.8 |
| Female headed households | 30.2 | 22.2 |
| Potato growers | 41.3 | 47.9 |
| Non potato growers | 58.7 | 52.1 |
| Wealth Category I | 4.1 | 3.5 |
| Wealth Category II | 36.0 | 18.1 |
| Wealth category III | 47.5 | 58.7 |
| Wealth Category IV | 12.4 | 18.8 |

**Table 8: Distribution (%) of male and female headed households in communities with and without FFS**

| | FFS community | | Non FFS community | |
|---|---|---|---|---|
| | MHH (n=170) | FHH (n=80) | MHH (n=224) | FHH (n=64) |
| Wealth category I | 4.1 | 2.9 | 3.5 | 3.1 |
| Wealth category | 28.5 | 19.7 | 18.1 | 7.8 |
| Wealth category | 53.2 | 56.9 | 59.7 | 60.9 |
| Wealth category | 14.2 | 20.4 | 18.8 | 28.1 |

*Land use distribution among households*

Other than fallowed land, FHHs have less acreage for each of land uses as compared to MHHs in FFS community. This is because FHHs have fewer resources such as labor to put much of their land under cultivation resulting into large acreage of land fallowed as compared to MHHs. Many of the households in FFS community solely depend on agricultural production and MHHs with resources hire in more land from other households mainly from FHH to increase agricultural production. In community without FFS, acreage of land under cultivation is small because this community thrives mostly on cross boarder business as alternative source of livelihood. Large acreage of land under woodlots is found with MHHs in both communities. This is because MHHs have more plots as compared to FHHs and can afford putting some of them under woodlots while hiring in more land for food production. Generally, more land under woodlots is found in community without FFS and this is attributed to cross boarder business making community members more so in MHH to put some of the land under woodlots as a way of investment and security. Abandoned land is one that has been regarded as unproductive by farmers. This land is characterized by shallow soils, rock outcrops, gullies and low soil fertility due to erosion. This land is normally found on either at the shoulder of hilltops or back of hill slopes with high gradient (> 75%). It is the FHHs in community with FFS that has the least amounts of abandoned land. This is because FHHs in community with FFS have less land and most of if it is located near homesteads. Such land near homesteads is more accessible by household members and is more fertile because it receives more inputs in form of farmyard manure (FYM) or household wastes and therefore cultivated most of the times.

*Soil conservation measures and soil fertility management*
Observations through the last three decades indicates soil loss in *Kabale* district has been caused by destruction of soil conservation structures that were put in place on hill slopes during the colonial periods (Nkonya, 2003). The study area is characterized by undulating landscapes with steep slopes in most areas and during rain season there is an always substantial amount of soil eroded from farmers' plots.
In the study area it was observed that destruction of soil conservation structures is wide spread in both communities **(Figure 31)**. High population pressure and poverty are one of the leading factors in land degradation in south western Uganda (Mbabazi *et al.*, 2003). Farmers are destroying soil conservation structures like grass bunds that formed the beautiful scenery in the colonial days as they search for fertile soil. Fertile soils with great depth exist around soil conservation barriers due to continuous accumulation as they get eroded from upper bench terraces.

Though destruction is high in both communities, it is the FHHs that have a higher proportion of plots with destroyed soil conservation structures. It is the FHHs with fewer plots with soil conservation structures such as grass bunds and trenches. This is mainly attributed to the reduced soil fertility in the few plots owned by FHHs forcing them to extend the area of cultivation to the edge of the fields. Furthermore, poverty widely observed in FHHs forces such households to hire out some of the plots to individuals who may destroy soil conservation structures to increase area under cultivation.

Likewise high percentage of plots does not receive technologies that improve soil fertility and this has resulted into declining crop yields over time (Nkonya 2003). Though low level of SFM is applied in farmers' fields, it was observed that the situation is worse in FHHs. This is mainly attributed to poverty among the FHHs having no resources such as labor to apply FYM if at all is available and money to purchase fertilizers and animals to produce manure. Improving soil fertility through use of FYM is more common compared to other technologies. Fertilizers are expensive to buy and are not readily available in the community for farmers to access and therefore farmers who can afford apply them to potato or to other crops such as beans which are being promoted in the community without FFS. Low soil inputs coupled with different market links has resulted into differential yields and income for the different households and communities **(Figures 32)**. In FFS community the price for potato is US$ 0.25 per kg compared to US$ 0.15 per kg in community without FFS. The higher price in community with FFS would be an incentive for farmers to manage their fields better than the community without FFS. However, the situation is different as farmers thrive to first satisfy the immediate needs of the households before investing in NRM.

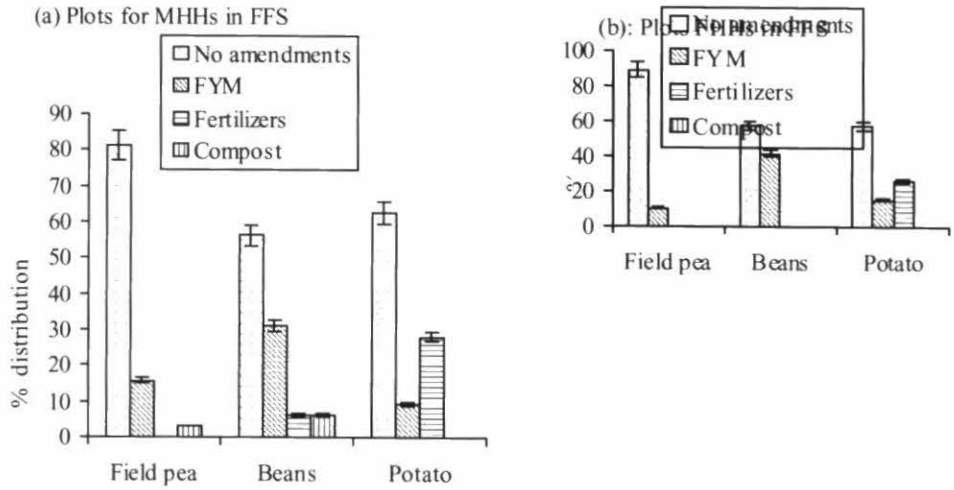



**Figure 31: Variation of plots receiving soil fertility management technologies.**

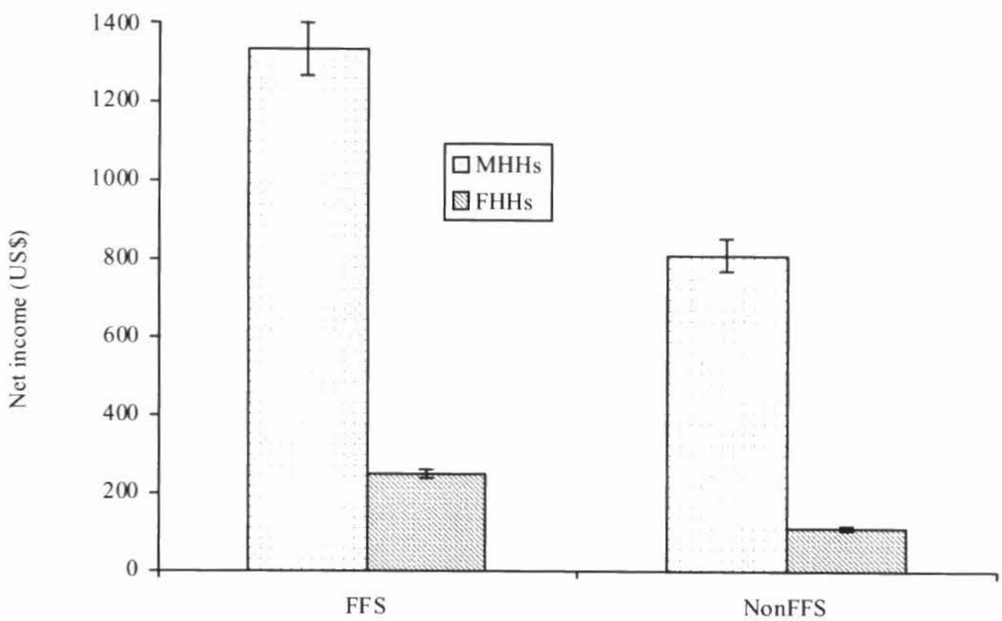



**Figure 32: Distribution of net income from potato sales in communities with and without FFS.**

**Preliminary conclusions**

Most households in *Kamuganguzi* Sub County are not potato producers despite the fact that potato is the main cash crop in communities with and without FFS. High poverty levels inhibit most households from potato production. To improve production there is need of more agricultural intervention. The available markets are not good enough as incentives for farmers to invest in potato production though the community predominantly rural. Income obtained from potato sales could entice farmers to invest back in NRM. Most household prefer investing their income in other enterprises such as cross boarder business other than agricultural production where the returns could be uncertain due to vagaries of weather, pests and diseases and price fluctuations. Low investments in NRM further degrade soils which manifests in low harvests and low income leading to perpetual poverty among the most households more especially FHHs with few alternatives for household incomes.

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

**J. Njuki[1], M. Mapila[1], S. Zingore[1], and R.J. Delve[2],**
*[1]TSBF - CIAT, Malawi; [2]TSBF - CIAT, Zimbabwe*

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

## Report on the evaluation of commercially available test-kits for soil fertility evaluation

**B. Vanlauwe[1], and W. Ngului[1],**
*[1]TSBF - CIAT, Kenya*

**Introduction**

In the context of the collaboration between TSBF- CIAT and AMARK aiming at enhancing the capacity of agro-dealers in western Kenya to give advice to farmers on Integrated Soil Fertility Management (ISFM), commercially available soil fertility assessment test kits were evaluated in a preliminary study based on their precision (repeatability of duplicate assessments) and accuracy (closeness to 5 or 6 values obtained through formal laboratory analysis).

## Materials and methods

Four test-kits were ordered in October 2008, three from the United States of America Rapitest-10, Rapitest-40, La Motte) and one from Uganda (Makerere University). All test-kits focus on the measurement of soil pH and the soil N, P, and K status. The cost per complete assessment varied between 0.5 and 3.3 USD without transport costs and between 0.7 and 3.8 USD including transport costs. Soils sampled from the 42 demonstration plots, established in cooperation with agro-dealers involved in the project were used as a basis for evaluating the test kits. Evaluation of the pH and K tests was carried out with 6 soil samples and evaluation of the P and N tests with 5 soil samples, covering the range observed across all 42 demonstration plots. Precision of the test kits was evaluated by duplicate measurements and accuracy by comparing the test kit results with formal laboratory analyses, obtained from the ICRAF soils laboratory at 19.8 USD per sample. Of the 4 soil test kits evaluated in this study, only the Makerere University kit produces relatively precise and accurate assessments of the soil fertility status, although pH and P assessments could still be improved.

*Description of the test-kits*

Based on above reasoning, 4 test-kits were ordered in October 2008, three from the United States of America and one from Uganda **(Table 9)**. The test-kits from the USA are mainly sold through stores providing gardening equipment. The kit from Uganda was developed for assisting farmers in determining their crops' nutrient requirements. All test-kits focus on the measurement of soil pH and the soil N, P, and K status because N, P, and K represent the most common deficiencies over a large fraction of the arable land and because low soil pH is one of the main chemical constraints to plant growth.

**Table 9: Selected characteristics of the used soil test kits.**

| Test kit | Supplier | Cost (USD) | | | Nr analyses per unit | Net cost per analysis (USD) | Total cost per analysis (USD) |
|---|---|---|---|---|---|---|---|
| | | Pur-chase | Trans-port | Total | | | |
| Rapitest – 10 tests Test Kit | www.amazon.com | 4.65 | 6.79 | 11.44 | 10 N, P, K, pH | 0.47 | 1.14 |
| Rapitest – 40 tests Test Kit | Biocontrol Network; 5116 Williamsburg Rd; Brentwood TN 37027; USA; Tel: +1-615-3704301; www.biconet.com | 19.90 | 6.30 | 26.20 | 40 N, P, K, pH | 0.50 | 0.66 |
| La Motte Garden Soil Test Kit | Edmund Scientific; 60 Pearce Avenue; Tonawanda; NY 14150; USA; Tel: +1-800-728-6999; www.scientificsonline.com | 49.95 | 6.48 | 56.43 | 15 N, P, K; 30 pH | 3.33 | 3.76 |
| Makerere University Test Kit | Prof J Tenywa; Makerere University; Kampala; Uganda; tenywamakooma@yahoo.com | 100.0 | 7.00 | 107.00 | 35 N, P, K, pH, OM[a] | 2.86 | 3.06 |

[a] The Makerere University Test Kit also contains the products to measure soil organic matter status (OM) although this test was not evaluated in the current report.

**Preliminary results**

The cost for a full assessment with this kit is 2.86 USD compared with 19.75 USD for a formal laboratory analysis. The former cost could easily be absorbed in the production cost of a farm, considering that 1 bag of fertilizer in western Kenya can cost between 35 and 70 USD. Besides cost, another advantage of test kits is the immediate availability of the data, whereas laboratory analysis can take at least several weeks before the data are reported. As for the Rapitest-40 test kit, its accuracy is relatively good for N and P but too low for K and pH. There are also limitations in terms of precision. The kit is, however, cheap and is commercially available, so it could be considered for more detailed evaluation. The Rapitest-10 and La Motte kits are not adapted to the soils of western Kenya or show too low precision to be suitable for use in the region. Since the current report covers a preliminary evaluation, a more detailed and complete evaluation of those test kits that have demonstrated substantial potential for use in western Kenya is required. This is especially important in view of the high demand by agro-dealers and development organizations interested in soil fertility improvement.

In terms of precision, only the Makerere test kit showed good reproducibility of the assessments, followed by the La Motte and the Rapitest-40 test kits (**Table 10**). The Rapitest-10 test kit showed a precision of less than 50%. In terms of accuracy, only the Rapitest-40 and the Makerere kits showed values over 50%, across all measurements. For those kits, N and P were mostly in line with formal laboratory analysis (**Table 10**).

**Table 10: Precision and accuracy of the different test kits for the various soil properties assessed. The results were scored as 0, 0.5, or 1, depending on the level of precision or accuracy and the proportions reported are scores received relative to the maximal score possible.**

| Test kit | Precision | | | | | Accuracy | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | pH | N | P | K | Avg | pH | N | P | K | Avg |
| | % accurate or precise values | | | | | | | | | |
| Rapitest – 10 tests Test Kit | 17 | --[a] | --[a] | --[a] | **17** | 25 | 90 | 40 | 42 | **49** |
| Rapitest – 40 tests Test Kit | 75 | 50 | 50 | 58 | **58** | 58 | 90 | 90 | 33 | **68** |
| La Motte Garden Test Kit | 33 | 90 | 90 | 58 | **68** | 75 | 30 | 40 | 25 | **43** |
| Makerere University Test Kit | 100 | 100 | 100 | 100 | **100** | 50 | 80 | 70 | 83 | **71** |
| **Average** | **56** | **73** | **73** | **67** | **67** | **52** | **73** | **60** | **46** | **58** |

[a] The Rapitest-10 test kits were only used once for assessing N, P, and K.

In terms of purchase and transport costs, the high price per assessment for the Makerere kit is partially balanced by the relatively cheap transport costs, relative to the kits from the USA. All test kits are cheaper and quicker in use than the formal laboratory route.

**Preliminary conclusions**

Of the 4 soil test kits evaluated in this study, only the Makerere University kit produces relatively precise and accurate assessments of the soil fertility status, although pH and P assessments could still be improved. The cost for a full assessment with this kit is 2.86 USD compared with 19.75 USD for a formal laboratory analysis. The former cost could easily be absorbed in the production cost of a farm, considering that 1 bag of fertilizer in western Kenya can cost between 35 and 70 USD. Besides cost, another advantage of test kits is the immediate availability of the data, whereas laboratory analysis can take at least several weeks before the data are reported.

Although the Rapitest kits cost less than a fifth of the La Motte and Makerere kits, the lack of precision and accuracy and the relatively high transport costs for these kits make them unsuitable for backstopping site-specific recommendations for nutrient management. The La Motte kit is more expensive than the Rapitest kits with little improvement in precision and accuracy.

## Study of water balance during the short rain in 2007 in Nyabeda, Kenya

**Z. Zacharie[1], PhD Student**
[1]*Wageningen University, the Netherlands*

### Introduction

For the purpose of a PhD work, a field water balance has been assessed in Nyadeba during the short and long rains 2007. The aim was to track water in and outflows of the root zone in order to construct the water balance scheme and to analyze the impact of the land management on the water distribution. To achieve this study, frequent measurement of soil moisture, soil evaporation, rain and runoff were done. These data provide information for the calculation of the equation of the water balance. This report presents the result of the short rain analysis since the other data are still being analysis.

### Materials and methods

A water balance study was organized during the short rain 2007 in Nyabeda (0° 06' N and 34° 34' E), is in western Kenya. The altitude is 1420 m, above sea level; the average annual rainfall is 1800 mm with a bimodal distribution. The soil has been classified as Ferralsol (FAO, 1990) with an average particle size distribution of 63.6 % clay, 21.1 % silt and 15.2 % sand and with a low pH range of 4.7 to 5.3 in the plough layer, 0-20 cm depth. The site was under native vegetation dominated by grasses and shrubs before it has been converted into cultivation in 2003 (Tunsisa T. H., 2007). In Nyabeda tillage as well as rotation has been studied in a full factorial, completely randomized block design started in 2003. The trial consists of Conservation (CT) and Conventional tillage (T) tillage and residue (removed or incorporated) and continuous maize (*Zea maize*) or maize-soybean rotation treatments. Within the four replications of the all trials, two replications of CT and T plots have been used in the study. So in total, 16 plots: 2 tillage options (CT, T) x 2 modes (+/- residues) x 2 rotations mode (continuous maize, maize-soybean) x 2 replications. Soil moisture at 5-150 cm depth was measured daily with the help of a TRIME. Soil evaporation was measured at 0-5 cm depth with the help of microlysimeter (diameter 11.6 cm). Rain was amounted with a rain and runoff with the help of runoff plot (1m$^2$).

*Analysis*
Statistical analysis was done by using GenStat for Windows Tenth Edition Copyright 2007 using the student Newman-Keuls test. Analysis of variance was used to establish the difference between the factors.

**Preliminary results**

There is a decreasing of the amount of water balance component from September to December. In November the amount decreases to 50% **(Figure 33)**. Evaporation remains low and infiltration supplies only half part of the total ET; however transpiration represents 80% of the ET.

*Global trend explanation*
Decreasing of ET is due to many factors: water supplying is decreasing; plants maturation does not allow more water up-taking into the soil because roots and soil are getting dry. Water is supply by rain and from September to December, rains remained regular and produce much water needed by plant to grow. On first September, total rain amount was 1012.9 mm more sufficient to keep the soil and the climatic factors (temperature, humidity) in favourable condition. Over the four months, rains remain regular and well distribute; 150 mm in September in 12 days, 166 mm in 12 days in October, 114 mm in 13 days in November and 154 mm in 7 days in December. Decreasing of ET was probably due to the fact of the physiological phenomena regulated by leaves which losses their physiological capacity since they are getting old. Decreasing of the transpiration is link to the development of the crops. While crop are getting mature leaves losses their ability to do the photosynthesis. The sudden decreasing of water balance in November will be explained latter once field observations were available. Decreasing of the evaporation is due to two phenomena water storage and surface coverage. Regularity of rain and crop development reduces soil evaporation. Infiltration decreases and supplies only half percent of the ET. Favourable climatic conditions may explain this situation. Indeed, infiltration during a runoff-generating rainfall event is regulated by the hydraulic properties of the root zone and the antecedent soil moisture (). Decreasing of the infiltration may be explained by water storage in the surface layer and the crust formation.

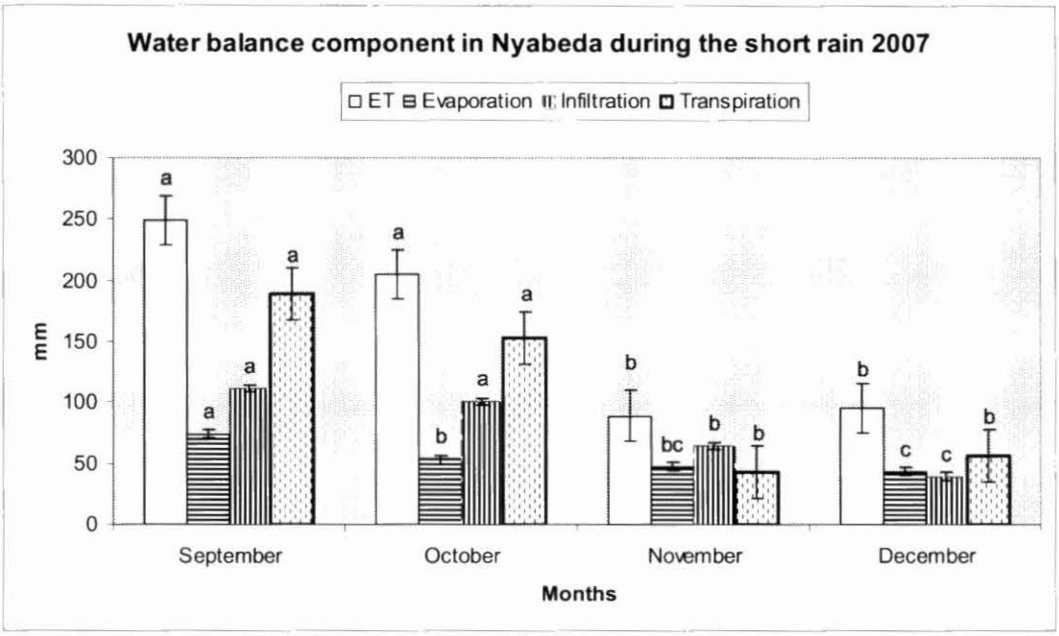



**Figure 33: Water balance components in Nyabeda field during the short rain 2007. Factors within a component with the same letter is not significantly different at P < 0.005 (student Newman-Keuls)**

*Interactive effects*

The factorial month x tillage, month x residues management, month x rotation, tillage x residues management and tillage x rotation do not have a significant (P < 5%) effect on the ET. ET may depend mainly on the climatic factor than on the land management. It is also possible that monthly scale of analysis was inappropriate and further analysis is needed in a weekly scale to determining the factorial effect. However, tillage affects significantly the infiltration. This is obvious since the tillage disturbs soil structure and allows infiltration. Field observations show a high percentage of infiltration when a rain comes just after a weeding. In Nyabeda, infiltration is high in tilled plot than in the CT plots. It was respectively in September 113.6 mm and 108.9 mm; in October 104.3 mm and 97.2 mm; in November 67.4 mm and 61 mm and in December 46.5 mm and 32.6 mm. This is probably because there was less physical disturbance in CT than in tilled plot.

**Preliminary conclusion**

Water balance data is needed in the process of water use efficiency calculation. That will allow further to work on the interactive effect of land management on WUE taking in account fauna diversity. Climatic conditions of Nyabeda influence the water balance and falling water remains on the vegetation and does not go deeply into the soil.

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

**J. Kihara[1,2], P. Vlek[2], C. Martius[2], W. Amelung[3], and A. Bationo[1]**

[1] *TSBF - CIAT, Kenya;* [2] *Zentrun fur Entiwicklungsforsung (ZEF), Germany;* [3] *Insitute of Crop Science and Resource Conservation, Soil Science and soil Ecology, University of Bonn, Germany*

### Introduction

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

### Materials and methods

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

(2mm, 250µm and 53µm). Isolation of POM, silt-clay and micro-aggregates within macro-aggregates was done according to the procedure of (Six et al. 2000). Bacteria and fungal diversity were determined from dry-incubated soils for Matayos and Machang'a and fresh soil for Nyabeda, using PCR-DGGE techniques.

**Preliminary results**

Conservation tillage systems could have similar or lower yields compared to conventional tillage systems. We observed similar yields between Tied-ridge and conventional tillage over 4 cropping seasons in Machang'a, but significantly lower yields in reduced and no-tillage systems (Table 1). In the dry land site also, although no-till yields were lower than conventional system for the initial seasons, they increased progressively and were significantly higher by the fourth season (data not shown). Application of crop residue increased yields by 13% in Matayos and 15% Nyabeda while combination of manure and CR in Machang'a increased yields by 24% over manure only treatments **(Table 11)**. CR is important also in soil water conservation and regulation of soil temperature especially when applied as surface mulch, as often done in reduced tillage. Recently, in order to improve water relations and crop performance in no-till and reduced tillage systems, modifications have emerged including ripping and sub-soiling and the results are promising (Motavalli et al. 2003), but also depending on the rainfall regime.

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

Diversity of bacteria is affected by tillage and organic substrates of different sources (Øvreås and Torsvik 1998). Diversity of bacteria in Machang'a and Nyabeda were not affected by tillage but in Matayos, reduced tillage showed higher bacteria diversity over conventional tillage system. Fungi diversity was higher in CT than in RT but nevertheless, we found no difference in the numbers of identified bands. Higher band volume under reduced tillage indicated that few fungal communities dominated this system, leading to the lower Shannon diversity index observed. Also there was significantly low diversity of fungal where crop residue was applied compared to treatments without crop residue, again due to domination by fewer species. Shannon diversity is high only when species numbers are high and evenness fulfilled. It could also be that domination by few species of fungi pushes other existing species to the <1% of microbial cells, usually too few to be detected by PCR-DGGE technique. As observed with soil aggregation, both bacteria and fungi diversity (Shannon index) were higher in intercropping compared to continuous maize system as observed in Nyabeda (data not shown). In Machang'a despite low carbon content, bacteria diversity was higher than in Matayos perhaps due to the towards neutral pH compared to more acidic soils in Matayos. In a continental-scale research involving different sites in North and South America, diversity of soil bacteria communities increased as soil pH increased from acidic to near neutral (Fierer and Jackson 2006).

**Table 11: Effect of tillage on maize grain yield, aggregate mean weight diameter and microbial diversity**

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

## Effects of tillage practice and crop residue application on soybean nitrogen fixation in a tropical Ferralsol

**J. Kihara[1,2], A. Bationo[1], C. Martius[2], and P.L.G.Vlek[2]**
*[1]CIAT-TSBF, Kenya; [2] Center for Development Research (ZEF), University of Bonn, Germany*

This study aimed at quantifying dinitrogen fixation of soybean under reduced and conventional tillage in a tropical Ferralsol of the sub-humid zone of western Kenya, using the isotope $^{15}N$ dilution method. Crop residue management was a superimposed treatment in a soybean-maize rotation and intercropping system. This study included the contribution of senesced soybean leaves over the growing season. Phosphorus fertilization greatly increased nodulation, but application of N had a depressive effect. Soybean nitrogen derived from the atmosphere (%NDFA) ranged between 41-65%; it was higher ($P<0.05$) in reduced (55.6%) than in conventional tillage (46.6%). Application of crop residue in rotation system decreased NDFA from 57% to 45% under conventional tillage (CT; $P<0.05$), whereas under reduced tillage (RT), it increased NDfA from 49% to 65% ($P<0.05$). Total fixed N under RT plus CR was at least 55% and 34% more than in the other treatments in intercropping and rotation systems, respectively. Nitrogen fixed in soybean aboveground plant parts was 26-48 kg N $ha^{-1}$ with intercropping and 53-82 kg N $ha^{-1}$ with rotation. Seasonal litter fall contained about 15 kg N $ha^{-1}$, with 54% derived from dinitrogen fixation. Soybean residues after removal of grains should be returned to the field plots after harvest, and an additional 10-30 kg N $ha^{-1}$ in RT and 40-60 kg N $ha^{-1}$ in CT systems added annually (to reduce soil N mining). We conclude (i) that RT combined with surface application of CR increases biological nitrogen fixation in soybean, over CT; and (ii) that phosphorus application is needed for better soybean nitrogen fixation and production in western Kenya.

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

**J. Kihara[1,2], A. Bationo[1], C. Martius[2], and P.L.G.Vlek[2]**
*[1]TSBF - CIAT, Kenya; [2]Center for Development Research (ZEF), University of Bonn, Germany*

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

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

**J.K. Maguta[1], P.L.G. Vlek[1], C. Martius[1], W. Amelung[2], and A. Bationo[3]**
*[1]University of Bonn, Center for Development Research (ZEF), Germany; [2]University of Bonn, Institute of Crop Science and Resource Conservation: Division of Soil Science, Germany; [3]TSBF - CIAT, Kenya*

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

| **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. |

## NO COMPLETED WORK

## WORK IN PROGRESS

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

**P. Pypers[1], J.M. Sanginga[2], N. Mbikayi[3], T. Ngoga[4], A. Gahigi[4], and B. Vanlauwe[1]**
*[1]TSBF - CIAT, Kenya; [2]CIAT, DR Congo; [3]INERA, DR Congo; [4]ISAR, Rwanda*

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. 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. 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 34)**. This is not 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.

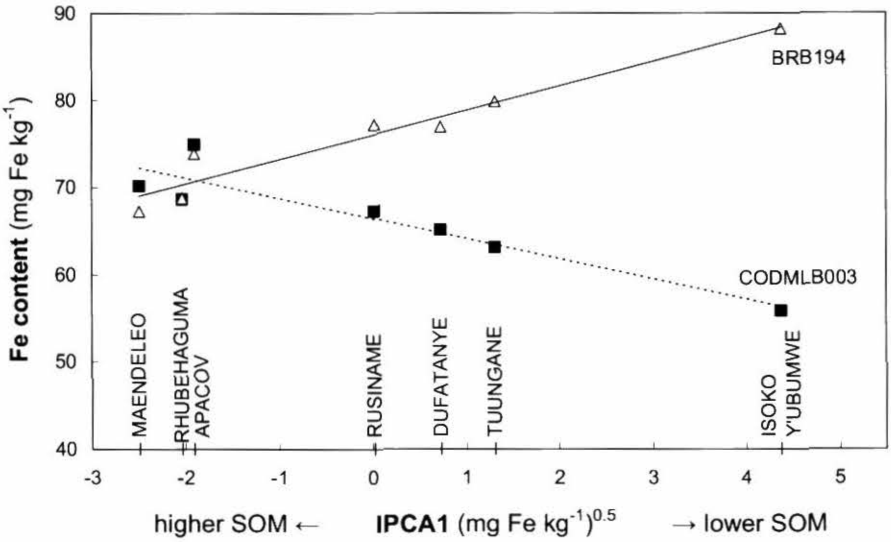



**Figure 34: Grain Fe content in two contrasting bean varieties as affected by environment, calculated using a principal component analysis. Factor scores for a number of fields used for germplasm evaluation with farmer associations are correlated with the soil organic matter content (organic C and total N).**

| **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. |

## COMPLETED WORK

### Combining Organic and Mineral Fertilizers for Integrated Soil Fertility Management in Smallholder Farming Systems of Kenya: Explorations Using the Crop-Soil Model FIELD *(2008) Agronomy Journal, vol. 100.5*

**Tittonell[1], P., Corbeels[2], M., van Wijk[3], M.T., Vanlauwe[4], B., and Giller[3] K.E.**
*[1]CIRAD, France; [2]TSBF - CIAT, Zimbabwe; [3]Wageningen University, The Netherlands*
*[4]TSBF - CIAT, Kenya*

Integrated soil fertility management (ISFM) technologies for African smallholders should consider (i) within-farm soil heterogeneity; (ii) long-term dynamics and variability; (iii) manure quality and availability; (iv) access to fertilizers; and (v) competing uses for crop residues. We used the model FIELD (Field-scale resource Interactions, use Efficiencies and Long term soil fertility Development) to explore allocation strategies of manure and fertilizers. Maize response to N fertilizer from 0 to 180 kg N ha–1 (±30 kg P ha–1) distinguished poorly responsive fertile (e.g., grain yields of 4.1–5.3 t ha–1 without P and of 7.5–7.5 t ha–1 with P) from responsive (1.0–4.3 t ha–1 and 2.2–6.6 t ha–1) and poorly responsive infertile fields (0.2–1.0 t ha–1 and 0.5–3.1 t ha–1). Soils receiving manure plus fertilizers for 12 yr retained 1.1 to 1.5 t C ha–1 yr–1 when 70% of the crop residue was left in the field, and 0.4 to 0.7 t C ha–1 yr–1 with 10% left. Degraded fields were not rehabilitated with manures of local quality (e.g., 23–35% C, 0.5–1.2% N, 0.1–0.3% P) applied at realistic rates (3.6 t dm ha−1 yr−1) for 12 yr without fertilizers. Mineral fertilizers are necessary to kick-start soil rehabilitation through hysteretic restoration of biomass productivity and C inputs to the soil.

## Yield gaps, nutrient use efficiencies and response to fertilizers by maize across heterogeneous smallholder farms of western Kenya. *(2008) Plant Soil 313:19-37*

**Tittonell[1], P., Vanlauwe[2], B., Corbeels[3], M., and Giller[4], K.E.**
*[1]CIRAD, France; [2]TSBF - CIAT, Kenya; [3]TSBF - CIAT, Zimbabwe [4]Wageningen University, the Netherlands*

**Abstract:** The need to promote fertilizer use by African smallholder farmers to counteract the current decline in per capita food production is widely recognized. But soil heterogeneity results in variable responses of crops to fertilizers within single farms. We used existing databases on maize production under farmer (F-M) and researcher management (R-M) to analyze the effect of soil heterogeneity on the different components of nutrient use efficiency by maize growing on smallholder farms in western Kenya: nutrient availability, capture and conversion efficiencies and crop biomass partitioning. Subsequently, we used the simple model QUEFTS to calculate nutrient recovery efficiencies from the R-M plots and to calculate attainable yields with and without fertilizers based on measured soil properties across heterogeneous farms. The yield gap of maize between F-M and R-M varied from 0.5 to 3 t grain ha−1 season−1 across field types and localities. Poor fields under R-M yielded better than F-M, even without fertilizers. Such differences, of up to 1.1 t ha−1 greater yields under R-M conditions are attributable to improved agronomic management and germplasm. The relative response of maize to N–P–K fertilizers tended to decrease with increasing soil quality (soil C and extractable P), from a maximum of 4.4-fold to −0.5- fold relative to the control. Soil heterogeneity affected resource use efficiencies mainly through effects on the efficiency of resource capture. Apparent recovery efficiencies varied between 0 and 70% for N, 0 and 15% for P, and 0 to 52% for K. Resource conversion efficiencies were less variable across fields and localities, with average values of 97 kg DM kg−1 N, 558 kg DM kg−1 P and 111 kg DM kg−1 K taken up. Using measured soil chemical properties QUEFTS over-estimated observed yields under F-M, indicating that variable crop performance within and across farms cannot be ascribed solely to soil nutrient availability. For the R-M plots QUEFTS predicted positive crop responses to application of 30 kg P ha−1 and 30 kg P ha−1 + 90 kg N ha−1 for a wide range of soil qualities, indicating that there is room to improve current crop productivity through fertilizer use. To ensure their efficient use in sub-Saharan Africa mineral fertilizers should be: (1) targeted to specific niches of soil fertility within heterogeneous farms; and (2) go hand-in-hand with the implementation of agronomic measures to improve their capture and utilization.

## Potential nutrient supply, nutrient utilization efficiencies, fertilizer recovery rates and maize yield in northern Nigeria

**Tabi[1], F.O., Diels[2], J., Ogunkunle[3], A.O., Iwuafor[4], E.N.O. Vanlauwe[5], B., and Sanginga[5], N.**
*[1]University of Dschang, Cameroon; [2]KU Leuven, Belgium; [3]University of Ibadan, Nigeria; [4]Institute of Agricultural Research, Nigeria; [5]TSBF - CIAT, Kenya;*

**Abstract:** Potential N (SN) and P (SP) supplies, N and P utilization efficiencies and fertilizer recovery rates for the northern Guinea Savanna (NGS) agroecological zone of Nigeria were

derived from data collected on farmers' fields, and used as input in the Quantitative Evaluation of the Fertility of Tropical Soils (QUEFTS) model. The potential N supply ranged from 7 to 56 kg N ha–1, with a mean of 25 kg N ha–1, while SP ranged from 2 to 12 kg P ha–1 with a mean of 5 kg P ha–1. Both SN (CV = 42%) and SP (CV = 57%) were highly variable between farmers' fields. Deriving potential nutrient supply from 'a' values gives lower estimates. The empirical equation in QUEFTS that estimates SN (SN ¼ 1:7 _ OC _ ðpH _ 3Þ) sufficiently predicted the SN of soils in the NGS (RMSE = 8.0 kg N ha–1 index of agreement (IOA) = 0.81). The SP equation (SP ¼ 0:35 _ ð1 _ 0:5 _ ðpH _ 6Þ2Þ _ OC þ 0:5_ OlsenP) predicted moderately potential P supply (RMSE = 6.80 kg P ha–1, IOA = 0.54). When N or P is maximally accumulated in the plant (i.e., least efficiently utilized), the utilization efficiency was 21 kg grain kg–1 N taken up and 97 kg grain kg–1 P taken up. When these nutrients were maximally diluted in the plant (i.e., most efficiently utilized), the utilization efficiency was 70 kg grain kg–1 N taken up and 600 kg grain kg–1 P taken up. The range in N recovery fraction (NRF) of N fertilizer applied was from 0.30 to 0.57, with a mean of 0.39, while the P recovery fraction (PRF) ranged from 0.10 to 0.66 with a mean of 0.24. Although SP was moderately predicted, when QUEFTS model input parameters were adjusted for the NGS, the model sufficiently (IOA = 0.83, RMSE = 607 kg DM ha–1) estimated maize grain yield in the NGS of Nigeria. The original QUEFTS model however, gave better predictions of maize grain yield as reflected by the lower RMSE (IOA = 0.84, RMSE = 549 kg DM ha–1). Consequently, QUEFTS is a simple and efficient tool for making yield predictions in the NGS of northern Nigeria.

### Modeling crop-livestock systems for achieving food security and increasing production efficiencies in the Ethiopian highlands. *(2008) Cambridge University Press doi: 10.1017/ s0014479708006741*

**Amede[1], T., and Delve[2], R.J.**
*[1]African Highlands Initiative, Ethiopia; [2]TSBF - CIAT, Kenya*

**Abstract:** An action research process was conducted with communities in Gununo, southern Ethiopia (2000–2003), to develop alternative cropping strategies for achieving their food security and cash needs. Farmers identified three major production objectives depending on their household priorities and socio-economic status. In Group I, farmers are currently food insecure and want to produce enough food from their own farms. In Group II, they produce enough food but want to fulfill their financial needs. In Group III, farmers rely on off-farm activities and want to increase cash income. The current system mostly fulfills the nutritional requirement of Group II. Groups I and III were highly food deficit from their own farms, with production covering less than seven months per year and fulfilling <50% of the recommended daily allowances (RDA) for human nutrition. Using a linear programming optimization model, it was possible to fulfill the RDA of Group I by reallocating the cropping area of maize, sweet potato, coffee and wheat to potato, enset and kale in proportions of 50, 29 and 15%, respectively. To satisfy both financial and nutritional needs of Group II, an increase in the proportion of coffee and beans by about 29 and 7.3%, respectively, over the current land allocation was needed. This shift would triple their cash income. The cash income of Group III increased four-fold by full replacement of the cereals and root crops by coffee (48%) and teff (52%), though the total income was not enough to secure food security due to their small landholdings. In farms of Groups I and II, the shift to the suggested cropping will reduce soil erosion by about 40%, while it will have no effect on farms of Group III. This shift will reduce the quantity and quality of livestock feed, except for Group I. Moreover, it will increase the farm crop water requirement 17.5 and 37% in Groups I and III (resource poor households) and reduce it in resource rich households of Group II. These changes did not

imply extra labour in any groups. Whilst this model can optimize systems for food security and cash income, its research for development value is in identifying possible intensification strategies for farming systems and their implications on the farming systems, rather than generating practical recommendations for all cropping systems.

## WORK IN PROGRESS

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

**S. Zingore[1], P. Tittonell[2], M. Corbeels[3], M.T. van Wijk[4], and K.E. Giller[4].**
*[1]TSBF - CIAT, Malawi; [2]CIRAD, France; [3]TSBF - CIAT, Zimbabwe; [4]Wageningen University, the Netherlands*

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.

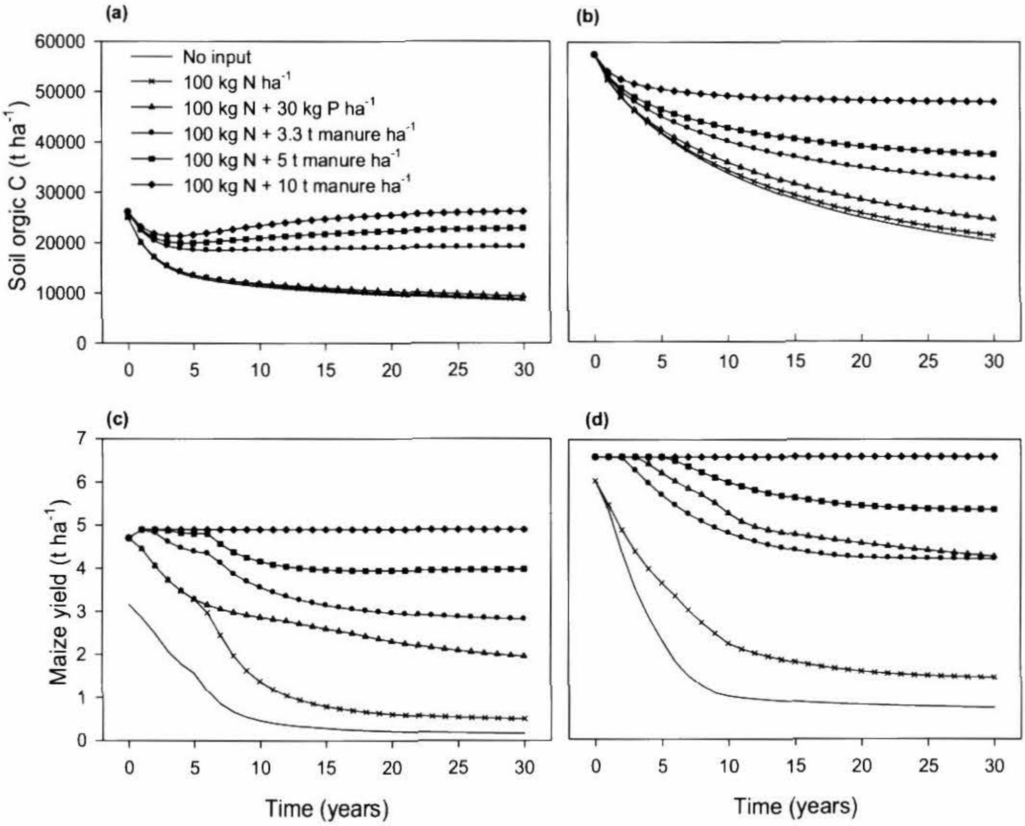



**Figure 35: Simulated effects of resource management options on long-term dynamics of soil organic C on the sandy (a) and clay soils (b), and maize grain yields on the sandy (c) and clay (d) soils.**

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

**P. Gottschalk[1], J. Bellarby[1], C. Chenu[2], B. Foereid[1], M. Wattenbach[1], J. Smith[1], and S. Zingore[3]**

*[1]University of Aberdeen, UK; [2]INAPG, UMR Bioemco, France; [3]TSBF - CIAT, Malawi*

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

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

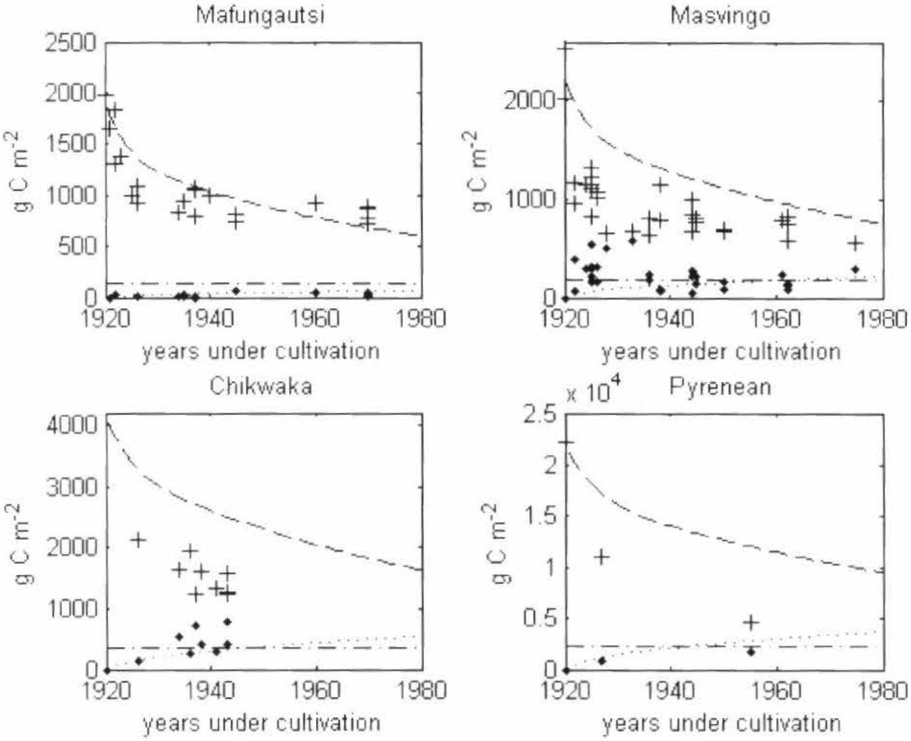



**Figure 36: Forest derived C (crosses) and maize derived C (squares) and simulated forest derived C (dashed line) and maize derived C (dotted line) for four chronosequence sites in Zimbabwe. IOM pool calculated using the model default Falloon equation (dashed-dotted line).**

| Output 1. Processes and principles |
|---|
| **Output Targets 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. |

## NO COMPLETED WORK

## NO WORK IN PROGRESS

| 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 COMPLETED WORK

## WORK IN PROGRESS

### Effect of long term application of organic and inorganic resources on soil properties and maize yield at Kabete, Kenya

**B.S. Waswa[1], A. Bationo[1], D. Mugendi[2], J.M. Okeyo[1], J. Kimetu[3]**
*[1]TSBF - CIAT, Kenya; [2]Kenyatta University, Kenya [3]Cornell University, NY, USA*

An experiment was established during the short rain season 1999 to assess the fertilizer equivalencies of organic and inorganic nutrient sources. Three organic resources, *Tithonia diversifolia* (tithonia), *Calliandra calothrysus* (calliandra) and *Senna spectabilis* (senna) were applied singly or in combination with inorganic fertilizer in the form of urea to supply an equivalent of 60 kg N ha-1. The above treatments were compared to an N fertilizer response curve involving application of urea at the rate of 0, 30, 60 and 100 kg N $ha^{-1}$. Results from this trial consistently showed higher maize grain yields in the treatments receiving combinations of organic and inorganic nutrient sources compared to the sole and control treatments. On average, Tithonia plus 30 kg N $ha^{-1}$ gave the highest grain and biomass yields. This trend could be attributed to improved synchrony in nutrient release and uptake by the crop. The organic resource gave a fertilizer equivalency of 130, 72 and 68% for tithonia, calliandra and senna respectively. Analysis on whole soil showed minimal changes in the whole soil carbon and nitrogen. However, higher proportions of C and N were observed in the aggregate size fractions. An analysis on the carbon-13 signature of the soil fractions testified that the application of the C3 organic resources was responsible for this shift in the SOM composition observed in at site.

### Influence of Land Use and Cropping Systems on the Soil Monosaccharides Content: Induced Effects on Soil Aggregation in the Western Cotton Area of Burkina Faso

**B. Ouattara[1], K. Ouattara[1], G. Piombo[2], A. Assa[3], P.M. Sédogo[1], A. Bationo[4]**
*[1]INERA, Burkina Faso; [2]CIRAD, Montpellier/France; [3]Université de Cocody, UFR/SVT, Côte d'Ivoire; [4]TSBF - CIAT, Kenya.*

Soil organic carbon (SOC) and more precisely its labile pools play a pivotal role in the sustainable soil fertility management of poorly-ranged swelling clays soils in sub-Saharan Africa. The role of soil monosaccharides was assessed, based on a large typology of land use intensity. Thus 33 plots were sampled at a depth soil of 0-15 cm, considering field-fallow successions and tillage intensity. Six monomeric sugars (arabinose, xylose, glucose, galactose, glucosamine, mannose) accounting for 12 to 15% of SOC content has been extracted. The soil total sugars contents are significantly reduced by crop setting. But this depletion is more affecting hexose monomeric sugars (glucose and mannose), in particular that of microbial origin (mannose). The first ten cropping years after old fallow lands induces a loss of 63% in mannose contents while annual ploughings practice in continuous cropping system leads to the greatest depletion (80%). As soon as the cropped plots are reconverted into fallow lands the soil monosaccharides contents record a renewed growth and rapidly get closer to the equilibrium level observed in the old fallow lands. Like soil polysaccharides contents, the amounts of soil water stable aggregates get lower as function of tillage intensity. But the total soil sugars explain only 13% of soil aggregation variability against 25% induced by galactose + mannose. Therefore, the soil monosaccharides from microbial neo synthesis could be considered as early indicators of SOC content depletion and key elements for soil aggregation.

| 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 COMPLETED WORK

## NO WORK IN PROGRESS

| 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. |

## COMPLETED WORK

### Interactive effects from combining fertilizer and organic residue inputs on nitrogen transformations. *(2008) Soil Biology & Biochemistry 40: 2375-2384.*

**Gentile[1], R., Vanlauwe[2], B., Chivenge[1], P., and Six[1], J.**
*[1]University of California, Davis, USA; [2]TSBF - CIAT, Kenya*

**Abstract:** Concerns about sustainability of agroecosystems management options in developed and developing countries warrant improved understanding of N cycling. The Integrated Soil Fertility Management paradigm recognizes the possible interactive benefits of combining organic residues with mineral fertilizer inputs on agroecosystem functioning. However, these beneficial effects may be controlled by residue quality. This study examines the controls of inputs on N cycling across a gradient of 1) input, 2) residue quality, and 3) texture. We hypothesized that combining organic residue and mineral fertilizers would enhance potential N availability relative to either input alone. Residue and fertilizer inputs labeled with $^{15}N$ (40-60 atom% $^{15}N$) were incubated with 200 g soil for 545 d in a microcosm experiment. Input treatments consisted of a no-input control, organic residues (3.65 g C $kg^{-1}$ soil, equivalent to 4 Mg C $ha^{-1}$), mineral N fertilizer (100 mg N $kg^{-1}$ soil, equivalent to 120 kg N $ha^{-1}$), and a combination of both with either the residue or fertilizer $^{15}N$-labeled. *Zea mays* stover inputs were added to four differently textured soils (sand, sandy loam, clay loam, clay). Additionally, inputs of three residue quality classes (class I: *Tithonia diversifolia*, class II: *Calliandra calothyrsus*, class III: *Zea mays* stover) were applied to the clay soil. Available N and $N_2O$ emissions were measured as indicators for potential plant N uptake and N losses. Combining residue and fertilizer inputs resulted in a significant ($P<0.05$) negative interactive effect on total extractable mineral N in all soils. This interactive effect decreased the mineral N pool, due to an immobilization of fertilizer-derived N and was observed up to 181 d, but generally became non-significant after 545 d. The initial reduction in mineral N might lead to less $N_2O$ losses. However, a texture effect on $N_2O$ fluxes was observed, with a significant interactive effect of combining residue and fertilizer inputs decreasing $N_2O$ losses in the coarse textured soils, but increasing $N_2O$ losses in the fine textured soils. The interactive effect on mineral N of combining fertilizer with residue changed from negative to positive with increasing residue quality. Our results indicate that combining fertilizer with medium quality residue has the potential to change N transformations through a negative interactive effect on mineral N. We conclude that capitalizing on interactions between fertilizer and organic residues allows for the development of sustainable nutrient management practices.

### Residue quality and N fertilizer do not influence aggregate stabilization of C and N in two tropical soils with contrasting texture. *(2008) Nutrient Cycling in Agroecosystems doi: 10.1007/s10705-008-9216-9*

**Gentile[1], R., Vanlauwe[2], B., Kavoo[2], A., Chivenge[1], P., and Six[1], J.**
*[1]University of California, Davis, USA; [2]TSBF - CIAT, Kenya*

**Abstract:** To address soil fertility decline, additions of organic resources and mineral fertilizers are often integrated in sub-Saharan African agroecosystems. Possible benefits to long-term C and N stabilization from this input management practice are, however, largely unknown. Our objectives were 1) to evaluate the effect of residue quality and mineral N on soil C and N stabilization, 2) to determine how input management and root growth interact to control this stabilization, and 3) to assess how these relationships vary with soil texture. We

sampled two field trials in Kenya located at Embu, on a clayey soil, and at Machanga, on a loamy sand soil. The trials were initiated in 2002 with residue inputs of different quality (no input, high quality *Tithonia diversifolia*, medium quality *Calliandra calothyrsus*, and low quality maize stover), incorporated at a rate of 4 Mg C $ha^{-1}$ $yr^{-1}$ alone and in combination with 120 kg N $ha^{-1}$ $season^{-1}$ mineral fertilizer. Maize was grown in the plots each season, and a section of the plots was left uncropped. All aboveground maize residues were removed from the plots. Soil samples (0-15 cm) were collected in March 2005 to assess aggregation and C and N stabilization. The fine-textured soil at Embu was more responsive to inputs than the coarse-textured soil at Machanga. Residue additions increased macroaggregation at Embu, and cropping increased aggregation at Machanga. At Embu adding organic residue, regardless of the quality, and cropping significantly increased total soil C and N. This increase was also observed in the macroaggregate and microaggregate-within-macroaggregate fractions. Input treatments had little effect on C and N contents of the whole soil or specific fractions at Machanga. Nitrogen fertilizer additions did not significantly alter C or N content of the whole soil or specific fractions at either site. We conclude that residue quality does not affect the stabilization of soil organic C and N. Inputs of C and soil stabilization capacity are more important controls on stabilization of soil organic matter.

## WORK IN PROGRESS

### Interaction between Resource Quality, Aggregate Turnover, Carbon and Nitrogen Cycling in the Central Highlands of Kenya

**A. Kavoo[1], B. Vanlauwe[1], J. Six[2], R. Gentile[2], D. Mugendi[3], G. Muluvi[3], H.K. Wangechi[1]**
*[1]TSBF - CIAT, Kenya; [2]University of California, Davis; [3]Kenyatta University, Kenya*

#### Introduction

Improved soil fertility is a prerequisite for agricultural production. Inorganic fertilizers have been used extensively in the past as source of nutrients but high cost has led to limited use. Organic resource (OR) provides an alternative source of nutrients. OR provide SOM (SOM enhances soil physical, biological and physical properties) and stabilizes soil aggregates. The big challenge to the use of organic resources is ensuring that crops efficiently utilize nutrients from the applied organic materials. Recent research shows that combination of OR with MR increases rate of decomposition and mineralization. Rate of decomposition affects aggregate turnover rate, C sequestration and N use efficiency. Residue quality and mineral N level governs the rate of aggregate formation and breakdown (i.e., the rate of aggregate turnover). High quality residue (class I) induce a high rate of decomposition and hence a high rate of aggregate turnover. Medium quality organic residues (class II and III) lead to a short term increased nitrogen use efficiency and carbon sequestration and a minimal N loss while low quality residues (class IV) lead to a low rate of decomposition, low aggregate turnover and long term C sequestration. The objective of this study was to investigate how organic and mineral resource management affect the balance between carbon (C) and nitrogen (N) stabilization through aggregate formation and C and N release following aggregate breakdown and how this affects system-wide N use efficiency and C sequestration.

## Materials and methods

The experiment was carried out in Embu district which is located in the Central highlands of Kenya at '0°30' S, 37°27' E and an altitude of 1380 m above sea level. The average temperature is about 20°C. The rainfall is bimodal with the long rain (LR) from March to May and short rains (SR) from mid October to December. The average annual rainfall is 1200mm. The Embu soil is clay loam (sand 32, silt 30 and clay 38%) derived from basic volcanic rocks. The soil is classified as Humic Nitisols (FAO, 1990) and has Kaolinite as the dominant clay mineral. The experiment was set-up in March 2002 as part of long-term trials aimed at determining the influence of repeated application of organic resources (ORs) of different quality and quantities on soil organic matter dynamics. Five organic resources belonging to the four quality classes proposed by Palm et al. (1997) were applied at a C rate of 4 t C $ha^{-1}$. The OR treatments applied were: class I: *Tithonia diversifolia*, class II: *Calliandra calothyrsus*, class III: *Zea mays* stover, class IV: *Eucalyptus saligna,* sawdust, and high quality farmyard manure. The ORs were broadcast and hand incorporated to a depth of 0.15 m using a hand hoe once a year at planting during the long rain (LR) season. A control treatment where no residues were applied was also included. The plot sizes were 12 by 6 m laid out in a randomized complete block design in a factorial experiment with three replicates. Maize was planted as the test crop in both the long rain and short rain seasons. The plots were split in half where 120 kg N $ha^{-1}$ N fertilizer was added in one-half of the main plot. One third of the N fertilizer was applied 3 weeks after planting and the remainder was applied 8 weeks after planting by broadcasting and incorporating in the soil. All plots received a blanket application of P at 60 kg P $ha^{-1}$ and K at 60 kg K $ha^{-1}$ at planting by broadcasting and incorporating in the soil. Before incorporation, the five residue types were sub sampled and analyzed for total organic C, N, lignin, polyphenol. These values were used to convert the C equivalent application rate to application rates of fresh biomass per hectare**.** Soil sampling was carried out before long rains 2002 and 2005. Soil samples were taken at a depth of 0-15cm. Separation of aggregate size classes by was done by wet sieving and sub samples of each soil fraction were ground and analyzed for C and N

## Preliminary results

Higher formation of macroaggregates was observed with the sole sawdust (low quality organic resource (OR)) treatment compared to the higher quality ORs **(Figure37)**. Results also indicated increased higher C and N levels with both the sole ORs and combined ORs and MR treatments in 2005 compared to 2002 **(Figure 38).** Soils amended with tithonia and stover treatments contributed significant C and N within the macroaggregates and microaggregates size classes **(Figure 39)**. Stover minus N (medium quality organic resource) treatment contributed the highest N within the small macroaggregates **(Figure 39)**. Combined application of tithonia, manure, calliandra and stover plus N treatments led to increased C contribution compared to the sole applications **(Figure 39)**

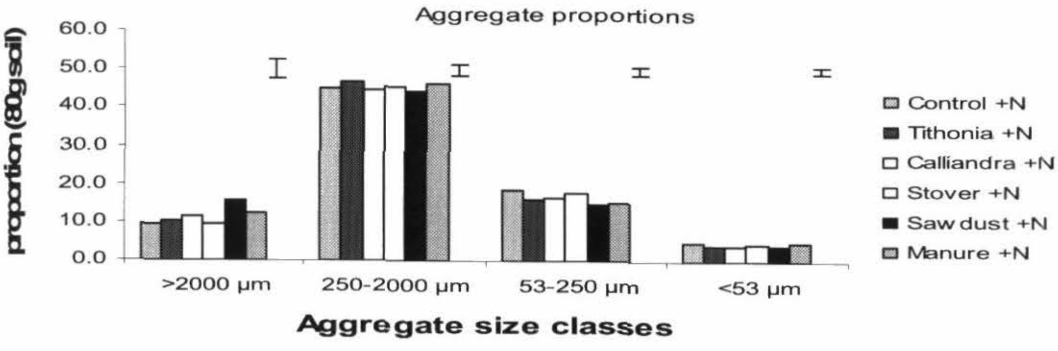



**Figure 37: Effect of combining organic resource quality and mineral fertilizer on the proportion of aggregate size classes at Embu in March 2005.**

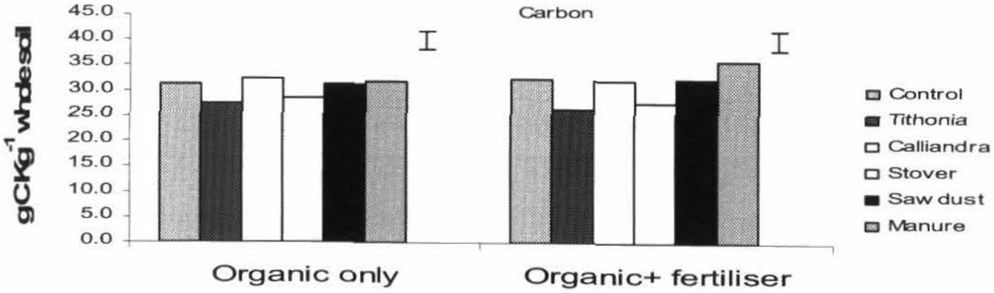
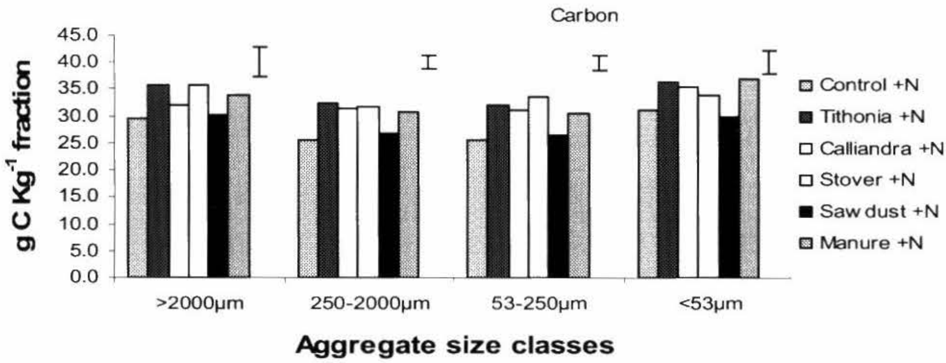



**Figure 38: Effect of resource quality and the combination of ORs and MR on the quality of nutrients (C and N) of whole soil at Embu in March 2005. Same trend was followed for Nitrogen**



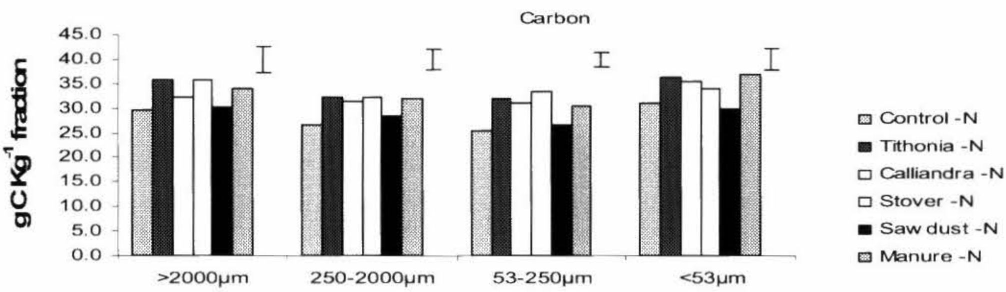




**Figure 39: Effect of organic resource quality and mineral fertilizer on C and N concentration of aggregate size classes at Embu in March 2005. Same trend followed for Nitrogen**

## Soil Organic Matter (SOM) Studies-Ghana: The interaction between resource quality and aggregate turnover controls ecosystem nitrogen and carbon cycling.

**E. Yeboah[1], J. Six[2], B. Vanlauwe[3]**
*[1]Soil Research Institute, Ghana; [2]KU Leuven, Belgium; [3]TSBF - CIAT, Kenya*

### Introduction

Maintaining soil quality and fertility is of a worldwide importance. Any changes in the factors influencing soil quality and soil processes can take decades to have any measurable effect. Similarly, the effects of agriculture on the wider environment may take years to become obvious. Long-term experiments with their contrasting treatments and management are invaluable resource, which can be used to examine these effects in greater detail. Currently, a core resource at the Soil Research Institute is a long-term field trial that compares crop and soil response to addition of organic resources of contrasting quality, and different rates of application, with and without additional chemical fertilizer. The experiment is fully replicated, intensively monitored and repeated at a second site on a contrasting soil.
The overall hypothesis of the study is that the impact of residue quality on soil organic carbon quantity and quality diminishes over time but the rate at which the impact of the residue quality diminishes is influenced by interaction among residue quality, mineral N addition, soil

texture and climate. One objective of the study was to examine the influence of organic resource quality on soil productivity. A second objective was to provide information on the resilience of the C pool in two contrasting soil textures (sandy loam and silt loam) in the semi-deciduous forest zone of Ghana.

**Materials and methods**

The experiment was established in 2003 in the semi-deciduous forest zone of Ghana at Ayuom and Kwadaso on two dominant soil series. The agroecology is primarily, a smallholder, subsistence farming area, with poor and degrading soils, very variable rainfall which in turn is reflected in low and uncertain crop production. Six organic resources commonly available to smallholder farmers and ranging from high, medium and low qualities with and without inorganic fertilizers were evaluated. Organic resources were applied at 4 t C $ha^{-1}$ $yr-^{1}$. The organic materials were: *Crotalaria juncea* (Class I), *Leucaena leucocephala* (Class II), Maize stover (Class III), *Afzelia africana* (Sawdust) (Class IV) and Cattle manure (unclassified). The experimental design was a split-split plot design. Maize was the test crop. Plant height and girth was determined at 4 weeks interval and at harvest, maize yield indices such as grain yield, biomass yield, harvest index and total yield were estimated. The data was analyzed using Genstat version 10.

Two soil organic matter fractionation methods were used to assess the impact of the treatments, a detailed one based on soil aggregation (Six *et al.*, 2001) and a second tied to simulation model (Sohi *et al.*, 2001). The use of natural abundance $^{13}C$ was also used to understand the trajectory of soil organic matter in tropical soils. Using the method of Six *et al* 2001; soil fractions were first separated by wet sieving into four different fraction sizes (>2000μm, 250-2000 μm, 53-250μm and <53μm). The >2000μm and 250-2000 μm fractions representing large and small macroaggregates respectively, were each fractionated further into >250μm, 53-250μm and <53μm fractions to assess the extent of macoraggregate occluded microaggregate under different resource quality application. Dried samples of soil fractions were analyzed for C, N and $^{13}C$ using mass spectrometry.

**Preliminary results**

Application of organic resources resulted in a substantial immediate benefit in maize grain yield of 85-150% depending on the quality of the organic resource applied at both sites. At both sites, high rate of application (4 t C $ha^{-1}yr^{-1}$) resulted in a significant maize grain yield compared to lower rate of application (1.2 t C $ha^{-1}yr^{-1}$). As shown in **(Figure 40)**, addition of inorganic N to low class materials (Class III and IV) appeared to result in relatively higher maize stover yield than with the high class materials (Class 1 and II).

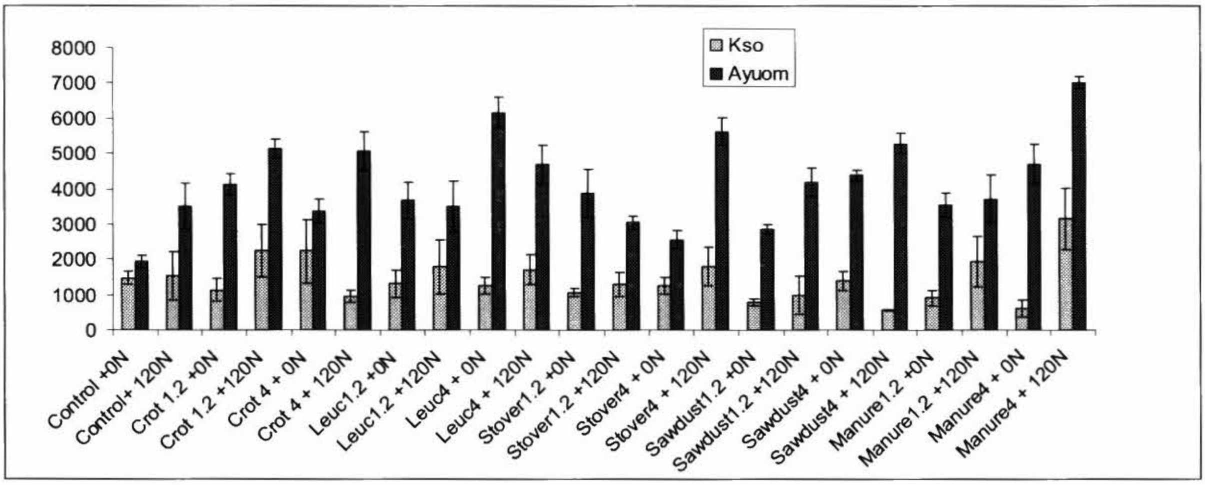



**Figure 40: Influence of organic resource quality and quantity on maize stover yield (kg/ha) for 2007 minor season. Error bars represent standard error about the mean.**

**Preliminary conclusions**

Cattle manure, classified as low quality material based on decision tree of organic resource management (Palm et al. 2001), can sustain continual maize production in the tropics and also ensure storage of organic carbon. Use of cheaper, readily available nutrient input can increase crop output. This may address a major constraint that resource –poor farmers face in developing countries. This notwithstanding, combined application of organic resource (especially cattle manure) and N fertilizer (120kgN/ha) greatly enhanced crop performance i.e. grain yield and below ground biomass. Maximum short-term benefits in terms of quantity of SOM can be achieved by applying high quality ORs such as tithonia and high quality manure or by combining ORs of medium quality and mineral fertilizer. Long-term build up of SOM can be achieved through sole application of medium quality ORs such as stover and calliandra. Application of low quality ORs such as sawdust, though important in the initial formation of macroaggregates, requires more experimental time to establish their role in SOM build up in the long term.

| **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 COMPLETED WORK

## NO WORK IN PROGRESS

| **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 COMPLETED WORK

NO WORK IN PROGRESS

## 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.<br>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.<br>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 **(Figure 3)**. This Outcome is the most crucial Outcome of this Outcome line.

*Major research questions are:*

→ *Which are the major drivers affecting the identification of ISFM practices that are adapted to the target cropping systems and impact zones?*

→ *Which levels of heterogeneity within communities and within farms affect the identification of best-fit ISFM practices?*

→ *Which soil fertility indicators are sufficiently sensitive to allow farmers to adapt ISFM practices to the soil fertility status of their various plots?*

→ *How can decision support tools, simulation modeling, and optimization models be integrated to develop improved productivity management options with farmers?*

→ *Which interventions that reduce production risks are available for evaluation?*

| 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

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

**Mairura[1], F.S., Mugendi[2] D.N., Mwanje[2], J.I., Ramisch[1], J.J., Mbugua[3], P.K., and Chianu[1], J.N.**
*[1]TSBF - CIAT, Kenya; [2]Kenyatta University, Kenya [3]Department of Botany, Kenyatta University, Kenya*

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

## WORK IN PROGRESS

### Targeted fertilizer management for maize-pigeon pea intercrops under variable soil fertility conditions in Chiradzulu

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

Malawi currently has blanket fertilizer recommendations for crop production and these only cover N and P. These recommendations were derived from fertilizer trials at district level and do not make any provision for adjusting nutrient applications according to site specific soil fertility conditions. Beyond this they also fail to consider potential deficiencies of base cations and micronutrients in soils caused by long-term intensive cultivation. The recommendations are also crop-specific and may not be suitable for inter-cropping systems, for example the maize-pigeon pea intercrop that dominates the densely populated areas in southern Malawi. Participatory on-farm experiments were conducted to determine the type of nutrients required for increasing productivity and profitability of maize within maize-pigeon pea intercrops for variable soil fertility conditions. To select sites with contrasting soil fertility conditions, farmers were asked to identify main land units with different soil types. Farmers identified sandy and light brown soils as less fertile than grey coloured loamy soils. Within units with similar soil types, fields which varied in soil fertility status were also selected according to management history – fertile fields that had received large amounts of nutrient resources in the past were distinguished from infertile fields which had been cropped for many years without fertilizer inputs. The criteria used to select the fields were generated and are easily identifiable by farmers. These will be validated by detailed soil characterization of the sites. Based on these criteria field were classified as low, medium and high fertility status. Ten fields were selected in each of these three soil fertility categories. Experimental results showed that maize productivity and response to addition of different nutrient combinations varied considerably in fields classified as having low, medium and high fertility. Maize yield response to application of N was significant across all field types. Addition of a micro-nutrient mix (K, Ca, Zn and B) substantially increased maize yields in fields of medium fertility by about 70%. There is therefore scope for farmers to increase maize productivity within intercrops by targeted application of fertilizer compound containing base cations and micronutrients.

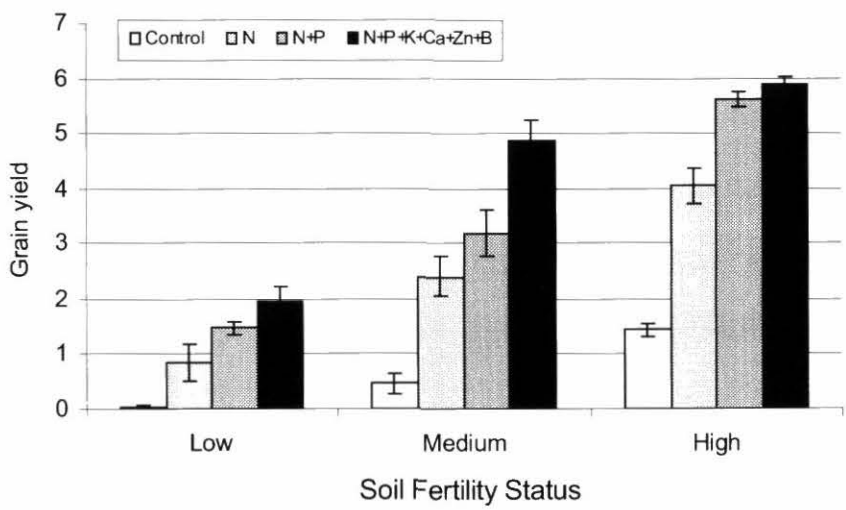



**Figure 41: Crop productivity as influenced by soil fertility status and different nutrient combinations.**

## Benefits of legume-maize rotation systems confirmed for the Humid Forest zone


**P. Pypers[1], J.M. Sanginga[2], K. Bishikwabo[2], J. Rehani[3], M. Walangululu[3], A. Chifizi[4], S. Mapatano[4], N. Mbikayi[5] and B. Vanlauwe[1]**

*[1]TSBF - CIAT, Kenya; [2]CIAT, DR Congo; [3]UCB, DR Congo; [4]DIOBASS, DR Congo; [5]INERA, DR Congo*


Rotation systems with promiscuous soybean have positive rotational effects on subsequent cereal crops. This has been demonstrated in several regions in Africa. These benefits are primarily related to improved N nutrition through the decomposing legume residues. This system was evaluated in Sud-Kivu and Rwanda using promiscuous, high biomass-yielding legume varieties. In Sud-Kivu, both soybean and climbing beans were evaluated. Two of the preferred improved varieties were used: climbing bean AND10 and soybean SB24. The results obtained confirmed the rotational benefits of legumes on a subsequent maize crop

(**Figure 42**). Maize yields were increased by 25 % and 40 %, when following AND10 and SB24, respectively, relative to a maize monoculture system (maize following maize). When combining the system with micro-dose fertilizer application (one capsule of NPK granules in every planting hole), maize yields are increased by an additional 35 %. Fertilizer application is particularly required in P-deficient soils. An improved, responsive maize variety is required to obtain maximal benefits. Information brochures and detailed technical descriptions will be developed for promotion and dissemination by research and development partners.

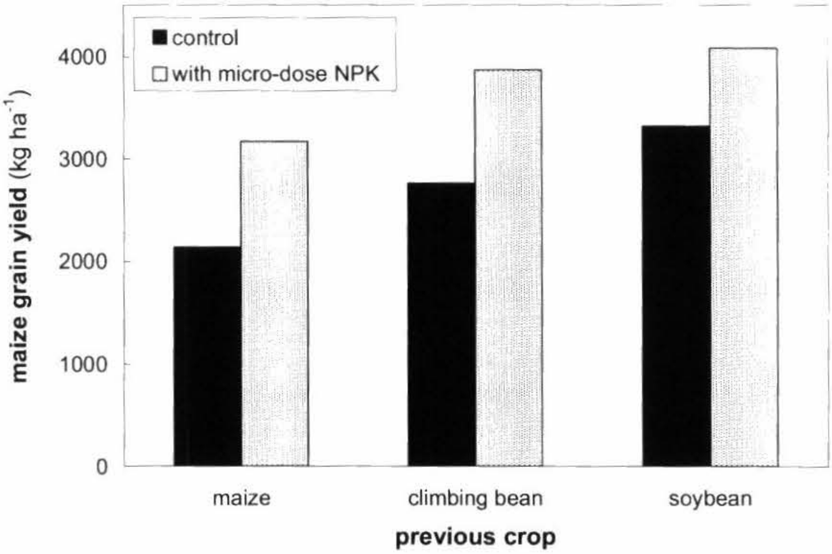



**Figure 42: Maize grain yields observed for a maize crop following maize, climbing bean AND10 or soybean SB24, as affected by micro-dose fertilizer application in Luhihi, Sud-Kivu, DRC.**

## Site-specific technologies for tackling soil fertility constraints


**P. Pypers[1], E. Vandamme[2], J.M. Sanginga[3], M. Walangululu[4], R. Tete[5], R. Merckx[2] and B. Vanlauwe[1]**

*[1]TSBF - CIAT, Kenya; [2]KU Leuven, Belgium; [3]CIAT, DR Congo; [4]UCB, DR Congo; [5]INERA, DR Congo*


Soil fertility constraints are tackled using the *Integrated Soil Fertility Management* framework. ISFM practices combine the use of improved germplasm and fertilizer application with appropriate organic matter management and local adaptation, in order to optimize the agronomic efficiency of applied inputs, and improve crop productivity. Under local adaptation, we understand modifications of the practices that take into account specific biophysical limitations or the heterogeneity of the local environment. Heterogeneity in soil fertility leads to differential responses to fertilizer. A sound knowledge base is required to determine best practices that maximize the agronomic efficiency of applied inputs. Farmers often have indigenous knowledge on soil quality, and distinguish fertility levels based on soil properties such as colour and texture, or based on prior knowledge on crop performance. Local soil quality indicators have been shown to correspond with formal analysis results (Mairura et al., 2006). The question arises whether such local soil quality indicators are a sufficiently accurate basis to formulate flexible guidelines for ISFM options, which would ultimately enable farmers to locally adapt technologies and maximize crop productivity.

This question was addressed in the eastern part of the Walungu territory in the Democratic Republic of Congo, an area that is ill-reputed for its unfertile and acid soils. Previous results from field and greenhouse trials showed that P deficiency was the major constraint for crop growth. Further investigations revealed other crop constraints, related to poor soil organic matter content and unresponsiveness to fertilizer, soil acidity and specific cation deficiencies. These require specific interventions, which can be related to local soil quality indicators. Farmers generally distinguish two soil types: black soils ("Civu") and red soils ("Kalonko"). Black soils are characterized by higher soil organic matter contents, and are responsive to fertilizer **(Figure 43)**. Red soils, contrarily, are generally less fertile and fertilizer application does not result in significant improvements in crop yields. These red soils require application of manure, and highest yields are obtained by combining mineral and organic inputs.

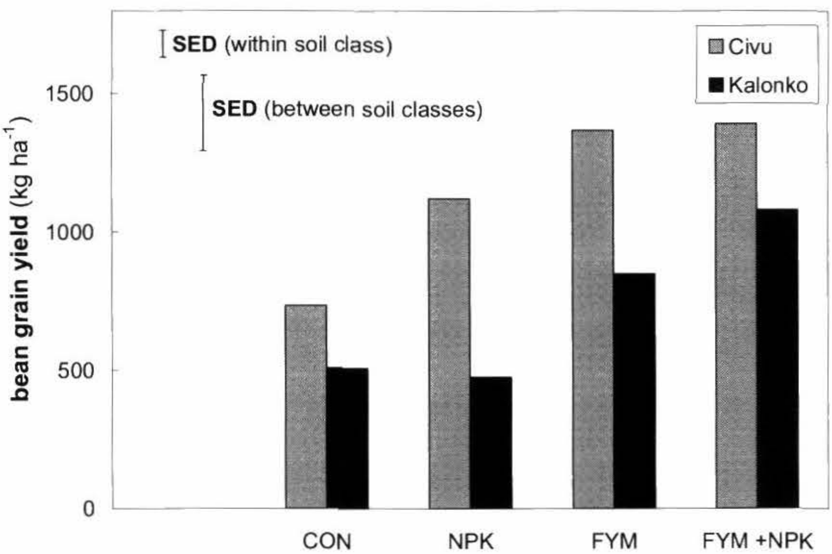



**Figure 43: Bean response to application of fertilizer (NPK at 20 kg P ha$^{-1}$) and/or farm yard manure (FYM applied at 5 t DM ha$^{-1}$), relative to the control (CON) in two soil types following the local classification system.**

Within each soil class, farmers generally acknowledge both fertile and poor soils. Fertile soils are generally characterized by higher pH values, higher concentrations of exchangeable bases, and lower levels of exchangeable acidity. Leaf analyses revealed important deficiencies of potassium and magnesium, which were most pronounced in the poor Kalonko soils. In greenhouse trials, K omission resulted in yield reduction by 40 % in poor soils, and micronutrient omission resulted in yield reductions which varied between 0 and 50 %, and could be related to leaf Mg concentrations.

These results indicate the need for targeted interventions, which can be based on local soil conditions. Fertilizer application can be recommended in "Civu" soils, but should be combined by manure in "Kalonko" soils. In addition, poor soils generally require amendments to correct soil acidity. Organic inputs were more effective than lime; only manure application resulted in significant improvements in crop growth. Finally, poor soils may also require supplements of K and Mg, which could, for example, be provided through Mavuno, a cheap fertilizer blend produced in Kenya by Athi River Mining Ltd that combines imported macronutrients (N and P) with locally granulated minerals (gypsum and dolomitic limestone), muriate of potash and micronutrients (B, Zn, Mn, Mo and Cu).

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

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

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

| **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

### The prospects of reduced tillage in tef (Eragrostis tef Zucca) in Gare Arera, West Shawa Zone of Oromiya, Ethiopia. *(2008) Soil and Tillage Research 99: 58-65*

**Tulema[1], B., J.B. Aune[2], Johnsen[2], F.H., and Vanlauwe[3], B.**
*[1]Holetta Research Center, Ethiopia; [2]Norwegian University of Life Sciences, Norway; [3]TSBF - CIAT, Kenya;*

Soils in Ethiopia are traditionally ploughed repeatedly with an oxen-drawn plough before sowing. The oxen ploughing system exposes the soil to erosion and is expensive for farmers without oxen. This study was undertaken to assess agronomic and economic impacts of alternative, reduced tillage methods. Field experiments were carried out on a Vertisol and a Nitisol for 2 years to study the effect of zero tillage, minimum tillage, conventional tillage, and broad bed furrows (BBF) on the yield of tef (Eragrostis tef Zucca). No significant differences in tef biomass and grain yields were observed between the treatments on both soils in the first year. In Nitisol in the second year, yield was lower in the zero tillage treatment as compared to the other treatments. No difference in yield was observed between single plough, conventional, and BBF. On Vertisol, the yields were higher in BBF as compared to the other treatments. The yields on Vertisol were 1368, 1520, 1560 and 1768 kg ha_1 for the zero tillage, minimum tillage, conventional tillage and BBF treatments respectively. More than twice as much grass weed was observed on zero tillage treatment as compared to the BBF treatment on both soils. Zero tillage gave the lowest gross margin on both soils whereas BBF gave the highest gross margin. The gross margin on Nitisols for the zero tillage and BBF treatments were _108 and 1504 Birr/ha respectively and corresponding numbers for the Vertisol were 520 and 1924 Birr ha_1. On Vertisol there were no significant difference in gross margin between minimum tillage and conventional tillage. Minimum tillage is an interesting option on Vertisols, particularly for female-headed households as it reduces the tillage cost. It may also improve overall productivity of the farming system because it allows partial replacement of oxen with cows and reduces soil erosion.

### Integrated management of Striga hermonthica, stemborers, and declining soil fertility in western Kenya. *(2008) Field Crops Research online, www.sciencedirect.com*

**B. Vanlauwe[1], F. Kanampiu[2], G.D. Odhiambo[3], H. De Groote[2], L.J. Wadhams[4], and Z.R. Khane[5]**
*[1]TSBF - CIAT, Kenya; [2]CIMMYT, Kenya; [3]Egerton University, Kenya; [4]Rothamsted Research, UK; [5]ICIPE, Kenya*

**Abstract:** Striga hermonthica (Delile) Benth, stemborers, and declining soil fertility are serious threats to sustainable food production in the Lake Victoria zone of Kenya. To address these constraints, promising integrated crop management technologies were evaluated, using a multi-locational design in four sub-locations in Siaya and Vihiga district (western Kenya) for six cropping seasons. Technologies evaluated consisted of the traditional maize (Zea mays L.) – bean (Phaseolus vulgaris L.) intercrop, maize – Desmodium (Desmodium uncinatum (Jacq.) DC.) push–pull intercrop, Crotalaria (Crotalaria ochroleuca G. Don) – maize rotation, and soybean (Glycine max (L.) Merr) – maize rotation. Within each of these systems, imazapyr-coated herbicide-resistant maize (IR-maize) and fertilizer were super-imposed as sub-plot factors. The push–pull system was observed to significantly reduce Striga emergence and stemborer damage from the second season onwards. IR-maize reduced and delayed Striga emergence from the first cropping season. Differences in Striga emergence and stemborer damage between the other systems were not significantly different. After five cropping seasons, the Striga seed bank was significantly higher in the maize-bean intercrop system than in the push–pull system under both maize varieties while the rotational systems had intermediate values not different from the day zero values. Under IR-maize, the Striga seed bank was significantly lower than under local maize for all cropping systems. Maize yields varied between seasons, districts, and cropping systems. Yields in the push–pull system were higher than in the maize-bean intercrop after two seasons and in the absence of mid-season drought stress. Both maize and soybean responded significantly to fertilizer application for both districts and for most seasons. The various interventions did not substantially affect various soil fertility-related parameters after five seasons. In the short term, IR-maize integrated in a push–pull system is the most promising option to reduce Striga while the rotational systems may need a longer timeframe to reduce the Striga seed bank. Finally,

farmer-led evaluation of the various technologies will determine which of those is really most acceptable under the prevailing farming conditions.

## Evaluation of application timing in fertilizer micro-dosing technology on millet production in Niger, West Africa. *(2008) Nutrient cycling in Agroecosystems Journal. Vol. 80, (3): 257-265*

**Hayashi[1,2], K., Abdoulaye[3], T. Gerard[1], B. and Bationo[4], A.**
*[1]ICRISAT, Niger; [2]Japan International Research Center for Agricultural Sciences, Japan; [3]INRAN, Niamey, Niger; [4]TSBF - CIAT, Kenya*

**Abstract:** Micro-dosing technology has been developed by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and its partners to help subsistence farmers in the Sahel improve inorganic fertilizer application. However, the ICRISAT's recommendations regarding fertilizer application through this technology are only applicable at sowing and do not allow any flexibility in terms of labor and/or capital management. In rural areas, fertilizer cannot always be applied at sowing due to financial and labor constraints. The purpose of this study was to evaluate the effect of the timing of fertilizer application on millet production. A 2-year on-station experiment and a 1-year on-farm field experiment were conducted in the western region of Niger, West Africa. Even under the heterogeneous climatic conditions of the region during our experimental period, the results showed that the trend was the same as observed in previous studies: millet production improved through fertilizer application compared to the control (without fertilizer). The harvest index was also higher compared to that of the control. This increased production was consistently the same for all application timings. The marginal value–cost ratio on the investment calculated using a budgeting analysis for the on-farm experiment showed that – regardless of application timing – millet farmers who fertilized their fields with inorganic fertilizer made more profit than those who did not (control). This was also true for farmers who were unable to fertilize at sowing – delayed application was still the more profitable option relative to the no fertilizer control. Our results indicate that small subsistence farmers can be offered more options for inorganic fertilizer application timing using the micro-dosing technology. Delayed inorganic fertilizer application can help small farmers who are often labor constrained at the sowing period improve their yields as well as their economic returns.

## Millet nutrient use efficiency as affected by natural soil fertility, mineral fertilizer use and rainfall in the West African Sahel. *(2008) Nutrient cycling in Agroecosystems Journal. Vol. 81, (1): 25-36*

**Fofana[1], B., Wopereis[2], M. C. S., Bationo[3], A., Breman[4], H. and Mando[2], A.**
*[1]IFDC, Burkina Faso; [2]IFDC, Togo; [3]TSBF - CIAT, Kenya; [4]IFDC, Rwanda*

**Abstract:** Field experiments were designed to investigate the effectiveness of integrated soil fertility management (ISFM), comparing fertilizer use efficiency and its impact on millet, cultivated close to the homestead ("infields") and away from the homestead ("outfields"). Millet yields and response to N (0, 30, and 60 kg $ha^{-1}$) and P (0, 15, and 30 kg $ha^{-1}$) were determined on nine infields and nine outfields over a period of 3 years (from 1999 to 2001) in the southern Sahel of Niger. Rainfall was 650, 470, and 370 mm during the three successive years, interaction between decreasing rainfall and millet yield performance was also analyzed. While soil organic carbon (1.5 g $kg^{-1}$ on outfields and 1.6 g $kg^{-1}$ on infields) and pH-$H_2O$ (4.8 on outfields and 5.1 on infields) were comparable, total-N, plant available P (measured as P-Olsen and P-Bray), and exchangeable Ca, K, and Mg levels were higher on infields as

compared to outfields. Without fertilizer, average grain yield (GY) and stover yield obtained on infields were three times as high as on outfields. GY across years and fertilizer treatments was higher on infields as compared to outfields ($P < 0.001$). Average yield was 800 kg ha−1 on outfields and 1,360 kg ha−1 on infields ($P < 0.001$). On outfields, average GY was stagnant over the 3-year experimental period. Despite declining rainfall, millet GY across all treatments gradually increased over time on infields ($P < 0.001$). P fertilization alone resulted on both field types to steadily and substantial yield increases while yield response to N fertilization was only obvious when fertilizer P was applied. With no fertilizer applied, N uptake on infields (19 kg N ha−1) was more than twice as high as on outfields (7 kg ha−1), and P uptake was four times higher on infields (3 kg ha−1) than on outfields (0.8 kg ha−1). Indigenous soil N supply was on average 24 kg N ha−1 on outfields and 46 kg N ha−1 on infields. Average value for indigenous soil P supply was 4 kg P ha−1 on infields and 2 kg ha−1 on outfields. Apparent recovery of fertilizer N applied varied considerably among treatments and ranged from 17 to 23% on outfields and 34 to 37% on infields ($P < 0.001$). Average apparent recovery of fertilizer P applied was significantly higher ($P < 0.001$) on infields (31%) than on outfields (18%) over the 3-year growing period, illustrating ISFM-induced positive effect on millet nutrient N and P use. Results indicate higher inherent soil fertility, underline ISFM-induced drought tolerance of soils on infields as compared to outfields, and highlight the crucial role of fertilizer P (especially on outfields) for millet production. These call for site-specific nutrient management and support, even under low rainfall conditions, the potential value of fertile infields for efficient and productive external input use and sustainable millet production in West African Sahel.

## Effects of conservation tillage, crop residue and cropping systems on changes in soil organic matter and maize–legume production: a case study in Teso District. *(2008) Nutrient cycling in Agroecosystems Journal*

**Anyanzwa[1], H., Okalebo[1], J.R., Othieno[1], C.O., Bationo[2], A., Waswa[2], B.S. and Kihara[3], J.**

*[1]Moi University, Kenya; [2]TSBF - CIAT, Kenya; [3]Center for Development Research (ZEF), Germany;*

**Abstract:** The effects of conservation tillage, crop residue and cropping systems on the changes in soil organic matter (SOM) and overall maize–legume production were investigated in western Kenya. The experiment was a split-split plot design with three replicates with crop residue management as main plots, cropping systems as sub-plots and nutrient levels as sub-sub plots. Nitrogen was applied in each treatment at two rates (0 and 60 kg N ha−1). Phosphorus was applied at 60 kg P/ha in all plots except two intercropped plots. Inorganic fertilizer (N and P) showed significant effects on yields with plots receiving 60 kg P ha−1 + 60 kg N ha−1 giving higher yields of 5.23 t ha−1 compared to control plots whose yields were as low as 1.8 t ha−1 during the third season. Crop residues had an additive effect on crop production, soil organic carbon and soil total nitrogen. Crop rotation gave higher yields hence an attractive option to farmers. Long-term studies are needed to show the effects of crop residue, cropping systems and nutrient input on sustainability of SOM and crop productivity.

## Strategic P application in legume-cereal rotations increases land productivity and profitability in western Kenya

**J. Kihara[12], B. Vanlauwe[2], B. Waswa[2], J.M. Kimetu[3], J. Chianu[2] and A. Bationo[2]**
*[1]Center for Development Research (ZEF), Germany; [2]TSBF - CIAT, Kenya; [3]Crop and Soil Science Department, Cornell University, USA*

Many food production systems in sub-Saharan Africa (SSA) are constrained by phosphorus (P). We hypothesized that within legume-cereal rotation systems, (1) targeting P to the legume phase leads to higher system productivity and (2), that use of grain legumes lead to better economic benefits than use of herbaceous legumes. Four P application regimes: (1) no P, (2) P applied every season, (3) P applied in season one only and (4) P applied in season two only were tested for four seasons in three cropping systems (continuous maize, mucuna-maize rotation and soybean-maize rotation) in a split-split plot experiment set up in Nyabeda, western Kenya. There was a significant response to P application and data showed that treatments where P was applied were different from no P treatments. While continuous cereal systems showed the need for application of P every other season, mucuna and soybean systems indicated that application in one out of three seasons could be sufficient. Mucuna without P had lower effect on yield indicating its inability to contribute to soil improvement in a P-limited soil as compared to soybean. However, from the treatments with P in one or more seasons, maize after mucuna was better than maize after soybean. The marginal rate of returns (MRR) showed that soybean-maize rotation with one application of P was the most economically viable option. Farmers are therefore better off if they switch from the other options to soybean-maize rotation since such a switch attracts an MRR of up to 220%.

## Exploring crop yield benefits of integrated water and nutrient management technologies in the Desert Margins of Africa: Experiences from semi-arid Zimbabwe

**I. Nyagumbo[1], and A. Bationo[2]**
*[1]University of Zimbabwe, Harare; [2]African Network for Soil Biology and Fertility of TSBF - CIAT, Kenya*

The benefits of integrating locally adaptable water and nutrient management technologies were explored under semi-arid conditions in Zimbabwe. On-farm maize based experiments were set up on six farmers' fields in Ward 5, Shurugwi. Three tillage systems namely post-emergence tied ridging (PETR), rip & pot-holing (RPH) and conventional moldboard ploughing (CMP) were integrated to three nutrient management regimes i.e. a control with no fertility amelioration, pit-stored cattle manure band applied at 10 t/ha and the latter with an additional top dressing of ammonium nitrate (34.5% N) at 100 kg/ha. On each site the treatments were set up as a completely randomized split-plot block design replicated 3 times with tillage (water management) as the main treatment and fertility as the sub-treatment. CMP mimicked the farmers common land preparation practice while PETR and RPH systems represented the improved water harvesting tillage techniques. The experiments were repeated for 3 seasons and crop yields analyzed using a combined analysis of variance across sites. Results revealed significant nutrient management effects right from the first season giving 3-year means of 1111, 1959 and 2464 kg/ha for the control, manure and manure plus fertilizer treatments respectively. On the other hand water harvesting tillage effects were insignificant initially but had beneficial effects in subsequent seasons with 3-year grain yield means of 1656, 2023 and 2129 kg/ha for CMP, PETR and RPH, respectively. The results therefore showed increased benefits when in-situ water harvesting tillage techniques are integrated with appropriate nutrient ameliorants giving realizable food security benefits to the farmer.

## Effect of Manure on Millet Production in a Long-Term Soil Fertility Management Experiment in Niger, West Africa

**A. Abdou[1], R. Tabo[1] and A. Bationo[2]**
*[1]ICRISAT, Niger; [2]TSBF - CIAT, Kenya*

Sahelian climate is characterized by erratic rainfall but soil fertility is the most limiting factor to crop production in this zone. Without fertilizer, millet grain yield that constitute the staple food of the rural people in the zone are very low (300-400 kg $ha^{-1}$). Since rural farmers are very poor, their income cannot allow them to buy mineral fertilizer, organic amendment through Crop Residue (CR) or/and manure is indispensable to enhance household food security and increase their income within a sustainable agriculture system. Two sites over six years *(2001-2005)* are used for this study with three factorial experiments in both cases: Sadore and Banizoumbou. At Sadore, the first factor was three levels of fertilizers (0, 4.4 kg P + 15 kg N $ha^{-1}$, 13kg P + 45 kg N $ha^{-1}$), the second factor was crop residue applied at (300, 900 and 2700 kg $ha^{-1}$) and the third factor was manure applied at (300, 900 and 2700 kg $ha^{-1}$). At Banizoumbou, manure (0, 2 and 4 t $ha^{-1}$), nitrogen (0, 30 and 60 kg N $ha^{-1}$) and phosphorus (0, 6.5 and 13 kg P $ha^{-1}$) was established to assess the fertilizer equivalency of manure for N and P. The results show significant effect of organic manure on both millet grain and total dry matter yields although they were variable over the years due to climatic constraints. Manure effect is less than inorganic P and N (5% in the total variation) but their combination is highly significant. High values of fertilizer equivalency for N and P of manure were observed, over 100% in most of the cases.

## Long-term land management effects on crop yields and soil properties in the sub-humid highlands of Kenya

**C.N. Kibunja[1], F.B. Mwaura[2], D.N. Mugendi[3], D.K. Wamae[1] and A. Bationo[4]**
*[1]NARL-KARI, Kenya; [2]University of Nairobi, Kenya; [3]Kenyatta University, Kenya; [4]TSBF - CIAT, Kenya.*

The effect of continuous cultivation using inorganic and organic fertilizers on crop yields and soil agro-properties was studied in a 30-year old long-term field experiment at Kabete, near Nairobi, in the highlands of Kenya. The area is sub-humid with an average bimodal rainfall of 980 mm and two cropping seasons per year. The soil is dark red, friable clay classified as a Humic Nitisol and is considered to be moderately fertile. The main treatments consisted of three rates of inorganic fertilizers nitrogen (N) and phosphorus (P), farmyard manure with or without stover restitution. Maize and beans were planted during the long and short rains seasons, respectively. Results indicate that the use of chemical fertilizers alone increased maize grain yields by more than 50% during the first six years of experimentation but declined thereafter. Application of combined chemical fertilizers and farmyard manure proved superior to inorganic fertilizers alone and maintained maize yields at 3 - 5 t $ha^{-1}$. Farmyard manure also gave better yields than chemical fertilizers. However, application of chemical fertilizers alone led to decreased maize yields, increased soil acidification from 5.5 to 4.3 and raised bulk density from 1.04 to 10.8 g $cm^{-3}$ soil. The total %N declined by 25% from 0.16% while soil organic carbon decreased from 2 to 1.2% after 27 years. Fertilizer N utilization ranged from 25 - 33% but was higher in plots supplied with chemical fertilizers than in those with combined organic and inorganic inputs.

## Reversal of productivity decline in agroecosystems with organic amendments of different stability

**J.M. Kimetu[1], J. Lehmann[1], D.N. Mugendi[2], A. Bationo[3], L. Verchot[4] and A. Pell[5]**
*[1]Cornell University, NY, USA; [2]Kenyatta University, Nairobi, Kenya; [3]African Network for Soil Biology and Fertility, Nairobi, Kenya; [4]World Agroforestry Centre (ICRAF), Kenya; [5]Cornell University, NY, USA*

In tropical agroecosystems, productivity declines associated with SOM degradation can be reversed through organic inputs of diverse quality which also increase crop fertilizer use efficiency. To soils that had been under continuous cultivation for 5, 20, 35, 80 and 105 years, four OM sources; *Tithonia diversifolia*, Hemsley A. Gray, cattle manure, biochar and sawdust were incorporated at the rate of 6 tons C ha$^{-1}$, for 3 seasons over a 2-year period. Full fertilizer N, P and K rates (120, 100, 100 kg ha$^{-1}$ respectively) were superimposed to the organic treatment plots. For soil with a long-term (105-year) cultivation history, full fertilization yielded a maximum of 3.0 t ha$^{-1}$ of maize grain which more than doubled with the addition of Tithonia (6.7t ha$^{-1}$ and 8.0t ha-1 in the first and second year respectively). For Tithonia and manure, there was an increase of 2.0 ± 0.6t ha$^{-1}$ and 2.0 ± 0.3t ha$^{-1}$ respectively above fertilized, no biomass treatment in soil with medium cultivation history (20 yrs). No immediate changes to maize yield were noted with application of highly recalcitrant OM (charcoal and saw dust) but in the second year, charcoal and sawdust addition yielded 2.9 t ha$^{-1}$ and 1.7 t ha$^{-1}$ respectively higher than control. Nutrient uptake by maize crop was significantly improved with the application of Tithonia and charcoal OM. Soil pH, $CEC_{pot}$ and $CEC_{eff}$ were improved with OM inputs. We demonstrate that improved SOM, especially in degraded soil, are an integral part of reversing soil productivity declines in tropical agroecosystems.

## The Potential of Increased Soybean Production in Uasin Gishu District resulting from soil acidity amendment using Minjingu Phosphate Rock and agricultural lime

**A.O. Nekesa[1], J. R. Okalebo[1], C. O. Othieno[1], M. Thuita[1], A. Bationo[2], B. Waswa[2]**
*[1]Moi University, Kenya; [2]TSBF - CIAT, Kenya*

In Kenya, soil acidity is a major contributor to declining soil fertility and 20% of the soils are acidic and are considered to be of low fertility. Most farmers are unaware of the benefits of liming acid soils and hence blame seed and fertilizers for low yields. A study was carried out during the 2005 LR and 2006 LR at Kuinet in Uasin Gishu District of the Rift Valley Province in Kenya to delineate the effects of Minjingu phosphate rock (MPR) and agricultural lime as liming materials on yields of soybeans intercropped with maize. The maize responded to application of soil amendment materials for the first season with the DAPL treatment giving the highest maize yields of 6.19 t ha$^{-1}$ compared to the control which gave 1.36 t ha$^{-1}$. Soybean yields were disappointingly low in the first season with the DAPL treatment and control treatment giving yields of 0.32 t ha$^{-1}$ and 0.14t ha$^{-1}$, respectively. This however changed significantly after the variety was changed in the second season, with yields going up to 0.68 t ha$^{-1}$ for the TSPL treatment. From the study, it was concluded that there is potential for growing soybean in Uasin Gishu District of Kenya. However, a study and/or research is

recommended to screen and identify a suitable variety for increased soybean yields in this District.

## Use of "Prep-Pac" Product to Improve Maize and Legume Yields, Legume Heights and Improved Farm Income in the Nutrients Depleted Soil of Western Kenya

**E.C. Ruto[1], J.R. Okalebo[1], C.O. Othieno[1], M.J. Kipsat[2] and A. Bationo[3]**
*[1]Moi University, Kenya; [2]Department of Agricultural Resource Economics and Marketing, Moi University, Eldoret, Kenya; [3]AfNet Programme, TSBF - CIAT, Kenya*

Western Kenya region contains 40% of the country's population on only 15% of the country's land area, with population densities ranging from 500 to 1200 persons per km2. This has resulted to reduced land sizes, continuous cropping with no addition of fertilizers due rising poverty levels, high rates of soil nutrients depletion and food insecurity. 'PREP-PAC' an integrated nutrient management package that targets the replenishment of 'lost' nutrients in the widespread low fertility patches, was felt to be a simple, effective and affordable package that can be adopted by resource poor farmers. PREP-PAC was tested on a small scale farm in Nyabeda, Siaya District western Kenya for three continuous seasons. The farm was characterized by low pH (5.35), low % carbon content (1.84), Olsen P (1.12 mg P/ka and low total nitrogen (0.27%) and classified as sandy clay loam (FAO classification). MBILI intercropping system involving seven legumes, intercropped with maize (Zea *mays*) was used. The treatments were arranged in a 7x2 factorial, in a randomized complete block design, each treatment replicated four times. PREP-PAC application significantly ($p<0.01$) increased legume and maize grain yields A significant increase ($p<0.01$) in legume heights five weeks after planting was reported. Economic analysis indicated a significant ($p<0.01$) increase improved farm income hence concluded that PREP-PAC can be utilized under MBILI intercropping system towards nutrient replenishment and food security in Western Kenya

## Water Harvesting And Integrated Nutrient Management Options For Maize-Cowpea Production In Semi-Arid Eastern Kenya.

**J.M. Miriti[1], A.O. Esilaba[2], P. Wakaba[1], A. Bationo[3], H. Cheruiyot[2] and A.N. Kathuku[1]**
*[1]Muguga ARC, Kenya Agricultural Research Institute, Kenya. [2]Desert Margins Programme, Kenya Agricultural Research Institute, Nairobi. [3]TSBF - CIAT, Kenya.*

Field experiments were conducted for four years at Emali, Makueni District in Kenya to compare the effect of tied ridging and integrated nutrient management practices on the yield of rainfed maize (Zea mays L.) and cowpeas (Vigna unguiculata L.). The main treatments were tied ridging and flat bed (traditional farmers' practice) as main plots. Farmyard manure (FYM) at 0 and 5 t $ha^{-1}$ in a factorial combination with nitrogen (N) fertilizer at 0, 40, 80 and 120 kg N $ha^{-1}$ ,phosphorus (P) fertilizer at 0 and 40 kg $P_2O_5$ $ha^{-1}$ and crop management were the subplots in a split plot in a Randomized Complete Block Design (RCBD). The results show that tied-ridging significantly ($P<0.05$) increased maize grain yields by 12% when compared to flat tillage. Maize grain and stover yields were significantly increased by 79% and 61%, respectively, when manure was applied. Cowpea grain yields in tied-ridging were 25% more than in flat tillage treatments and the highest cowpea grain yield was1354 kg $ha^{-1}$. Intercropping maize and cowpea lowered maize grain yield by more than 50% and 11% without and with nitrogen at 40 kg N $ha^{-1}$, respectively and also reduced cowpea grain yields. However, crop rotation increased the yields of both maize and cowpea. Combining tied ridges with manure and inorganic fertilizers increased crop yields when compared to when either of

them is used separately. Thus, integration of in situ water management with integrated nutrient management has a potential in increasing food production in arid and semi-arid areas of Kenya.

## Spatial patterns of soil properties as influenced by soil fertility management in small-scale maize farms in Njoro, Kenya

**N.W. Mungai[1], A. Bationo[2] and B. Waswa[2]**
*[1]Egerton University, Kenya; [2]TSBF - CIAT, Kenya.*

Soil testing by small–scale farmers in rural Kenya is relatively uncommon for several reasons key among them is lack of information on the possible benefits and limited access to testing laboratories. However, most of the farmers are aware of soil fertility variations within their farms which influence their management decisions. The purpose of this study was to assess spatial variation in soil quality as influenced by slope and soil management. Soil sampling was done in 37 small – scale farms in Njoro division of Nakuru district at 0-20 cm depth in March 2006. Sixty five percent of the farmers used inorganic fertilizers predominately DAP, 15% used only farmyard manure, 15% used both organic and inorganic fertilizer, while only 6% did not use any soil fertility amendments. Most of the farms had a pH ($CaCl2$) of less than 5.2, Twenty seven percent of the farms had a pH lower than 4.0. Organic C ranged from 1.6 to 5.8%, with a median value of 2.6%. Most of the farms were P deficient with a $NaHCO3$ extractable P of less than 15 mg $kg^{-1}$. All farms had sufficient amounts of extractable K. Total N ranged from 0.12 to 0.33% with 76% of the farms with low N content (< 0.2%). Farms amended with farmyard manure had higher organic C and total N levels in Kikapu with correspondingly lower C: N ratios. Overall most of the farms were acidic and of low soil fertility. Farmers were advised to apply lime and manure. Interestingly none of the farmers had heard of liming.

## Effect of Zai soil and water conservation technique on water balance and the fate of nitrate from organic amendments applied; a case of degraded crusted soils in Niger.

**D. Fatondji[1], C. Martius[2], P. Vlek[2], C. L. Bielders[3], A. Bationo[4]**
*[1]ICRISAT Niamey, Niger; [2]Center for development Research – ZEF; University of Bonn, Germany; [3]Université catholique de Louvain, Belgium; [4]TSBF - CIAT, Kenya.*

The Zaï is a technology that creates conditions for runoff water harvesting in small pits. This water accumulates in the soil and constitutes a reservoir for plants. The organic amendment applied in the Zaï pits releases nutrients for these plants. During the dry season of 1999 at ICRISAT research station and the rainy seasons of 1999 and 2000 on-farm in Niger, experiments were conducted on degraded crusted soils to study the water status and nitrogen release in the soil throughout the season. In these experiments, the effect of application rates and organic amendment sources on millet biomass production in Zaï systems were tested on-station. While the effect of planting technique (Zaï versus flat) millet grain yield and biomass production was tested on on-farm. A rapid progress of the wetting front during the cropping period could be observed. It was below 125 cm in the Zaï treated plots 26 days after the rain started vs 60 cm for the non-treated plots. Applying cattle manure lead to shallower water profile due to increased water consumption. Plant available water was often exhausted in non-Zaï treated plots presuming shortage of water. Total nitrate content increased throughout the profile compared to the initial status, suggesting potential loss to the soil-plant system with drainage, which was less pronounced when cattle manure was applied. This study shows that the system improves soil water status allowing plants to escape from dry spells, however at the same time it can lead to loss of nutrients, particularly nitrogen.

## Effects of Conservation Tillage, Fertilizer Inputs and Cropping Systems on Soil Properties and Crop Yield in Western Kenya

**H.K. Githinji[1], J.R. Okalebo[1], C.O. Othieno[1], A. Bationo[2], J. Kihara[2] and B.Waswa[2]**
*[1]Moi University, Kenya; [2]TSBF - CIAT, Kenya*

An on-farm experiment was conducted in Western Kenya (Busia) in the long rain season of 2005 to investigate the effects of conservation tillage on soil properties and the crop yields. The experiment based on a split-split-split plot design with three replicates and six core treatments arranged in a factorial combination of Nitrogen application and cropping systems was adopted. Maize variety IR (striga resistant) was used as a test crop, soybean (SB20) variety as an intercrop and for maize-legume rotation. Soil pH, Olsen P, soil N and organic carbon were analyzed in soil whereas total P total N and yield were analyzed in the plant tissue. Conservation and convention tillage systems combined with cropping systems (intercropping, rotation and continuous) at 0 and 60kg N/ha application were tested. Residue incorporation was done to all plots. The soil was sampled before and also after harvesting to compare the effects of the treatments. Weeding for conservation tillage plots was by hand pulling. Combinations of conservation tillage, continuous and with application of 60 kg N/ha for maize gave the highest yield of 2.8 tonnes/ha. The combination of conservation tillage, rotation and at 60 kg N/ha gave 2.5 tonnes/ha maize grain. Combination of conservation tillage rotational cropping system and at 60kg N/ha application gave the highest soybean yield (1.23 tonnes/ha).Soil carbon showed that there was significant difference between the conservation tillage and conventional tillage as well as the increase of the soil carbon from initial level of 1.44% to the highest percentage soil carbon of 1.9%.

## Conservation tillage, local organic resources and nitrogen fertilizer combinations affect maize productivity in Arid and Semi-Arid Lands in Kenya

**J. Kihara[1,2]**
*[1]University of Bonn, Germany; [2]TSBF - CIAT, Kenya.*

Small holder land productivity in drylands can be increased by optimizing resources available locally through nutrient enhancement and water conservation. In this study, I investigated the effect of tillage and crop residue on productivity in a sandy soil in eastern Kenya. The objectives were to determine (1) effects of soil, water and nutrient management practices on crop yield and, (2) optimum organic-inorganic nutrient combinations for Arid and Semi-Arid lands in Kenya. This experiment initiated in 2005 short rains is a split split plot design involving tied ridges, conventional tillage and no-tillage as main factors and manure and crop residue as sub-factors. Each plot was also superimposed with four N fertilizer application rates (0, 30, 60, 90 kg N $ha^{-1}$) and was replicated three times. Tied ridge treatments have highest yield followed by conventional tillage while no-till treatments performed poorly. The data also shows that combined application of 1t $ha^{-1}$ of manure plus 1t $ha^{-1}$ of crop residue is better than sole application of manure at 2t $ha^{-1}$. There was response to N fertilizer application with the highest yield observed at 60kg N $ha^{-1}$. It can be concluded that farmers are better off using tied ridges while applying 1t ha-1 each of manure and crop residue.

## Exploring nitrogen replenishment options for improving soil productivity in sites with varied soil fertility status in the Central highlands of Kenya (Final title on my thesis)

**M.W. Mucheru-Muna**[1]
[1]*Kenyatta University, Kenya*

### Introduction

Declining land productivity is a major problem facing smallholder farmers in Kenya today. This decline primarily results from a reduction in soil fertility caused by continuous cultivation without adequate addition of external nutrient inputs. The use of manure in the area is limited due to its low quantity and quality in the farms. Use of mineral fertilizers on the other hand has generally been restricted to a few farms with high endowment of resources and it has been reported that less than 25% maize growers in the central highlands of Kenya use mineral fertilizers. Nitrogen is the plant nutrient taken up in the greatest quantities by crops and is also the nutrient most frequently limiting to plant growth in smallholder farms in central Kenya due to its high susceptibility to microbial transformations and losses by leaching, volatilization and denitrification. Locally available organic inputs (tithonia, manure, calliandra) could be used to curb this problem. Since nitrogen (N) is the most limiting nutrient for crop production in the central highlands of Kenya, intercropping legumes with cereals are suggested alternative soil replenishment approaches. The input of fixed N from grain legumes may be a significant contributing factor in relation to sustaining productivity in smallholder systems if the legumes leave sufficient amounts of residues. In central Kenya, several organic and mineral N inputs have been proposed but the challenge is to identify soil fertility amendments that can act as alternative sources of N, with high N use efficiency as well as being economically feasible. There is little documentation on the effects of the proposed soil fertility amendments on soil N in the study area. With this background, the study sought to determine the effects of organic mineral fertilizer soil fertility amendments on yields, soil properties, soil mineral N concentrations, N uptake and N fertilizer equivalencies in Meru South and Mbeere districts. The study also determined the effect of different legumes in various intercropping systems in terms of yield benefit, economic returns and mineral N fertilizer equivalencies.

*Objectives*

The aim of the study was to determine the nitrogen dynamics as affected by soil fertility status and nutrient replenishment inputs in the central highlands of Kenya. To achieve this aim the study sought to address the following objectives:

1. To compare and contrast the effects of different soil-incorporated organic inputs on maize yields, economic returns and soil chemical properties.
2. To determine soil mineral N concentration and N uptake by a maize crop following different soil fertility amendments in different soil fertility status
3. To determine the effects of the conventional and MBILI intercropping systems on maize and grain legume yield, and economic returns with or without P fertilizer.
4. To determine the fertilizer N equivalency values of the different biomass transfer and intercrops systems.

## Materials and methods

The study was carried out in Meru South and Mbeere districts and two trials were established during the short rains 2004 in two distinct agro-ecological areas with the aim of enhancing soil productivity. In Meru South, the study was carried in Mucwa and Mukuuni which are classified as upper midland 2 (UM2) and UM 3respectively, the soils are deep, well drained; Nitisols with moderate to high inherent fertility. In Mbeere, the study was carried in Machang'a which lies in the marginal cotton (lower midland 4 - LM 4) agro-ecological zone. The soils are sandy-clay-loam, blackish grey or reddish brown, classified as the Nitro-rhodic Ferralsols, mainly low in fertility and must be intensively manured and fertilized season after season. The rainfall in both districts is bimodal, falling in two distinct seasons, the long rains (LR) are received in March to June and the short rains (SR) in October to December. The 1$^{st}$ trial, was based on biomass transfer system and was established in Machang'a and Mucwa (two sites, one with fertile soils and the other with infertile soils). The aim of the biomass transfer trial was to determine the effects of various organic sources (tithonia, lantana, mucuna, calliandra and manure) and combinations with mineral N fertilizer on maize grain yield during four consecutive seasons. All the amendments were applied to give an equivalent of 60 kg N ha$^{-1}$ and there was a blanket application of P in all the treatments to avoid any confounding effects since P is also limiting in the area. The 2$^{nd}$ trial, was an intercrop established in two sites (Mukuuni and Machang'a) to evaluate contribution of various legumes (beans, cowpea and groundnut) and plant spacing to overall productivity of the intercropping system. The conventional spacing (a legume row alternating a cereal row) was compared to MBILI spacing (two legume rows alternating two cereal rows), both with and without P.

## Preliminary results

*Maize grain yield and soil properties*

Sole manure, sole tithonia and sole calliandra recorded the highest maize grain yield across the seven seasons in Machang'a, Mucwa poor and Mucwa good sits respectively. Generally the maize grain yields were lower in the treatments with fertilizer alone compared to the treatments with organics across the three sites due to the poorly distributed rainfall. The maize grain yields were higher in the sole organics compared to the integrations in Mucwa good and poor sites. In Machang'a, however the sole organic had higher yields during the short rains season while the integrations recorded higher yields during the long rains season. The seven seasons during which this study was carried out received rainfall that was poorly distributed across the season, indicating that in such seasons the sole organics would be better options compared to integration with mineral fertilizer. There was a general negative effect of cultivation on soil chemical characteristics in the three sites after four seasons. The seasonal addition of organic and mineral fertilizers to the soil was not able to prevent the decrease in soil fertility due to cultivation. Among the different organics applied in the soil, manure was superior in terms of improving soil chemical properties for instance manure recorded an in increase in soil pH, magnesium, potassium, calcium and nitrogen in the three sites.

*Maize and legume grain yield and N equivalencies in intercrop systems*

A significant interaction effect on both maize and legume grain yields ($P<0.05$ and $P<0.01$, respectively) was observed between factors site, P application and season. In Machang'a, maize responded significantly to P application ($P<0.01$, except in SR04). Average grain yields were rather small and equaled 0.4 and 1.2 t $ha^{-1}$ in the control and treatment with P application, respectively. The legumes only responded significantly ($P<0.05$) to P application in seasons SR04, SR06 and LR07. Moreover, legume yields tended to decrease with the seasons in Machang'a, particularly if no P was applied. In Mukuuni, no response to P was observed, except in the last season (SR07) for maize only. Maize yields in Mukuuni were considerably higher (varying between 1.4 and 5.4 t $ha^{-1}$ in the 7 seasons, averaged across the different cropping systems), while legume yields were rather poor (between 0.16 and 0.44 t $ha^{-1}$), relative to yields observed in Machang'a. Yields of the legumes differed between sites and seasons. In Machang'a, highest grain yields were generally obtained for cowpea, initially about 1.3 t $ha^{-1}$ but decreasing readily in following seasons. Bean and groundnut yields varied between 0.2 and 0.8 t $ha^{-1}$, across seasons, systems and P treatments. In Mukuuni, beans generally gave highest yields, followed by cowpea (maximally 0.7 and 0.5 t $ha^{-1}$, respectively). Groundnut yields were poor in all seasons (less than 0.2 t $ha^{-1}$). In the intercrop system, the N equivalencies were very low both in the MBILI and conventional actually in most cases the N equivalencies were negative meaning that they performed worse than the control. The low fertilizer equivalency values indicate that grain legumes do very little soil improvement in these intercropping systems since they use most or all of the nitrogen they fix and the organic matter produced is negligible for soil improvement.

**Table 12: Maize yields (t ha$^{-1}$) under different treatments during seven cropping seasons at Mucwa good and poor sites, Meru South District**

| Treatment | SR 04 | LR 05 | SR 05 | LR 06 | SR 06 | LR 07 | SR 07 |
|---|---|---|---|---|---|---|---|
| **Mucwa good** | | | | | | | |
| Calliandra | 3.39 | 5.21 | 4.75 | 3.70 | 4.90 | 5.38 | 6.17 |
| Calliandra+30 kg N/ha | 2.01 | 5.39 | 2.93 | 2.60 | 3.71 | 3.29 | 4.92 |
| Mucuna | 0.66 | 6.47 | 3.04 | 2.23 | 2.82 | 4.45 | 4.75 |
| Mucuna + 30 kg N/ha | 0.82 | 6.09 | 3.00 | 2.67 | 3.80 | 4.50 | 6.40 |
| Tithonia | 2.97 | 6.04 | 3.07 | 2.86 | 3.93 | 4.03 | 3.40 |
| Tithonia +30 kg N/ha | 1.85 | 6.05 | 3.51 | 2.75 | 3.03 | 3.19 | 5.10 |
| Manure | 1.35 | 5.45 | 3.51 | 2.28 | 4.38 | 4.06 | 5.60 |
| Manure + 30 kg N/ha | 1.01 | 5.89 | 2.97 | 0.79 | 3.00 | 3.33 | 3.66 |
| Fertilizer (60 kg N/ha) | 1.35 | 5.84 | 3.02 | 1.69 | 3.76 | 3.30 | 4.09 |
| Control | 0.64 | 3.32 | 1.62 | 0.34 | 0.84 | 1.04 | 1.24 |
| **SED** | **0.16*** ** | **0.39*** ** | **0.86*** | **0.38*** ** | **0.67*** ** | **0.79** ** | **1.03** ** |
| **Mucwa poor** | | | | | | | |
| Calliandra | 2.10 | 5.57 | 2.60 | 2.91 | 3.42 | 3.50 | 6.26 |
| Calliandra+30 kg N/ha | 2.82 | 4.80 | 1.74 | 1.08 | 2.36 | 2.64 | 5.22 |
| Mucuna | 0.28 | 4.79 | 1.44 | 1.05 | 1.67 | 2.39 | 3.00 |
| Mucuna + 30 kg N/ha | 0.21 | 5.88 | 2.65 | 2.74 | 3.32 | 4.39 | 4.80 |
| Tithonia | 2.88 | 6.65 | 2.80 | 3.06 | 4.17 | 3.85 | 5.60 |
| Tithonia + 30 kg N/ha | 2.34 | 5.00 | 2.18 | 1.78 | 3.11 | 2.53 | 3.67 |
| Manure | 0.73 | 5.85 | 2.76 | 1.80 | 4.66 | 2.81 | 4.11 |
| Manure + 30 kg N/ha | 1.17 | 4.79 | 1.70 | 0.73 | 2.39 | 2.16 | 4.15 |
| Fertilizer (60 kg N/ha) | 0.76 | 4.27 | 1.68 | 0.52 | 2.87 | 1.00 | 3.39 |
| Control | 0.76 | 2.35 | 0.76 | 0.54 | 0.50 | 0.63 | 1.41 |
| **SED** | **0.53*** ** | **0.76** ** | **0.53*** | **0.52*** ** | **0.74*** ** | **0.58*** ** | **0.72*** ** |

*, **, *** = significant at $p < 0.05$, $p < 0.01$ and $p < 0.001$, respectively
SED = Standard error of differences

*$^{13}C$ assessment*

During seasons LR05 and LR06, $^{13}C$ isotopic discrimination was assessed in Mukuuni. In season LR05, $\delta^{13}C$ values were unaffected by intercropping system, legume intercropped or P application, and measured on average -11.9‰ **(Figure 44)**. In season LR06, a moderately significant interaction effect ($P$=0.08) between P application and intercropping system was observed. In the control, $\delta^{13}C$ values (on average -12.89‰) were not affected by the intercropping system. In the treatment with P application, however, $\delta^{13}C$ values were more negative in the MBILI system than in the ordinary 1:1 intercropping system ($P$=0.01).

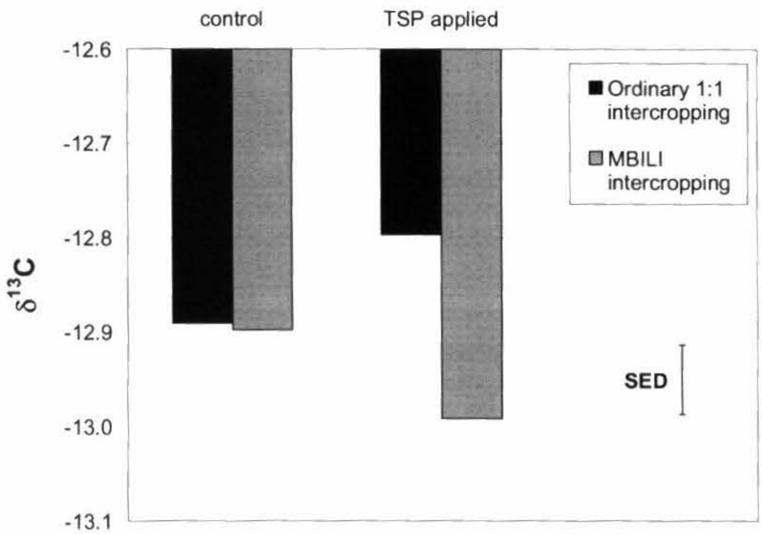



**Figure 44:** $^{13}C$ **isotope discrimination (** $\delta^{13}C$ **) in maize stover observed during the LR06 season in Mukuuni, as affected by P application and intercropping system (averaged across legume intercrops). The bar represents the standard error of difference for the P application × intercropping system interaction.**

**Preliminary conclusions**

Generally the treatments with application of organics resulted in higher maize grain yields compared to the treatments with sole mineral fertilizer, demonstrating the superiority of the organics in yield improvement due to their beneficial roles other than the addition of plant N like in the mineral fertilizer treatments. During the seven seasons in which the study was carried out, rainfall was poorly distributed across the seasons, and in such seasons the sole organics were better options for soil productivity enhancement compared to integration of organics with mineral fertilizer. High fertilizer N equivalencies of over 100% suggest that the organic amendments have beneficial roles other than the addition of soil N such as addition of micronutrients and better water holding capacity. There was a general negative effect of cultivation on soil chemical characteristics. The seasonal addition of organic and mineral fertilizers to the soil was not able to prevent the decline in soil fertility due to cultivation. Soil chemical properties declined in all treatments with the exception of manure. The treatments that had very high maize grain yields did not lead to improved soil fertility. This therefore means that there is need for tradeoffs when selecting the treatment to apply in the soil. For instance, if a farmer's basic interest is to increase maize grain yields, then they should go for tithonia, on the other hand, if the principal interest is soil improvement then they should go for animal manure. In the intercrop trial, the MBILI system resulted in higher grain yields and economic returns, relative to the ordinary 1:1 intercropping system, and should be promoted among farmers in the Central Kenya Districts. While highest returns were obtained with beans as legume intercrop in the Meru South district, groundnut and cowpea were more suitable legumes in the Mbeere district. Mineral fertilizer supplements are essential to sustain yields over time. A moderate N addition, targeted to the cereal crop, is necessary since contributions from N fixation by the legumes cannot compensate for the N exported through the produce, and N deficiency is a constraint in both areas (as observed in neighbouring maize N response trials). P addition is essential in the Mbeere District, although we observed that the recommended rate of 60 kg P $ha^{-1}$ was too high for optimal economic returns in our test site. In the Meru South District, P deficiency did not occur, and the necessity for P fertilization should be assessed for individual fields.

## Effects of newly established buffer-strips and tillage practices on fodder production and crop performance in the smallholder farming system of central Kenya.

**S Guto[1], P Pypers[2], K. Giller[1], and B. Vanlauwe[2],**
*[1]Wageningen University, the Netherlands; [2]TSBF - CIAT, Kenya*

### Introduction

Observed trends in land-use changes, soil degradation, soil and water conservation and soil productivity across the central Kenya region indicate intensified land use, increased soil degradation across farms and declining soil fertility. Rapid population growth therefore has led to intensified land use thus increasing soil degradation. The present scenario is that of "more people and more degradation" that potentially threatens sustainable increased agricultural production.

To sustain increased agricultural production, efforts towards conservation of the soil and water resources are essential. An on-farm research on soil and water conservation whose overall objective was to formulate an improved farming package for sustainable productivity within the smallholder farming system of central Kenya was initiated. The specific objectives were to:

- Determine crop yields between different tillage techniques and buffer-strips
- Measure soil and nutrient losses for different buffer-strips and tillage techniques
- Measure biomass production for the vegetative species making the buffer strips grown under different tillage techniques.
- Assess implications of identified buffer-strip and tillage effects on the productivity of crop and livestock systems in the smallholder farming systems of central Kenya.

### Materials and methods

*Description of the study area*
The study was conducted in a farm (0.3541°S, 37.6525°E) with a mean slope of 12% and an altitude of 1429 meters above sea level in Chuka division of Meru East District within the upper midland agro-ecological zone.

*Experiment design*
A Randomized complete block experimental design was used with three buffer strip treatments; *Leucaena* (*Leucaena trichandra*), Napier (*Pennisetum purpureum cv.* cameroun) or control without buffer-strips and two tillage techniques (traditional tillage and no tillage) giving 6 treatment combinations (3 by 2 complete factorial). The plots under traditional tillage were manually cultivated by hand-hoe and weeds controlled by scrapping the soil with a panga twice or three times during the cropping season. For the plots under no-till, a modified no till system was employed that required limited labour input at critical periods during the cropping season. For the experimental plots with buffer-strips, every plot consisted of three

vegetative strips laid along the contour at the upper, middle and lower areas of each plot. The control plots had a similar design except that there were no buffer-strips.

**Preliminary results**

The Napier buffer-strips produced significantly more biomass compared to the *Leucaena* buffer-strips. The dry biomass production for the buffer-strips was 1.82 and 5.44 kg $m^{-1}$ of the buffer-strip that corresponded to 2.28 and 6.80 Mg $ha^{-1}$ for *Leucaena* and Napier buffer-strips respectively. There were no significant differences in dry matter biomass production for the different fodder species across tillage practices. The maize grain yields differed between tillage and cropping systems at $P<0.05$ **(Figure 45)**. For the buffer-strips, the mean grain yields were 4.83 and 3.83 Mg $ha^{-1}$ for traditional and no tillage respectively under Napier, and 5.63 and 5.41 Mg $ha^{-1}$ for traditional tillage and no tillage under *Leucaena*. These maize grain yields take into account that 81.25% of the plot area was occupied by the maize crop in the in the plots with buffer strips. Between the first and middle row from the lower end **(Figure 46)**, row maize yields increased for all the buffer-strips. In the cropping system with Napier hedgerows, row maize yields increased significantly by 68% between the $1^{st}$ and $6^{th}$ row (about 3m from the lower end of the hedgerows) under no tillage and, by 56% between the $1^{st}$ and $4^{th}$ row (about 2m from the lower end of hedgerows) under traditional tillage.

**Preliminary conclusions**

Tillage and buffer-strip land use management practices have an impact on fodder and crop production in the central Kenya region. Specific recommendations on the appropriate buffer-strip and tillage practice depend on the farmer's production objectives. In a smallholder mixed farming system, the *Leucaena* contour hedgerow intercrop under no tillage system probably offers a likable compromise with high crop yields due to minimal competition, reduced erosion and fodder provision for livestock. Napier hedgerows provided more fodder, but were highly competitive with the maize crop, and traditional tillage should be recommended to control superficial root expansion. In mono-crop systems, zero-tillage should be recommended to reduce soil loss, but appropriate buffer-strip pruning and crop residue management strategies may need to be employed for sustained crop yields in the mid to long term period.

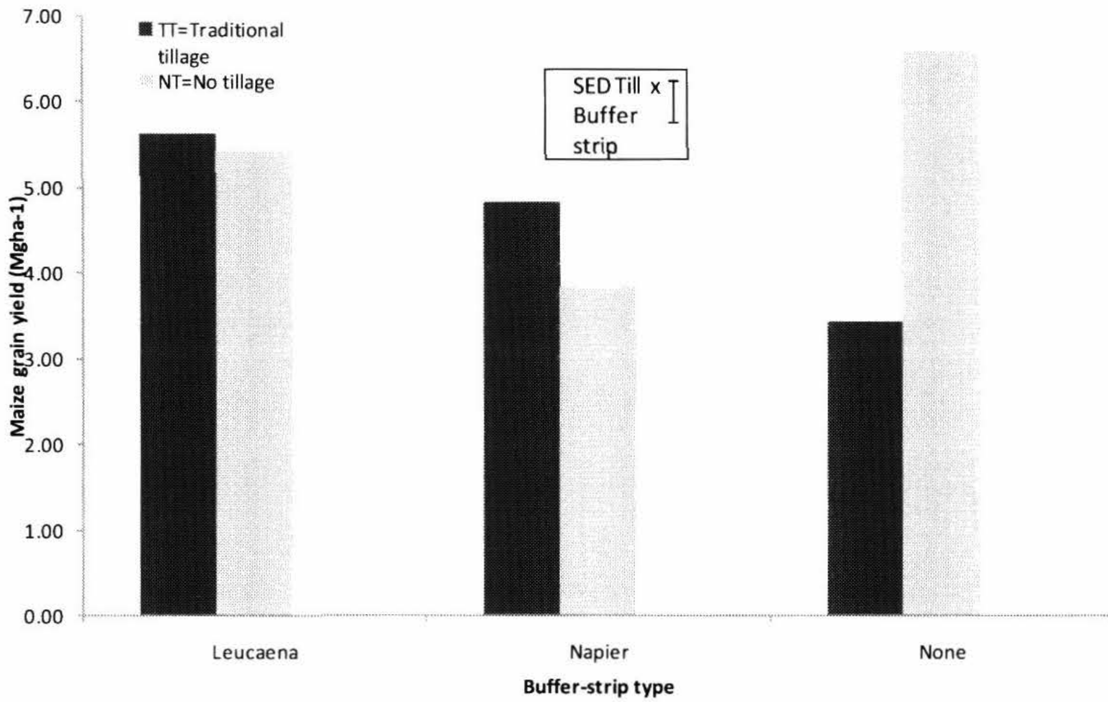



**Figure 45: Maize grain yield (Mg/ha) averaged across rows for the different tillage and buffer-strips in the short rains of 2007/08 in central Kenya.**

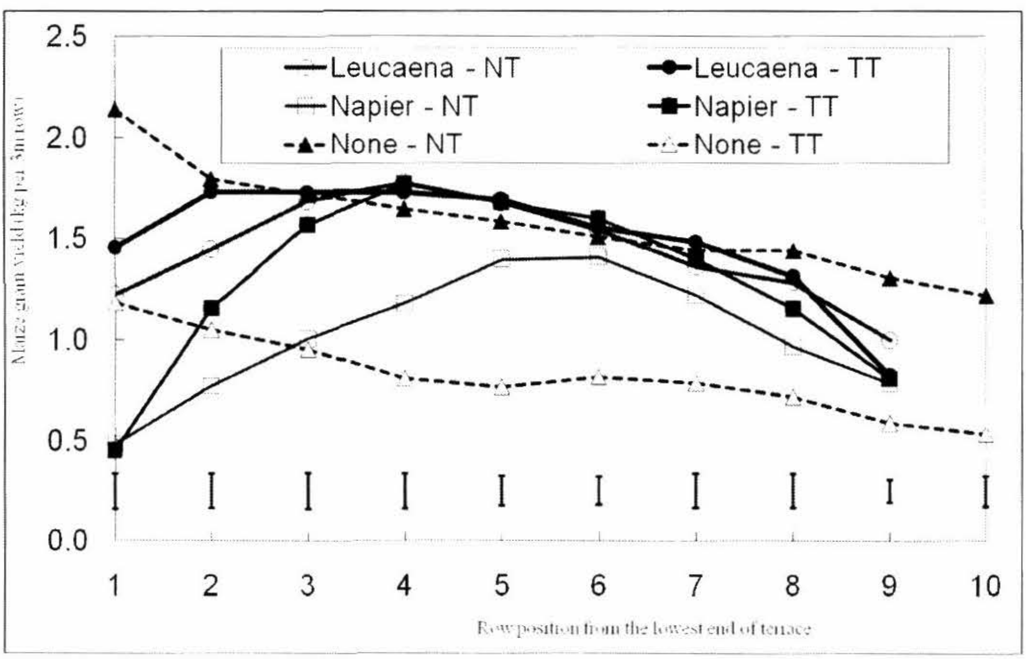



**Figure 46: Means and SED's of row maize grain yield against row position from the lowest end of the terrace for the different buffer-strip and tillage practices in central Kenya in the short rains of 2007/08.**

## Soil conservation on slopes in Sud-Kivu, DRCongo

**P. Pypers[1], M. Manzekele[2], J.M. Sanginga[3] and B. Vanlauwe[1]**
*[1]TSBF - CIAT, Kenya; [2]INERA, DR Congo; [3]CIAT, DR Congo*

Soil erosion is a serious threat to soil fertility and crop production in Sud-Kivu, DRC. A set of on-station and on-farm trials have been conducted to investigate the potential of soil and water conservation technologies that proved successful elsewhere, for crop yield improvement in these regions.

Data has been collected during 4 consecutive seasons on the effectiveness of physical embankments ("fanya juu"), *Calliandra callothyrsus* hedgerows and minimal tillage practice to reduce soil loss and improve productivity on sloping land. Combining physical embankments with Calliandra hedgerows was most effective to reduce soil erosion. The area loss due to the installation of these measures resulted in lower yields per terrace in the first season. Therefore, the high initial investment has no short-term benefits. After 4 seasons however, significant soil loss had occurred and yields declined in plots without embankments or hedgerows. Highest yields were then obtained in the plots with embankments and hedgerows. As such, a minimal period of 2 year can be expected before farmers will obtain benefits from the investment in anti-erosive measures. Because the investment capacity of resource-poor farmers is low, some support is likely to be essential for farmers to take up soil conservation measures.

A number of forage species were also installed as grass strips or hedgerows in farmers' environment, with the objective of assessing their ability to retain soil and produce fodder, as well as to understand farmers' preferences. Farmers generally preferred forages that are characterized by good rooting (which is related to the capacity to reduce soil erosion), that can serve as a green manure, and that are a good fodder. *Tithonia*, *Tripsacum* and *Calliandra* were the most preferred forage species. The ability of the forages to intercept and retain soil was determined by measuring the slopes on the terraces formed by the hedgerows or grass strips. *Calliandra*, especially when planted densely, was the most effective anti-erosive species, followed by *Pennisetum*, *Setaria* and *Brachiaria ruziziensis*. The use of *Calliandra* can therefore be recommended for further on-farm testing, since it both very effective to reduce erosion, and preferred by farmers.

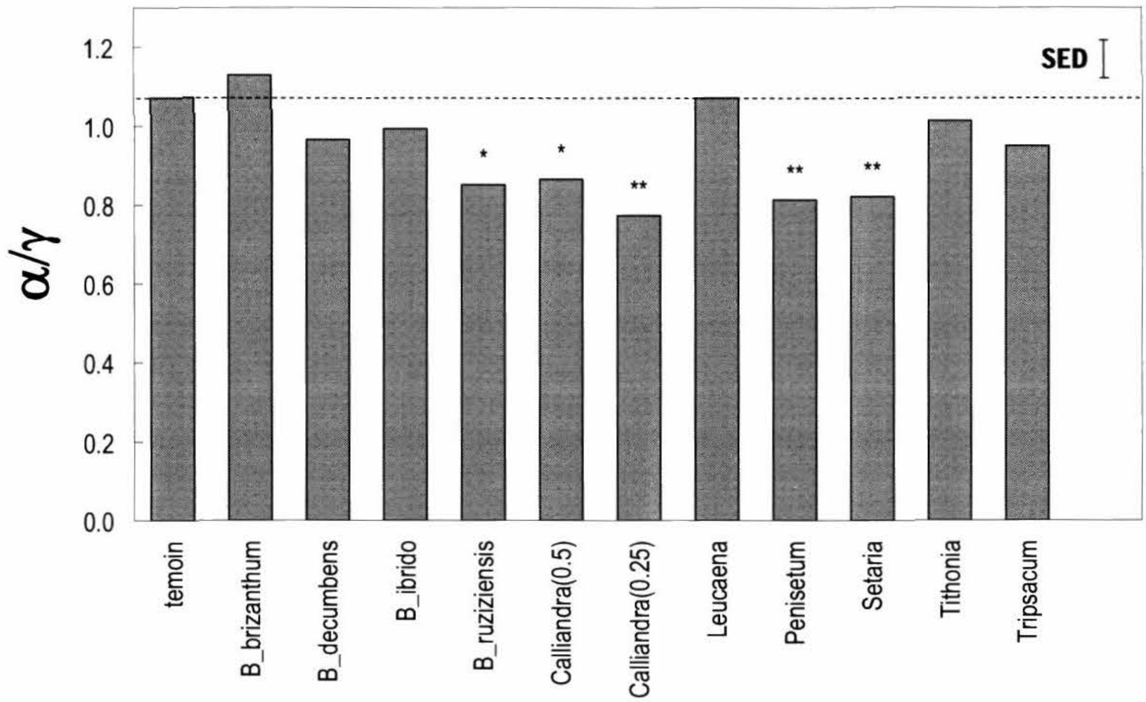



**Figure 47: Anti-erosive potential of a number of forage species when planted as hedgerows or grass strips on sloping land in Sud-Kivu, DRC. A lower value refers to a higher soil interception and/or soil retention capacity. Species marked with an asterisk are significantly effective, relative to the control.**

## Improving Agriculture Technique on the slope land in Sud Kivu


**M. Audry[1], P. Pypers[2], B. and Vanlauwe[2]**

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


### Introduction

In DRC, agriculture production is not enough to nourish population although his multiple agriculture regions. Not only soil acidity and soil low organic matter cause low agriculture yield in East of DRC, but the soil erosion and low soil fertility are also enough to assert low production on the slop land. In Sud Kivu, because of lack soil conservation methods, then because of land scarce, while increase of the demography it's adding over the land problems above, access to agriculture product becomes a great matter for mountainous farmers. In actually context to lead soil exploitation in Sud Kivu mountainous below absence methods to stop erosion soil, it's in no doubt evident to increase full of undernourished population. It becomes necessary to improve agriculture production on the small land available in Sud Kivu mountainous region, by extending appropriated technique which can allow farmers to conserve soil and restore fertility in their small field. Among methods to improve agriculture production, hedgerows system on the slop land, is the one which can allow farmers to reduce soil erosion and lost of nutrients in Sud Kivu mountainous.

## Materials and methods

The study was conducted in sud kivu, province of DRC. On the slop lands, cassava, beans, sorghum, sweet potatoes, potatoes, ground nut, and maize are predominant, while rise can be founded in the lowland. The study area has a humid tropical climate. Annual means temperatures range from a high of 20.5°C to a low of 18°C. The first rainy season lasts from September to November followed by a dry season from June to August and a second rain season from March to Jun. The total annual rainfall in Sud kivu amounted to 1300mm.

*Experimental design*

The field experiment (ERO1) was established on acid soil with pH (4-4.5) and covered by grass on a slope gradient ranging from 40-46%.

Land preparation was done by hoe before starting the experimental study. In ERO1, the experiment was laid out as a split-plot design. Plot size was 3-4 by 6 m with a collection eroded soil installed at the lower end in drain of fanyachini. Callindra trees were planting along the lines as hedgerows by using two rows spacing of 50 by 50cm following the contour row. Soya bean followed by maize was applied on the terrace while calliandra application was compared with fanyajuu technique to stop soil erosion and to improve yields. Grain yield and lost soil were measured in each terrace.

## Preliminary results

After one year of experimentation, we observed that soil conservation technique was no significantly effect in season 1 (p=0.05) when calliandra is used to counter sediments erosion. And no difference was between plots when yields are reported in kg ha-1. On the other hand, in the same season in kg by terrace, fanyajuu conservation measure has significantly (p=0,05) affected soil lost but no significantly deference between using fanyajuu -calliandra and fanyajuu-without calliandra was detected. In the second season, improving calliandra hedgerow effect was observed. Calliandra hedgerow affected significantly the soil lost in comparison with the first season but both in plots without or without calliandra barriers no difference was not yet observed. **(Figure 48)** below presents soil lost results obtained in the second season in the sediment trap installed in the fanyachini drain.

**Figure 48: Soil lost season 2 (kg/terrasse)**

*Yield response*

Soya been yield showed that in the first season Soil conservation measures did not affected significantly soya been grain yield($p = 0,05$). However, digging has a significant ($p = 0.05$) effect .The highest soya been grain was obtained in the plots without fanyajuu than with fanyajuu. The second season when grain yields were reported in kg ha-1, the highest grain yields were obtained on the fanyajuu plots and in plots with calliandra barriers. The lowest maize grain yields were obtained on the plots when fanyajuu are combined with calliandra barriers. The use of contour hedgerows ($p = 0,05$) improved maize grain in the second season as compared to the control without hedges. However, this increase in maize grain yield was much higher both in plots with calliandra barriers and in the control plot without hedgerows **(Figure 49)**.

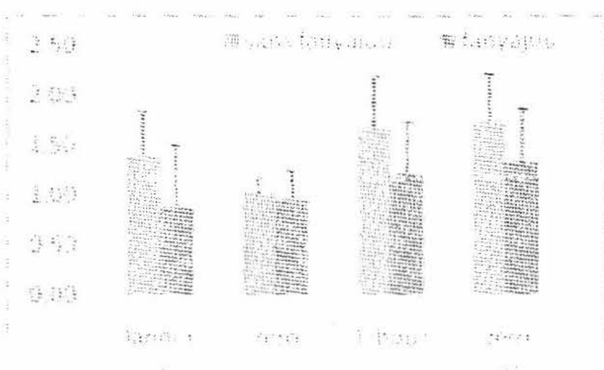


**Figure 49: Maize yields season 2 (kg/terrace)**

**Preliminary conclusion**

Soil conservation measures improve crop by reducing soil loss. Contour hedgerows were shown to be important in reducing soil loss, in particular at the second season of field establishment. When contour hedgerows are combined with the use of fanyajuu, it has a less important role to play in the reduction of soil loss and improving yields. The use of contour hedgerows ($p = 0,05$) improved maize grain yields in the second season as compared to the control without hedges. Results above show that it is possible to improve yields on the slop land with establishment of hedgerows or fanyajuu but the choice of each or other method may depend on farmers according to his possibility or objectives followed. Leucaena, ruzi grass or vetiver grass were planted in three one meter wide barriers at intervals of 6m on April 29, 2003, occupying about 17% of the total plot area **(Figure 49)** according to recommendations of the Land Development Department, Thailand and IBSRAM. Six rows of maize were planted between each hedgerow or grass strip. Apart from the initial slash and burn activities followed by hand hoeing to 10 cm depth for land clearing, no further soil preparation was carried out apart from hand weeding. Maize was relay cropped with Jack bean (Canavalia ensiformis (L.) DC), planted one month before maize harvest, starting in September 2003. After maize or Jack bean harvest (0.3-0.5 Mg ha-1 year-1), maize stover and all Jack bean material were left on the plots as mulch to protect soil from erosion and suppressing weeds in the following growing season. Plots with hedgerows or grass barriers were pruned 3-6 times per year, and prunings spread evenly over the alley. Thus, over the three years a total of 10, 19, 21 and 20 Mg ha-1 plant residues were applied as mulch in the control, leucaena, vetiver grass and ruzi grass treatments without fertilizer application, respectively, and 18, 32, 39 and 48 Mg ha-1 in the corresponding fertilized treatments. In all treatments, weeding was done by hand when necessary. Therefore, the trial setup was considered as a minimum tillage system (Bergsma, 1996).

## Rotation Effect of Soybean on the Production of the Subsequent Maize Crop, 2nd season

**I. Vandeplas[1,2], S. Deckers[2], R. Merckx[2] and B. Vanlauwe[1]**
*[1]KULeuven, Belgium; [2]TSBF - CIAT, Kenya;*

### Introduction

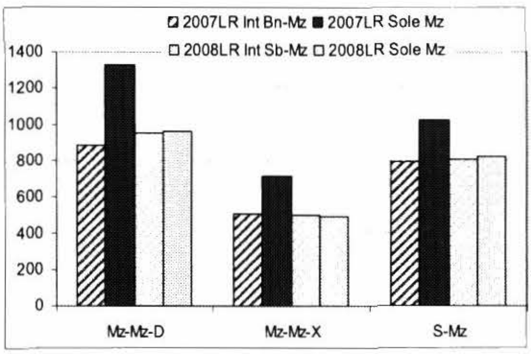
During the short rains of 2006 and 2007 an experiment was set-up testing different inputs and labour options for soybean production in Migori and Rongo districts. In each field, two maize control plots were established, with the aim of looking at the rotational effects of soybean on maize during the long rainy seasons. Indeed, farmers plant more maize during the more secure long rains, as they need to secure their food production. The experiments were conducted in 10 fields in 2007 long rains spread over 4 "zones" of the Uriri Farmer Cooperative Society and in only 5 remaining fields during the 2008 long rains.

### Material and methods

The experiments were conducted during the long rainy seasons in 10 fields in 2007 and 5 fields in 2008, containing each 19-24 plots of 8x8m to 10x10m depending on the available space. During the short rains of 2006 and 2007, soybean had been planted in all but two plots with different treatments of 'labour' and 'input'. Two plots had been kept for maize without input. During the long rains of 2007 and 2008, the whole field was planted with maize, with a planting distance of 0,25m * 0,75m. All plots were left without input, except one of the previous maize plots, which received 100 kg di-ammonium phosphate (DAP), and 100 kg urea per hectare. The research also compared the effect of soybean-maize rotation on the yield of subsequent sole maize and maize intercrop (with beans in 2007, soybeans in 2008), as intercropping is the most common practice in the region. Therefore, all plots were divided into two sub-plots, both with the same density of maize. One of the subplots was intercropped with one seed of beans (2007) or soybeans (2008) planted between each two maize plants. Yields were analyzed at harvest but the produce remained with the farmers. A field day was organized during the season to look at the maize crops standing, compare the performance of the maize after soybean or maize, and to discuss the previous soybean yields with the farmers. The soil C and N are also being analyzed for the initial soils, before the experiments, and for the final soils after 2 rotation cycles. These analyses are still ongoing.

### Preliminary results

Statistical analysis is still ongoing to finalize the conclusions on the effect of the rotation of soybean and maize on the maize yield. The maize grain yields after soybean ranged between those obtained on continuous maize with and without input. Using soybean in rotation with maize, allowed to increase the yields of the maize planted without input considerably. Considering the current cost of DAP and urea in Migori district, this gives a positive prospective to farmers who cannot afford to purchase inputs. The soybean-maize rotation benefited most the biomass yield of the maize crops. Maize planted without input but after soybean, yielded the highest quantity of biomass. This effect was visible in the fields, plants were taller and larger, what allowed farmers to appreciate visually the effect of soybean-maize rotations. The effect of rotation was similar for the sole cropped maize yield and for the intercropped maize. Nevertheless, while the intercropped maize in 2007 yielded less than the sole maize, as a result of competition between maize and beans, the maize in 2008 did not lose grain yield when intercropped with soybean.



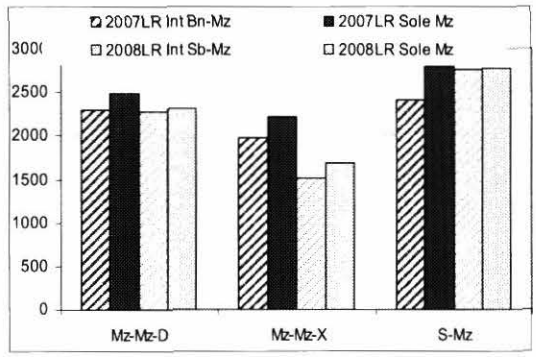




**Figure 50 and 51: Maize Grain yield (kg ha$^{-1}$) (left) and Biomass yield (kg ha$^{-1}$) (right) for the long rains of 2007 and 2008, for the different treatments. Mz-Mz-D = Continuous maize, receiving DAP and urea (50kg N ha$^{-1}$) during the long rains only. Mz-Mz-X = Continuous maize, never receiving any input. S-Mz = maize grown in rotation with soybean (during the short rains), no input applied on the maize.**

**Preliminary conclusion**

The visual analysis of the soybean-maize rotation cycle showed improvement of the maize yields, as compared to continuous maize. As mentioned in the 2007 report about this same project, farmers were impressed by the performance of the maize which did not receive any input, but was merely preceded by soybean. Many farmers voted for the rotation system as being the 'best', followed by maize with DAP and urea. The results are important in the context of increasing fertilizer prices ad transport cost worldwide and in Migori district. In only 2 years time, the cost of 50kg DAP increased from 1600KES to 5000KES in Migori district (market survey).

## Integrated soil fertility management in conservation agriculture systems in southern Zambia


**R. Delve[1] and S. Zingore[2]**
*[1]TSBF - CIAT, Zimbabwe; [2]CIAT-TSBF, Malawi*


Although conservation agriculture has been highly disseminated through donor support, the technologies being promoted lack a scientific foundation to support the technological packages. Experiments were designed to investigate (i) the environmental conditions conservation farming performs best (ii) the reasons for better yields; and (iii) the amount of inorganic and organic amendments are best for improving production potential under conservation farming. The experiments were conducted for two seasons in two locations of the Southern Province, Monze and Choma, with the latter having lighter soils and the former having a slightly heavier soil. The sites were characterized in the first season to establish the baseline environment. The experiment was arranged in a split plot Randomized Complete

Block Design (RCBD) with tillage systems as the main treatments and the manure levels as the sub-treatments. Fertilization was applied as a blanket at 100 kg D compound (10N, 20P, 10K and 5S) at planting and 200 kg urea (46% N) as top dress. Lime was also applied as blanket application at 400 and 1000 kg $ha^{-1}$ in conservation and conventional tillage systems respectively. Fertilizers were applied in both seasons.

The grain yield at Monze (from 4.4 t to over 5 t $ha^{-1}$) was greater than at Choma (from 1.3-2.5 t $ha^{-1}$). Application of manure at 8 t $ha^{-1}$ gave the largest yield at both sites, however, there was little difference across treatments at both sites, especially at Monze. The grain yield at Choma steadily increased with increasing manure application rate. This was not evident at Monze. The low yield at Choma could partly be attributed to the poor distribution of rainfall. The high rainfall that was concentrated within two months could have enhanced fertilizer leaching. Over 80% of the rainfall at Choma fell between November and December leaving the critical periods of tussling, silking and grain filling very little moisture for a successful physiological maturity of the crop. Ripping yielded the least at monze while basins and conventional gave similar grain yields. On the other hand, basins gave the lowest yield in the lighter soils at Choma.

Conservation agriculture in combination improved soil fertility status across the two sites after two seasons of experiments. pH increased more at Choma than Monze, because the soils in Choma are sandy and poorly buffered. However, the pH response patterns were similar with conventional tillage influencing the largest pH change while ripping raised the pH the least, and these changes were significantly different ($p<0.05$) at Choma. There was a general increase in pH with increase in manure application levels at monze. At Choma the top soil at point of application had a significantly higher pH than the other sampling points. Soils at Monze had more exchangeable calcium than those at Choma. A significant decrease in exchangeable calcium at Monze was recorded between 0 to 1 t manure. However, the levels steadily increased with corresponding manure application thereafter, reaching a maximum at 8 t $ha^{-1}$. On the other hand, there were no significant changes in exchangeable calcium with increases in manure levels at Choma. This observation highlights the importance of organic matter in the light textured soils at Choma.

## Participatory research linked to market opportunities: Fertilizer and soil fertility management options for irrigation and rain-fed cropping systems in southern Malawi

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

Over the past 50 years, there has been huge investment in infrastructure for irrigation in Malawi, realizing its importance for food production and alleviation of rural poverty, particularly in semi-arid and drought prone southern Malawi. However, since the 1980s, government run schemes have experienced numerous problems. Irrigation infrastructure has deteriorated and crop production has declined substantially. There are renewed efforts to rehabilitate degraded irrigation schemes and plans to promote stakeholder participation in irrigation management, including transfer of entire management into the hands of the beneficiary farmers. Parallel efforts are also required to build the capacity of farmers to produce crops profitably and sustainably.

Irrigation provides opportunities for smallholder farmers to intensify and diversify crop production, and allows farmers to produce 2-3 crops a year. Use of improved crop production technologies such as use of fertilizers, hybrid varieties, plant protection techniques is necessary to fully exploit this potential. For long-term sustainability of intensive cropping system under irrigation, soil maintenance through integrated soil fertility management (ISFM) is required. Though the application of mineral fertilizer is an effective means of increasing yields, mineral fertilizer alone are inadequate to sustain yields, and should be combined with low-cost ISFM technologies such as the use animal manure and compost, and rotating the main cereal crops with grain legumes. Soil organic matter maintenance in ISFM is crucial to the sustainability of smallholder farming systems, as organic mater improves chemical, biological and physical properties of soils.

There is limited land available for irrigation in schemes Chikwawa (< 0.2 ha per household), and most farmers augment crop production under irrigation with rain-fed crop production during summer. Due to availability of different land units within farms, farmers face challenging decisions on use of scarce land, water and nutrient resources to improve crop productivity and profitability. The decisions that strongly affect crop productivity include: (i) targeting of cash crops and food security crops to irrigated fields and rain-fed fields; (ii) allocation of fertilizer and organic nutrient resources to different fields or different crop cycles under irrigation; (iii) increasing the resilience of the cropping system by diversifying the current maize and rice dominated cropping systems by including multi-purpose grain legumes. Participatory experiments were conducted as part of the Enabling Rural Innovation (ERI) approach, to identify crop production constraints and opportunities for crop diversification and increasing productivity of the main cash and food security crops in the Nkhate catchment area. The participatory experiments also focused on building the capacity of farmers in deciding on soil fertility management technologies for different production units.

Soils in Nkhate irrigation scheme are highly productive and show good resilience after many years of cultivation with small fertilizer inputs. N was the most limiting nutrient for both irrigated rice and maize. Under irrigation, fertilizer application should focus on N and its management to reduce losses. Contrary to recommendations and farmers' impression that fertilizer use is not viable for rain-fed cropping in Nkhate, experimental results showed significant maize yield response to application of N, NPK and NKP+micronutrients+manure. Maize yield response to N application was positive at low rates (<80 kg ha-1) outside the scheme and up to 120 kg N $ha^{-1}$ inside the scheme. Addition of manure also had significant effects on maize yields and there is need to promote use of manure or other organic nutrient resources under rain-fed maize outside the scheme. Productivity and profitability of groundnut under rain-fed and bean under large-scale winter irrigation was high, and these crops have potential to increase income and improve soil fertility management in various land units.

| 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, in press.

**Zingore[1], S., González-Estrada[2], E., Delve[3], R.J., Herrero[4], M., Dimes[5], J.P., and Giller[6], K.E.**

*[1]TSBF - CIAT, Malawi; [2]Heifer-International, USA; [3]TSBF - CIAT, Zimbabwe; [4]ILRI, Kenya; [5]ICRISAT, Zimbabwe; [6]Wageningen University, the Netherlands*

In African smallholder agriculture, improved farm scale understanding of the interaction between the household, crops, soils and livestock is required to develop appropriate strategies for improving productivity. A combination of models was used to analyze land-use and labour allocation strategies for optimizing income for wealthy (2.5 ha with 8 cattle) and poor (0.9 ha without cattle) farms in Murewa, Zimbabwe. Trade-offs between profitability, labour use and partial nutrient balances were also evaluated for alternative resource management strategies. Farm data were captured using the Integrated Modelling Platform for Mixed Animal-Crop Systems (IMPACT), which was directly linked to the Household Resource-use Optimization Model (HROM). HROM was applied to optimize net cash income within the constraints specific to the households. Effects of alternative nutrient resource management strategies in crop and milk production were simulated using the Agricultural Production Systems Simulator (APSIM) and RUMINANT models, respectively, and the output evaluated using HROM. The poor farm had a net income of US$ 1 $yr^{-1}$ and the farmer relied on selling unskilled labour to supplement her income. The poor farm's income was marginally increased by US$18 $yr^{-1}$ and the soil nitrogen (N) balance was increased from 6 to 9 kg $ha^{-1}$ $yr^{-1}$ by expanding groundnut production from the previous 5% to 25% of the land area. Further increases in area allocated to groundnut production were constrained by lack of labour. On the poor farm, maize production was most profitable when cultivated on a reduced land area with optimal weeding. The wealthy farm had a maize-dominated cropping system that yielded a net cash balance of US$290 per annum, mainly from the sale of crop produce. Net income could be increased to US$1,175 $yr^{-1}$, by re-allocating the 240 hired labour-days more efficiently, although this reallocation substantially reduced partial soil N and phosphorus (P) balances by 74 kg N $ha^{-1}$ and 11 kg P $ha^{-1}$, respectively, resulting in negative nutrient balances. Limited opportunities existed to increase productivity and income of the Small holder farms without inducing negative nutrient balances. On the wealthy farm, groundnut was the least profitable crop; shifting its production to the most fertile field did not improve income, unless the groundnut residues were fed to lactating cows. The analysis carried out in this paper highlights the need to develop practical technological recommendations and developmental interventions that consider farm resource endowment (land, fertilizers, manure and labour), variability in soil fertility within farms and competing resource use options.

## Lessons Learnt From Long Term Experiments in Africa

**A. Bationo[1], S.B. Waswa[1], A. Adamu[1], V. Bado[1], B. Moussa[1], E. Iwuafor[1], C. Kibunja[1], J. Kihara[1], M. Mucheru-Muna[1], D. Mugendi[1], J. Mugwe[1], C. Mwale[1],J.M. Okeyo[1],A. Olle[1], K. Roing[1] M. Sedogo[1] and R. Tabo[1]**
[1]*African Network for Soil Biology and Fertility (AfNet), Long term Trials Research Team. c/o TSBF - CIAT, Kenya.*

Sub-Saharan Africa is the only remaining region of the world where per capita food production has remained stagnant over the past 40 years. About 180 million Africans do not have access to sufficient food to lead healthy and productive lives. The low food production is as a result of the breakdown of traditional practices and the low priority given by governments to the rural sector. Over the years, the paradigms underlying soil fertility management research and development efforts have undergone substantial change because of experiences gained with specific approaches and changes in the overall social, economic, and political environment the various stakeholders are facing. Long term experiments (LTE) have played a key role in understanding the changes in soil fertility as a result of the changing land management practices. The history of LTE in Africa dates back to the colonial days. A number of these experiments still exist and actively researched while others have been discontinued or diminished in intensity because of lack of resources. Most of these experiments were designed to determine the effects of inorganic fertilizers and organic inputs on crop yields and soil properties. However over time other components such as rotation and intercropping were also assessed. Although yields were measured in all the experiments, climatic and soil variables were documented in only a few trials. There was no evidence of other measurement factors outside the treatments e.g. pests, diseases incidences and economic parameters. This paper presents a review of some key lessons learnt from selected LTE in Africa.

## Does the combined application of organic and mineral nutrient sources influence resource use efficiency? A meta-analysis.

**Chivenge, P[1], Vanlauwe, B[2], and Six, J[1]**
[1]*University of California, Davis, USA;* [2]*TSBF - CIAT, Kenya;* Institutions?

### Introduction

Food production in sub-Saharan Africa (SSA) is critically dependent on external inputs of nutrients, especially N and P. While mineral fertilizers are widely used globally to overcome nutrient deficiencies, their use remains very low in SSA with average application rates of eight kg $ha^{-1}$ $yr^{-1}$. Fertilizer use has been limited mainly because of low availability and lack of purchasing capacity by the smallholder farmers in SSA. Organic resources (ORs) are, where available, often used as major nutrient sources to plants and their application usually leads to increased crop yields but depressed yields with OR use have also been reported. The differential yield responses following OR application have been attributed mainly to differences in OR quality and soil fertility status. High quality ORs result in a fast release of nutrients, which may be subsequently lost from the soil, while low quality ORs result in a delayed release of nutrients, in both situations resulting in a mismatch between supply and demand of nutrients. To overcome this lack of synchrony, intermediate to low quality ORs have been applied in combination with mineral fertilizers and greater yields have been observed compared to adding either resource alone. This approach is increasingly gaining recognition as one of the appropriate ways to address soil fertility depletion, especially in low-external input systems in SSA, and forms part of the backbone of integrated soil fertility management. However, results observed with combined ORs and mineral fertilizers have been variable across soil textures and agro-climatic regions, and depend on OR quality. In the current study, a meta-analysis was conducted to synthesize existing published data to provide a comprehensive and quantitative synthesis of conditions under which ORs, N fertilizers, ORs + N fertilizers positively or negatively influence crop yields in SSA.

**Materials and methods**

Fifty five studies that were carried out on smallholder farms and experimental stations under rain-fed field conditions in SSA where ORs and N fertilizers were added separately and in combination with each other were identified. The studies used in the meta-analysis covered 101 sites in 14 countries in SSA (Benin, Burkina Faso, Cote d'Ivoire, Ethiopia, Ghana, Kenya, Malawi, Niger, Nigeria, Tanzania, Togo, Uganda, Zambia, and Zimbabwe) and represent the humid rainforest, the moist savanna, the dry savanna, the sudano sahelian, and the guinea savanna agro-ecological zones. Four OR quality classes were assessed, with classes I and II having >2.5% N while classes III and IV have <2.5% N and classes I and III have <4% polyphenol and <15% lignin. Amounts of N supplied by ORs ranged from 6-547 kg N ha-1 annually; while fertilizer N ranged from 20-175 kg N ha-1 per season; and the total N in the combined treatments ranged between 26 and 667 kg N ha-1annually. Meta-analysis was conducted using Metawin 2.1.

**Preliminary results**

Yield increases over the control were 57%, 84% and 112% following the addition of ORs, N fertilizers and ORs+N fertilizers, respectively **(Figure 52)**. The greater yield benefits with OR+N fertilizers has been attributed to positive interactions between the two resources where temporary immobilization of N from fertilizers may improve the synchrony between supply and demand of nutrients. For sole ORs (data not shown) and when combined with N fertilizers, the greatest yield responses were observed when class I or II ORs were added but there were no differences between the two classes **(Figure 53a)**. Yield responses increased with increase in OR N quantities added across all soil textures but greater yield responses were observed from sandy soils than finer textured soils. However, differences among OR quality and OR N added were more distinct in clayey soils probably because of the greater contact between OR and soil particles. Yield responses of ORs+N fertilizers versus sole ORs increased with a decrease in OR quality and greater yield increases were observed in sandy (73%) than clayey soils (26%; **Figure 54a**). This was probably because greater yields were observed with high quality ORs (data not shown) such that supplementary additions of N fertilizers resulted in smaller yield increases while low quality ORs may have induced immobilization which was alleviated by the addition of N fertilizers. In contrast, responses to ORs+N fertilizers versus sole N fertilizers increased with increase in OR quality **(Figure 54b)**. The lack of response to negative yield responses observed with class IV ORs was an indication that some of the added N fertilizer was immobilized by the ORs.

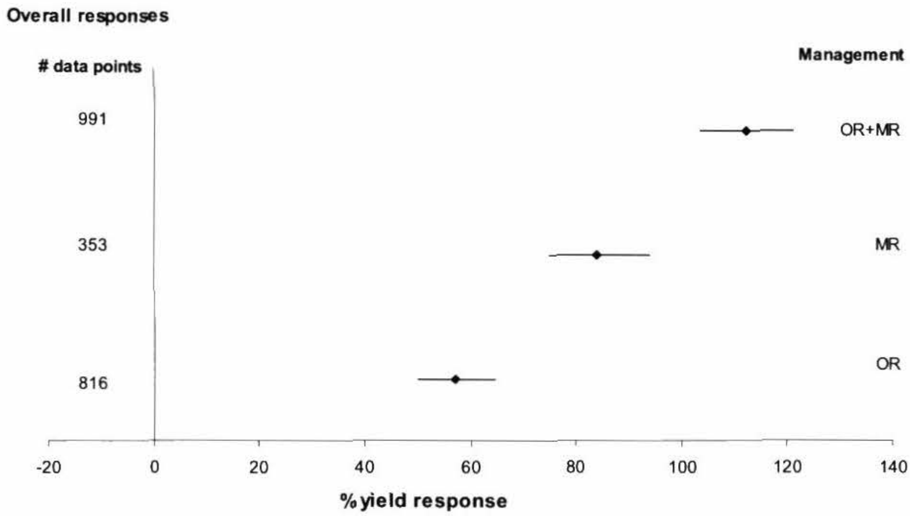



**Figure 52: Yield responses to the addition of organic resources (OR), mineral N fertilizers and the combined application of the two (OR + N fertilizer) compared to the no input control expressed as yield responses and relative yield responses kg$^{-1}$ N applied. Responses are expressed as weighted average response percentage with 95% confidence intervals represented by error bars.**

## Preliminary conclusions

While OR quality clearly influences crop yield responses, the lack of differences between classes I and II imply that the use polyphenol content to separate the two classes is of less importance under field conditions. Although greater yield responses were observed when high quality ORs were applied in combination with N fertilizers than other ORs compared to the no input control, the lower responses observed when compared to sole ORs indicate a greater need to add low quality ORs with N fertilizers than high quality ORs

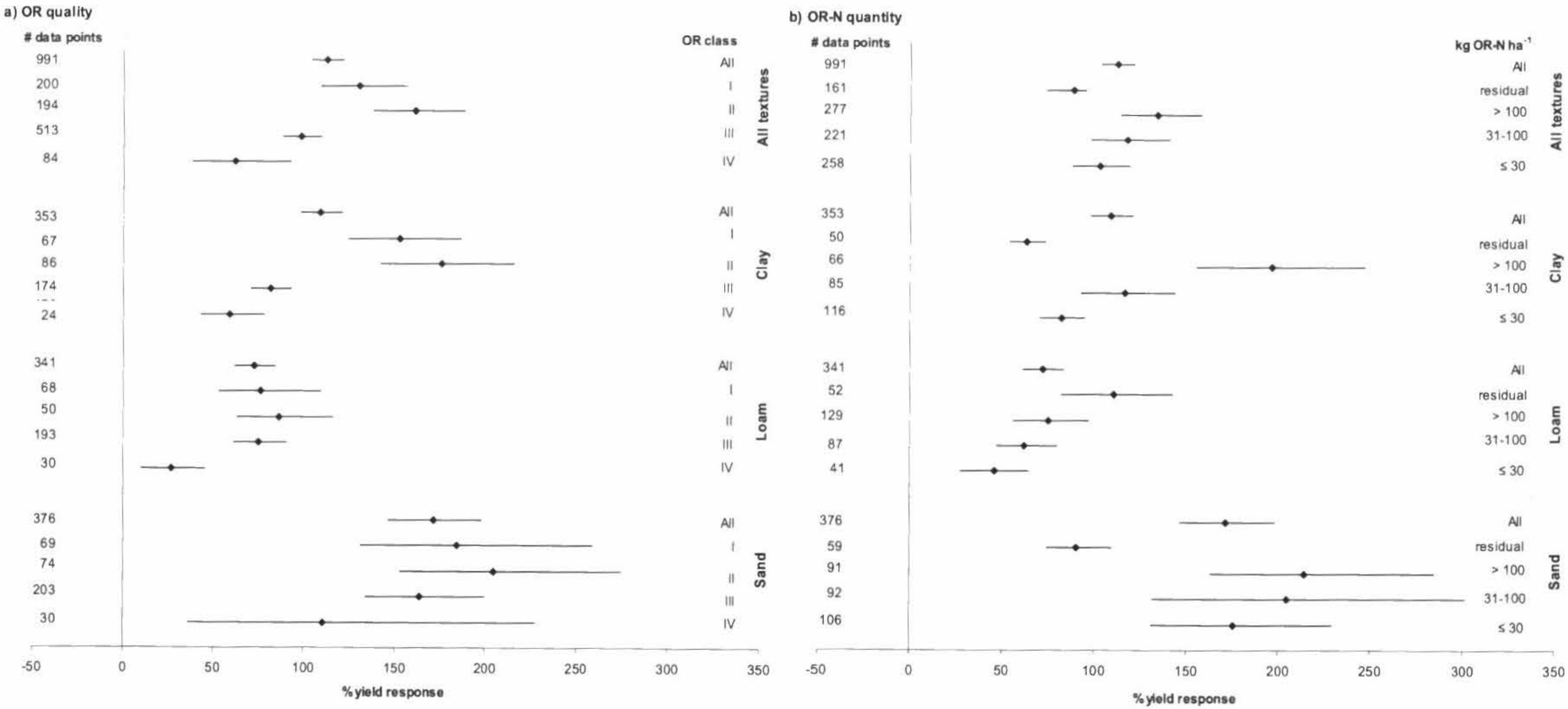



**Figure 53a and b: Yield response to the combined addition of organic resources (OR) with mineral N fertilizers compared to the no input control categorized into a) four OR quality classes, and b) three OR-N quantities applied. Yield responses are expressed as weighted average response percentage with 95% confidence intervals represented by error bars.**

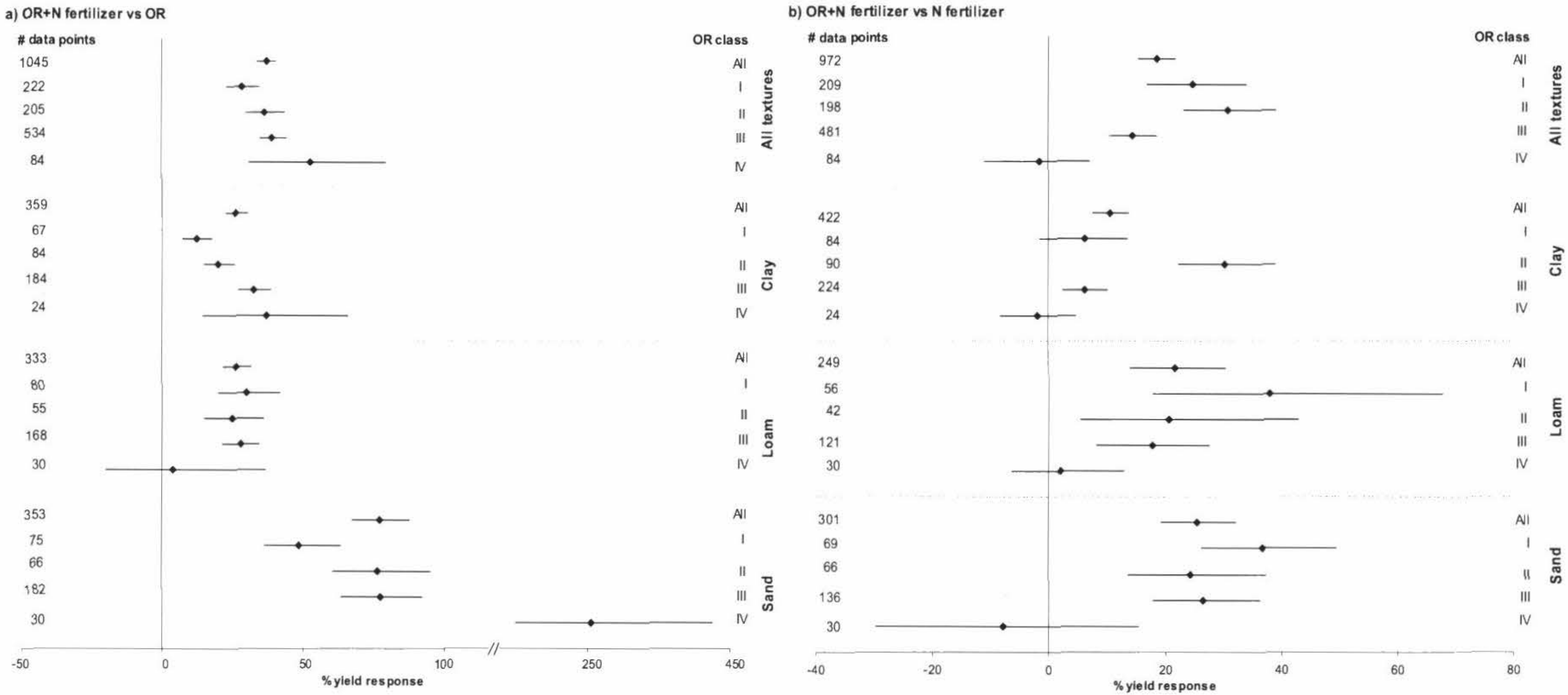



**Figure 54a and b: Yield response to the combined addition of organic resources (OR) with mineral N fertilizers compared to a) sole ORs and b) sole N fertilizers expressed as yield responses, categorized into the four OR quality classes for clayey, loamy and sandy soils. Yield responses are expressed as weighted average response percentage with 95% confidence intervals represented by the error bars.**

## Collective management of feed resources at village scale and the productivity of different farm types in a smallholder community of North East Zimbabwe

**M.C. Rufino[1], J. Dury[1], P. Tittonell[2], M.T. van Wijk[1], M. Herrero[3], S. Zingore[4], and K.E. Giller[1].**
*[1]Wageningen University, the Netherlands; [2]CIRAD, France; [3]ILRI, Kenya; [4]TSBF - CIAT -Malawi*

Addition of organic materials is needed to sustain the crop productivity of inherently poor soils in the mixed crop-livestock systems of the communal areas of NE Zimbabwe. In these systems, livestock feed resources are collectively managed, with the herds of the village grazing on natural grasslands during the rainy season and on crop residues during the dry season. This creates different types of interactions between the members of the community, cattle owners vs. non-cattle owners, including competition for the organic resources. In this study we explored the magnitude of such interactions in terms of nutrient flows and the long term effects of the current practices on soil productivity, hypothesizing that the collective management of feed resources brings negative consequences for non-cattle owners. We used information on crop and cattle management collected in a village of the communal area of Murewa in NE Zimbabwe, and a dynamic farm-scale simulation model (NUANCES-FARMSIM) of which the individual models have been calibrated and tested with existing information for the same area, and adapted to include the main interactions at village scale. The simulations of 10 years showed that the grasslands contributed the majority of the annual feed intake of the herd of the village (c. 75%), and that the crop residues produced by the non-cattle owners sustained a substantial (c. 30%) amount of the intake of cattle during the dry season. This removal of C (0.3–0.4 t C $y^{-1}$) from the fields of the non-cattle owners resulted in a long term reduction of the already poor yields of their farms. Impeding the access of cattle to the crop residues of non-cattle owners increased the quality of their soils modestly and improved yields in the mid- to long term, but not enough to meet the needs of the family. Due to poor management of the manure, from the 80–120 kg N deposited in kraal per year on the wealthier farm type (resource group 1, RG1) and the 40–60 kg N per year for resource group 2 (RG2), only 15–32 and 8–18 kg manure N per year were available to be applied to the crops respectively, with an efficiency between N excreted and N available to be applied to the fields of 20–30%. According to the model simulations, the whole herd of the village with average size of 187 animals transferred 100 t faecal dry matter $y^{-1}$ from grasslands to cropland. With minimum losses, that amount will not suffice for 10% of the 116 ha of cropland, if it were to be applied at the recommended rates of 10 t $ha^{-1}$ $yr^{-1}$. Due to the harvest of grain and the removal of most crop residues by grazing cattle, there was a decline in soil C stocks of all farm types over the simulation period. The smallest decrease (−0.5 t C $ha^{-1}$ in 10 years) was observed in the most fertile fields of the cattle owners who compensated for the removal of C through the addition of manure. To sustain the herd size, cattle of the farmers from RG1 (in average 10 heads) consumed between 20–25 t of grass biomass $y^{-1}$. Without taking into account negative effect of overgrazing on the pastures, each farmer of RG1 would need to have access to 12–27 ha of grassland to apply about 3–4 t of manure $y^{-1}$ in their farms with an average size of 3 ha. Increasing amounts of mineral fertilizers used concurrently with changes to the current management of the crop residues and manures by redistributing manure from the more fertile fields of the farm to the poorer fields, appears to be a promising strategy to boost the productivity of the community as a whole. The likelihood of this scenario being implemented depends on the availability of fertilizers and the willingness of farmers to invest in rehabilitating soils to obtain benefits in the long term, as opposed to concentrating all organic inputs in small areas and creating islands of fertility where crop yields are secured.

| **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 |

## COMPLETED WORK

### Aggregating field-scale knowledge into farm-scale models of African smallholder systems: summary functions to simulate crop production using APSIM

**R. Chikowo[1], M. Corbeels[1,2], P. Tittonell[1], B. Vanlauwe[3], A. Whitbread[4] and K.E. Giller[5]**

*[1]CIRAD, France; [2]TSBF - CIAT, Zimbabwe; [3]TSBF - CIAT, Kenya; [4]CSIRO, Australia; [5]Wageningen University, the Netherland*

**Abstract:** The efficiency with which applied resources are utilized in sub-Saharan African cropping systems is especially critical as the resources are generally scarce. Research efforts to improve farm productivity increasingly focus on resource interactions and trade-offs operating at farm scale. Farm-scale models that integrate summary models of the various subsystems (crops, livestock, household) are proposed to analyze the complexity of management systems. NUANCES-FIELD is a summary model of the crop/soil system that calculates seasonal crop production based on resource availability, capture and utilization efficiencies. A detailed mechanistic crop growth model, APSIM, was used to generate parameters and variables that can be introduced as descriptive functions in NUANCES-FIELD. To such end, we first parameterized and tested APSIM based on several field experiments carried out on different soil types in western Kenya farms where nitrogen and/or phosphorus were applied. The model was further configured to generate nitrogen and phosphorus response curves as a function of soil condition (carbon content, clay content, phosphorus-sorption characteristics) and the effects of alternative weed management scenarios in relation to labour availability. Nitrogen, phosphorus and rainfall capture efficiencies ranged between 0.22-0.85 kg $kg^{-1}$, 0.05-0.29 kg $kg^{-1}$ and 0.10-0.53 mm $mm^{-1}$, respectively, depending on soil nutrient and physical conditions. Variation in the integrated seasonal fraction of radiation intercepted (intFRINT) with plant density was adequately described by the function $y = 0.058x +$

0.11 within a range of 1.5-5.5 maize plants per $m^2$. Investigation of weed management using the APSIM model identified a weed-free period of at least five weeks from maize emergence for minimum yield loss from weed-crop competition. The simulation exercises confirmed that resource-use efficiencies sharply decrease on moving from relatively fertile fields 'close' to the homestead towards degraded 'remote' fields within the same farm, giving impetus to expedite the search for better targeted management strategies for spatially heterogeneous farms.

## WORK IN PROGRESS

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

**M. Corbeels[1], C. Thierfelder[2], R. J. Delve[1] and C.H. Porter[3]**
*[1]TSBF - CIAT, Zimbabwe; [2]CIMMYT, Zimbabwe; [3]University of Florida, USA;*

**Introduction**

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

**Material and methods**

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

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

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

**Preliminary results**

Using DSSAT-CSM we predicted water-limited maize grain yield for the Henderson site under the 4 weather scenarios (including the baseline climate) and for the 2 tillage treatments (CT and CA). Planting date was during the last week of October. For the baseline scenario (BS) simulated maize grain yield was on average about 720 kg/ha higher under CA then under CT **(Table 13)**. This was mainly due to increased water availability as a result of decreased runoff under CA compared to CT. Predicted yields varied broadly, from a minimum of 1003 kg/ha to a maximum of 6483 kg/ha depending on seasonal rainfall amount and distribution. As expected average grain yields for both tillage practices were lower for future climate scenarios **(Table 13)**. The simulation results indicate that the impact of a 15% increase in the duration of seasonal dry spells (DS scenario) is at least as large as that of a 15% decrease in annual rainfall (RS scenario). Under the RDS scenario of decreased rainfall with longer dry spells model predictions suggest a decrease in maize grain yields of about 25 to 30%, which is in agreement with the value (30%) projected for Southern Africa in a broad-scale analysis by Lobell et al (2008). The cumulative distribution functions of simulated maize grain yield for the BS and RDS climate scenarios under CT and CA are presented in **(Figure 55)**. Under the current climate the probability of producing at least 3000 kg/ha grains is 41 and 67 % for respectively CT and CA. Under future climate, due to water stress the probability drops to respectively 15 and 43%. The results indicate that the negative impact of climate change can be mitigated by adopting CA in the 'normal' years, but with a higher risk of lower yields in the 'good' and 'bad' years.

**Table 13: Effect of climate change on maize yield (kg/ha) as simulated by DSSAT-CSM under conventional tillage and CA for the Henderson site nearby Harare, Zimbabwe. Variation coefficient in parenthesis**

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

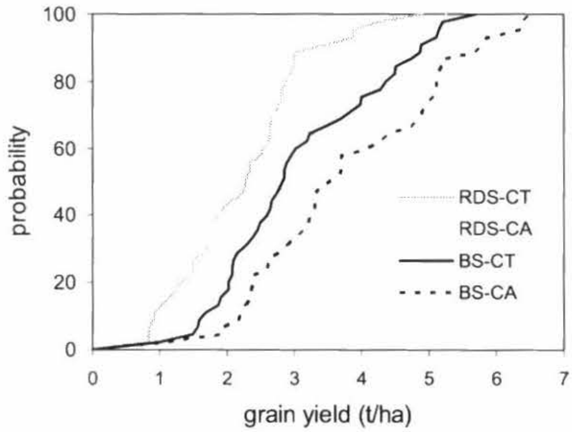



**Figure 55: Cumulative probability functions of maize grain yield as simulated by DSSAT-CSM for the BS and RDS climate scenarios under CT and CA practices.**

**Preliminary conclusions**

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

| |
|---|
| **Output 2. 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 |

## NO COMPLETED WORK

## WORK IN PROGRESS

## Soil fertility management in cassava systems

**P. Pypers[1], W. Bimponda[2], J.P. Lodi-Lama[2], B. Lele[3], R. Mulumba[3], C. Kachaka[3] and B. Vanlauwe[1]**
[1]*TSBF - CIAT, Kenya;* [2]*INERA, DR Congo;* [3]*UNIKIN, DR Congo*

Cassava is the main staple crop in Bas-Congo, and one of the major food crops in Sud-Kivu. Low soil fertility and disease pressure, particularly *Cassava mosaic disease*, are the two major constraints to cassava production. Trials were conducted to investigate the response to fertilizer and organic inputs in improved CMD-resistant varieties obtained through INERA's cassava program. Responses to fertilizer however differed **(Figure 56)**, indicating again the importance for local adaptation and taking into account the soil fertility level when making fertilizer recommendations.

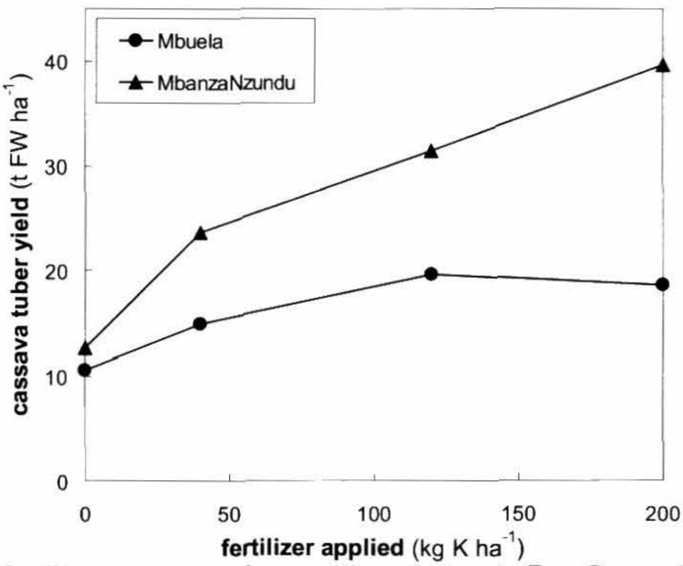



**Figure 56: Cassava fertilizer response observed in two sites in Bas-Congo, DRCongo.**

Substituting two thirds of the K supplied by the fertilizer by locally available green manures did not result in significant changes in cassava tuber yields, relative to a full addition as fertilizer **(Figure 57)**. In general, higher yields were obtained with partial substitution by *Tithonia* leaf residues than with *Chromolaena* leaf residues. These green manures, particularly *Chromolaena*, are easily available, although in relatively small quantities. Most farmers have very little access to manure, and fertilizer is expensive (generally about 1 – 1.5 $ per kg of NPK 17:17:17). The use of such locally available green manure therefore appears an economically viable option, although its large-scale applicability can be contested. Marginal rates of return for the use of green manures, whether applied solely or combined with a low rate of fertilizer vary between 4 and 5, while returns to sole fertilizer application generally vary between 2 and 3.

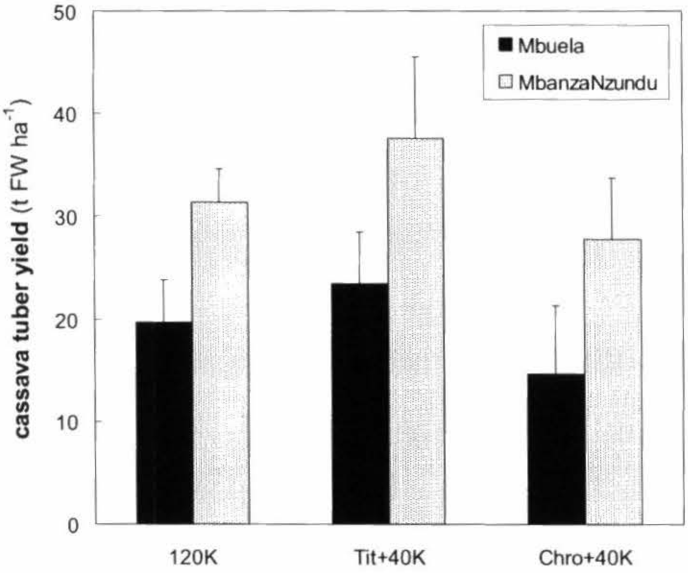



**Figure 57: Cassava tuber yield as affected by fertilizer application, either solely or combined with Tithonia or Chromolaena leaf residues, in two sites in Bas-Congo, DRC. In all treatments, approximately 120 kg K ha$^{-1}$ is applied.**

Based on these observations, green manure application has been recommended and included in farmer-managed adaptation trials on improved legume-cassava intercropping. We are currently investigating the effects of green manure and fertilizer application (combined or applied solely) on cassava and legume yields across a range of soil types and fertility levels.

## Improved legume-cassava intercropping systems

**P. Pypers[1], J.M. Sanginga[2], K. Bishikwabo[2], S. Mapatano[3], A. Chifizi[3], M. Walungululu[4], W. Munyahali[4], J. Bashagaluke[4], W. Tatahangy[5], N. Mbikayi[5] and B. Vanlauwe[1]**

*[1]TSBF - CIAT, Kenya; [2]CIAT, DR Congo; [3]DIOBASS, DR Congo; [4]UCB, DR Congo; [5]INERA, DR Congo*

An improved legume-cassava intercropping system was developed that maximizes productivity by combining a number of components, namely (i) improved germplasm, (ii) fertilizer application, (iii) organic matter management, and (iv) adapted agronomic practices and crop spacing. In this system, the cassava is spaced at distances of 2 m between rows and 50 cm within the row. After the harvest of the first legume, the system allows planting 2 rows of another legume (e.g., a climbing bean) during the second season. Spacing the cassava in this manner allows higher legume production, without affecting the cassava tuber yield **(Figure 58)**. Productivity is maximized when fertilizer is applied: legume yields are increased by 300 % and cassava yields by 200 %, relative to the common practice (random spacing, local varieties and sole organic input application). It is important to use adapted, responsive germplasm, and a cassava variety without proliferous branching to allow light interception by the second legume. In poor soils, application of farm yard manure is recommended. The system can be modified following production objectives and different legumes can be intercropped. In Sud-Kivu, farmers prefer intercropping with beans and soybean, while in Bas-Congo, intercropping with groundnuts or soybean is preferred (see CIALCA report 2007). After evaluation in demonstration trials in the different action sites, the system is now evaluated in farmer adaptation trials (see further). All preliminary results confirm increased productivity, relative to the common practice. Some early indications of farmers experimenting and taking up the system have been recorded. Information brochures and detailed technical descriptions will be developed for promotion and dissemination by research and development partners.

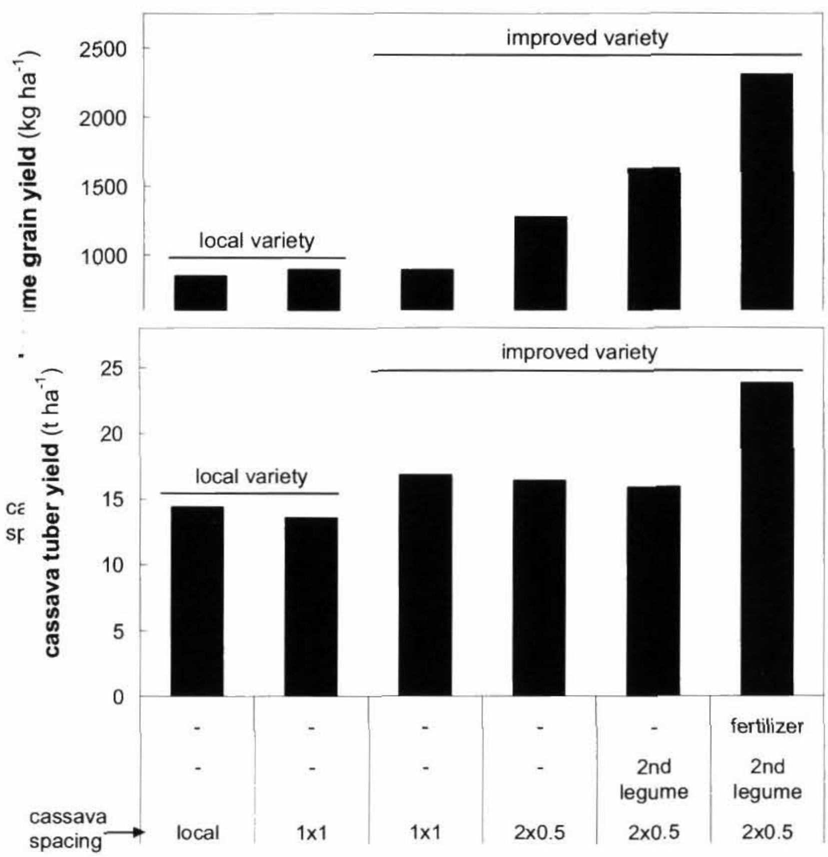



**Figure 58: bush bean (above) and cassava tuber (below) production as affected by cassava or legume variety, cassava spacing, fertilizer application, and intercropping a second legume in the improved cassava-legume intercropping system.**

| 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 COMPLETED WORK

## NO WORK IN PROGRESS

| 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 COMPLETED WORK

## NO WORK IN PROGRESS

| 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 |

## NO COMPLETED WORK

## WORK IN PROGRESS

### The effect of farm fertility variability on the efficiency of banana productivity in central Kenya

**M. Okumu[1,4], P. Van Asten[2], E. Kahangi[1], S. Okech[1], B. Vanlauwe[3]**

*[1]Jomo Kenyatta University of Agriculture and Technology, Kenya; [2]International Institute of Tropical Agriculture, Uganda; [3]CIAT-TSBF, Kenya. [4]Ministry of Agriculture, Kenya*

#### Introduction

The phenomenon of progressive yield decline in bananas has been reported extensively world wide. Several causes have been suggested, including pests, diseases, poor farmer management practices and decline in soil fertility. However, the interactive influences between these factors and yield decline have not been clearly understood. The conversion of nutrients to crop yield depends on many factors during the production period of a crop. Soil factors play a major role in influencing the way plants absorb and utilize nutrients. This consequently affects the partitioning of dry matter to the various plant parts and determines the desired crop yields.

## Materials and methods

Ten banana farmers were randomly selected in Maragua, Central Kenya ($00^0$47'S, $037^0$07'E) for a 14 month on-farm study. The objectives of this study were (i) to determine key factors influencing banana yields and their interactions and (ii) to determine banana yield variability within the farms, and amongst farmers of different resource endowment levels. Three plots with Giant Cavendish cultivar in different banana farm portions were selected in each farm based on the relative distance from the homestead. Data collected included farmer management activities, plant and soil nutrient status and yields. The plant nutrient indices were calculated as described by Mourao Filho (2004).

## Preliminary results

Yields were more influenced by soil factors (67%) while non-soil factors influenced only 33% yield variability. The Bunch weights, harvest indices and bunch yields were significantly higher closest to the homesteads, compared with the furthest study points from the homesteads. The mean bunch weights were 15.44, 12.23 and 11.62 kg/bunch for mats nearest to the homesteads, mid-farm and furthest from the homesteads respectively. The mean bunch yields were 32.29, 29.04 and 21.90 t $Ha^{-1}$ for mats nearest to the homesteads, mid-farm and furthest from the homesteads respectively. The harvest indices were 49.98%, 45.02% and 37.94% for mats nearest to the homesteads, mid-farm and furthest from the homesteads respectively. There was however no variation in the plant total above ground dry matter weights with distance from the homesteads. Soil pH, soil levels of K, and K/Mg were higher closest to the homesteads compared to the furthest, whereas soil Mg and Ca levels were higher furthest from the homesteads. Apart from K and N, most soil nutrients were within the recommended ranges for the banana crop. The foliar K and N content were relatively low in all study farms. Plants furthest from the homestead were more deficient in most nutrients compared to those nearest. Whereas foliar K index continuously decreased with distance from the homestead, the foliar indices of N, Mg and Ca increased. The harvest indices tended to decrease as the nutrient imbalance increased. This occurred as the distance from the homestead increased.

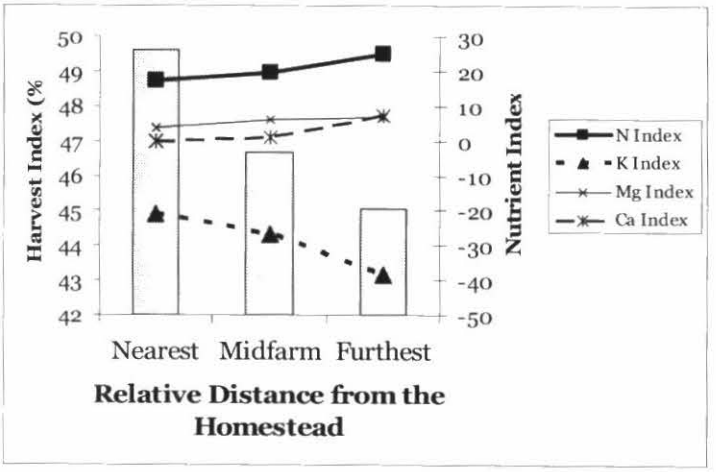



**Figure 59: Banana Harvest (bars) and Nutrient Indices (lines) with progressive distances from the homesteads in Maragua**

**Preliminary conclusion**

Production efficiency was greatest with proximity to the homesteads. Though there was no difference in the total above ground dry matter yields, the convertion of nutrients to the bunch was highest nearer the homesteads than further. The differences in yields were mainly driven by differences in harvest indices, which appeared to be related to cation nutrient imbalances. The harvest indices declined with rise in nutrient imbalances. Using both the soil and foliar nutrient levels, fertilizer recommendations that enhances higher harvest indices can be formulated. More research efforts should focus on the manipulation of situations to obtain higher harvest indices as a means to improve banana productivity.

## 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.<br>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.<br>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 in vestment 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 **(Figure 3)**.

*Major research questions are:*

→ *How does access to input and output markets and to knowledge on improved health and nutrition affect the investment of farmer communities in ISFM practices?*

→ *How does the role of access to input and output markets and to knowledge on improved health and nutrition in fostering ISFM practices vary with changes in human, social, and infrastructural capital?*

→ *Which combinations of technological, institutional, policy, and market innovations work for expanding smallholder farmer investments in agricultural systems and under what circumstances?*

→ *What are the implications of farmer-market linkages on farming systems, livelihood assets and intra-household dynamics?*

| 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. |

## NO COMPLETED WORK

## NO WORK IN PROGRESS

| 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. |

## COMPLETED WORK

### Nutrition and Health Status of Orphaned and Vulnerable School Children Aged 6-9 Years In Suba District, Kenya. *(2008) Applied Biosciences 4: 45-53*

**Kamau[1], J., Ohiokpehai[2], O., Kimiywe[1], J. and Oteba[3], L.**
*[1]Kenyatta University, Kenya; [2]TSBF - CIAT, Kenya; [3]Moi University, Kenya*

**Abstract:** This study investigated the effect of soybean supplementation on the nutritional status of school children from HIV affected households in western Kenya. An experimental research design was used with 54 subjects in experimental group and 56 controls randomly selected. The experimental group received corn-soy blend porridge for three months at school. A structured questionnaire and anthropometry were used to collect data. Malnutrition levels among the experimental group reduced from 10.2, 28.9 and 5.6% for underweight, stunting and wasting, respectively to 6.2, 16.7 and 3.4%, respectively. The control group registered 11.4, 28.5 and 8.7% underweight, stunting and wasting, respectively at baseline. Underweight and wasting rose to 14.3 and 9.5% while stunting dropped to 21.5%, which were insignificant changes at $P>0.05$.
Conclusion and application of findings: The feeding trial using corn-soy blend improved the nutritional status of school children in Suba District and it is likely that significant improvement of nutritional status could have been realized if the trial was longer. Soybean has potential to curb protein energy malnutrition and its utilization should be promoted in HIV and AIDS affected areas to alleviate malnutrition

## The Effects of Soybean (*Glycine Max*) and Pigeon Pea (*Cajanus Cajan*) Food Mixtures on the Nutritional Status of School Children in Suba District, Kenya. *(Accepted for JFAE V. 7)*

**Ohiokpehai[1], O., Mbithe[2], D., David[2], D.M., and Kamau[2], J.**
*[1]TSBF - CIAT, Kenya; [2]Kenyatta University, Kenya*

The effects of HIV and AIDS are reversing the developmental gains on malnutrition in Africa. It is important to reposition nutrition for development that is sustainable especially in resource poor areas an example which is Suba district in Nyanza province. Suba District has the highest prevalence of HIV and AIDS which is currently 31%. This has resulted in inadequate food at the household level leading to macro and micronutrient deficiencies.

The objective of the work was to establish the effect of corn-soy and corn-pigeon pea blends on nutritional status of school children aged 6-9 years in Suba District, Kenya. An experimental research design was adopted that would enable the data to be analyzed statistically. Two primary schools were purposively selected followed by a systematic sampling of the pupils leading to the selection of 49 pupils from Mbita and 52 pupils from Ong'ayo schools. The children were purposely chosen to be affected by HIV and known to be vulnerable in the community. Soybeans or pigeon peas-corn mixtures were commercially prepared at NUTRO EPZ, Athi River, Kenya to give 14% protein of roasted flour. The children were fed at mid-day in school and a take home ration was prepared to serve a family of five during the weekend to ensure that the index child was allowed to eat his/her portion. Anthropometric techniques were used for data collection. Pupils from Mbita were fed on corn-soy while those from Ong'ayo were fed on corn-pigeon pea blends for five months. Nutrisurvey and SPSS were used for data analysis. Descriptive and inferential statistics were used to interpret results at $p<0.05$ confidence interval. Stunting level in Mbita decreased from 21.6% to 16.4% and in Ong'ayo from 21.5% to 18.8%. Underweight and wasting decreased significantly ($p<0.05$).

Grain legumes can improve nutritional status of children; however a longer feeding (intervention) period and a more dense food type are needed to allow for a better impact. Grain legume especially soybeans contains genistein and immune-boosting substances that can improve growth and could decrease the use of nutritional intervention.

# WORK IN PROGRESS

## Serum Zinc level of school children affected by HIV/AIDS on a corn soy feeding trial in primary schools in Suba district Kenya.

**O. Ohiokpehai[1], D. Mbithe[2], and J. Kamau[2]**
*[1]TSBF - CIAT, Kenya; [2]Kenyatta University, Kenya*

Micronutrient deficiencies are among the ten top leading causes of death in sub Saharan Africa. In Suba district the problem is compounded by high poverty levels and a high prevalence of HIV which is currently 31%. This is associated with inadequate food at the household leading to macro and micronutrient deficiencies. Suba district is resource poor with high levels of food insecurity and lack of diet diversification and 30% of school children orphaned by HIV. The objective was to determine the effect of corn soybean supplementation on serum zinc. An experimental study was conducted with 2 schools being fed with corn soy blend. A third school was taken as control. Blood samples at baseline were drawn from 156 schools age 6-9 years from the three schools while blood samples at follow up were drawn from 138 children. Assessment of serum zinc was done before and after three months of corn-soy blend feeding trail. The WHO precaution and guidelines for drawing blood were followed. Blood samples were wrapped in foil centrifuged at 30000 revolutions and stored in liquid nitrogen at 70 for onward transportation to the analysis center. SPSS and nutrisurvey were used to analyze data into descriptive and inferential statistics. At baseline nearly all the pupils wee deficient with low serum zinc. There was a significant reduction after at three month corn soy blend feeding trial. The mean serum zinc improved from 8.4 to 10.2. The supplements had a positive effect on serum zinc levels. A longer intervention period is recommended to significantly improve zinc deficiency

## Soymilk Fermentation for income generation

**O. Ohiokpehai[1] and J. Maina[2]**
*[1]TSBF - CIAT, Kenya; [2]Jomo Kenyatta University of Agriculture and Technology, Kenya*

### Introduction

Value added soybean based fermented products are being developed using modern biotechnology tools with an objective of providing sustainable solutions to human health, nutrition and development needs particularly in school feeding program.

### Materials and methods

Selected potential multifunctional bacterial strains are being tested for commercial application in soybean based fermented foods. Viable and functional bulk starter culture is being developed first for use in production of fermented functional soy-yoghurt. In this respect, four *Lactobacillus* probiotic strains have been used for process model development of multifunctional starter culture. Time and temperature conditions requirements have been established with respect to acid development and physical chemical characteristics of bulk starter culture. Other multifunctional starter culture processing factors such as soy milk heating conditions, compositional and quality attributes are being established. Further research work is going on to verify the application of the model in functional soy-yoghurt production. Further studies will be done to establish storage stability and safety of the functional product. Microbial safety characteristics of soybean products are ongoing.

*Activities*

1.1 Activation and media growth medium optimization for multi-functional bacteria strains

1.2 Extraction and fermentation trials of soymilk with bacterial strains.

**Preliminary results**

**Table14: Fermentation quality attributes of soymilk with four probiotic strains**

| Strain code | Product quality attributes | | | |
|---|---|---|---|---|
| | After 6h fermentation | | After 48 h storage at 4 °C | |
| | pH | % TA | pH | %TA |
| KG 12 | 4.6 | 0.55 ± 0.02 | 4.5 | 0.60 ± 0.02 |
| KG 16 | 4.5 | 0.51 ± 0.01 | 4.5 | 0.55 ± 0.02 |
| KG 20 | 4.6 | 0.54 ± 0.04 | 4.5 | 0.55 ± 0.03 |
| KG 21 | 4.7 | 0.55 ± 0.03 | 4.6 | 0.55 ± 0.02 |

The four strains were able to utilize soymilk as fermentation substrate lowering the pH from initial average value of 6.8 to pH of between 4.5 and 4.7. The percent total titratible acidity expressed as lactic acid was reported to range from 0.51 to 5.5. These observations are encouraging given the fact that the strains were incubated at 37 C for only 6 hours. This is however shorter period of incubation of yoghurt starter cultures at similar conditions in milk.

**Table 15: Extracted raw soymilk quality attributes per 100ml**

| **Component** | **100 ml sample** |
|---|---|
| Protein | 3.6 ± 1.3 |
| Fat | 2.3 ± 2.6 |
| Carbohydrates | 3.4 ± 2.2 |
| Total soluble solids | 11.5 ± 0.9 |

We report the chemical composition of soymilk, and a key highlight is the high level of total soluble solids extracted. Mineral distribution in soymilk is being evaluated.

**Table 16:** Starter viability quality attributes in soymilk (Log cfu/ml) after fermentation and during storage at 4 °C

| **Strain** | **After 6 Hours incubation at 37 °C** | **After storage at 4 °C** | | |
|---|---|---|---|---|
| | | **24 hours** | **1 week** | **2 weeks** |
| KG 12 | 8.23 | 8.16 | 8.20 | 8.17 |
| KG 16 | 8.92 | 8.92 | 8.90 | 8.80 |
| KG 20 | 8.88 | 8.88 | 8.74 | 8.73 |
| KG 21 | 8.70 | 8.69 | 8.68 | 8.66 |

It was observed that soymilk could support the simultaneous growth of the four probiotic Lactobacillus strains to as high as 8 log cycles. Viability of strains upon storage at 4°C is also reported in (**Table 16**). These are noteworthy observations necessary for a probiotic functional product.

Probiotic bacteria generally do not grow rapidly in cows' milk. However, these studies have shown that the four strains can effectively utilization soymilk as substrate of fermentation. Suitable pH and acidity levels were demonstrated with the four strains.

## Collaborative Creation of Cooking Posters for Soybean

**I. Vandeplas[1,2], C. Akech[2], O. Ohiokpehai[2], S. Deckers[1], R. Merckx[1] and B. Vanlauwe[2]**

*[1]KULeuven, Belgium; [2]TSBF - CIAT, Kenya*

### Introduction

During meetings with farmers in Migori District, in the context of soybean agronomy experiments, the farmers mentioned the lack of knowledge about soybean processing and cooking at home. Although several rounds of cooking training sessions had already been organized in all zones of the soybean project, many women still lacked the knowledge or the confidence to prepare soybean products at home. Therefore, on demand of the women, cooking posters based on pictures were developed in late 2008 and used for demonstrations in December 2008. The activity happened in collaboration with women and the representatives of the different zones of the Uriri farmer cooperative society and with collaboration of various researchers of CIAT-TSBF, mentioned above.

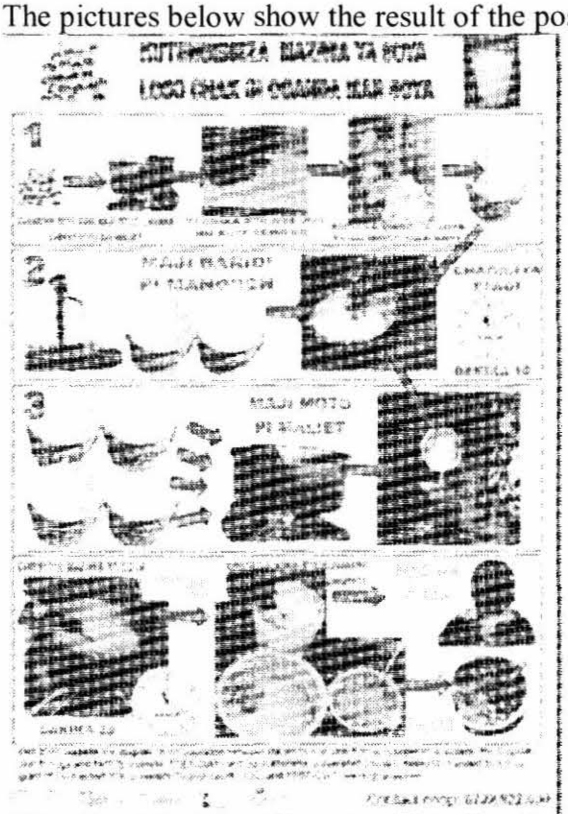
### Material and methods

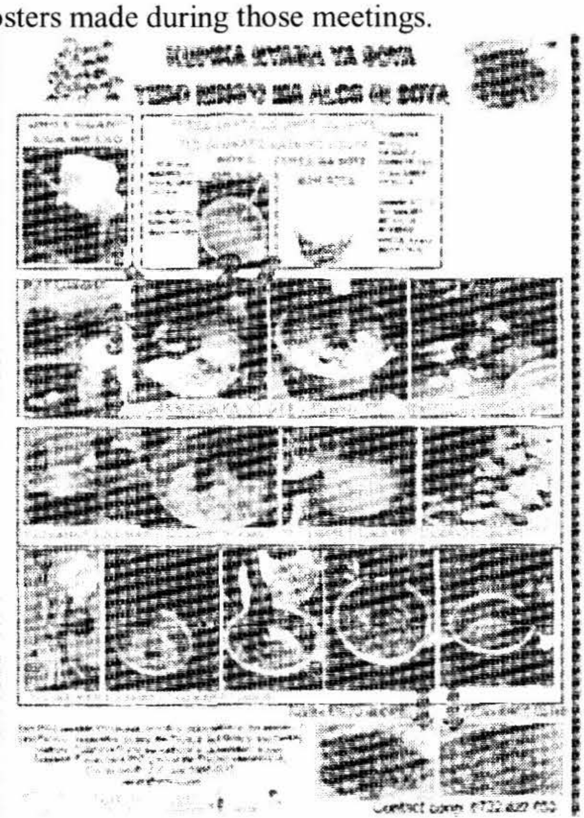
The creation of the posters happened in collaboration with 11 women from the different zones of the soybean project in Migori district. The women comprised of three types: illiterate women, who mostly had had no access to the cooking trainings organized earlier, literate women who didn't know soybean processing, and some literate women who had attended the cooking trainings and had further developed some recipes at home. One poster, previously made using pictures of soybean milk production from a previous meeting, was used to test the concept of picture-recipes. The poster was given to the illiterate women, who were in charge of reading the recipe and teaching the others. As this exercise was successful, the other posters were made in a similar way. The women first voted which recipes were the most important for home-based soybean processing. They elected soymilk, soybean nuts, soymilk residue (okara) for cooking vegetables, soybean meat substitute, and soybean tea substitute. The group of women who knew the recipes taught the group how to proceed. Pictures were made to illustrate all actions taken and the quantities of all ingredients used. When all recipes were made, the women had a chance to taste the food prepared. The pictures were then selected and compiled into recipe-posters for each of the recipes cooked. The draft versions of all posters were given for correction to the nutritionist of CIAT - TSBF and were translated in both Kiswahili and Kijaluo by a research assistant of CIAT -TSBF The posters were then tested among researchers and then among some of the farmers of the Uriri farmer cooperative society before being printed in large quantities. The zonal representatives of the cooperative assisted in the identification of the best places where to post the posters. In most zones, posters were posted at hospitals, maize mills, schools and churches, as to reach as many women as possible from the different villages where the soybean project is active in the district. Finally, the posters were tested during demonstrations with farmers, both men and women, in all different zones in December 2008 and photocopies of the posters were given to all people present.

## Preliminary results

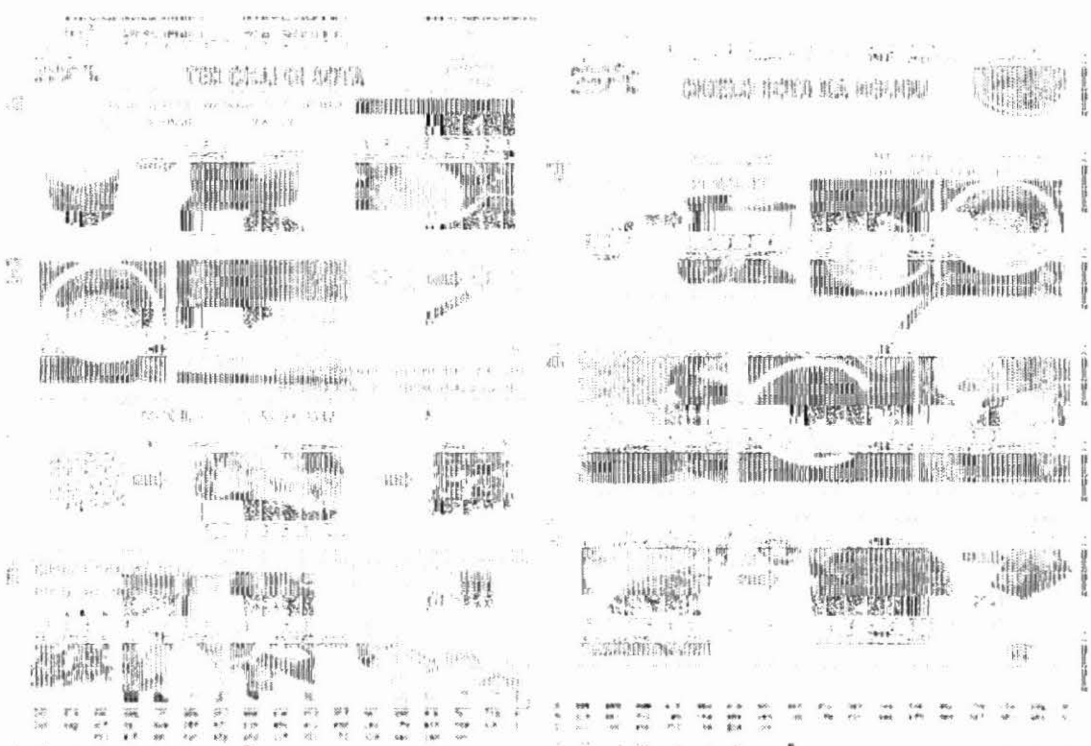
A total of 11 women were present during the poster preparation and feel encouraged teaching others. They were in charge of demonstrating the food preparation during the meetings in December 2008. During those meetings, a total of about 270 people were present and benefited from the demonstration and went home with a copy of the posters. In each zone 7 to 10 sets of the 5 different posters were placed in a visible location were many women have access to them.

The pictures below show the result of the posters made during those meetings.






KUSANGA UNGA WA SOYA
REGO MOK SOYA
CHEMCHA SOYA KWA MAJI YALIO CHEMKA
CHWAK SOYA EPI MALIET
1
MAJI MOTO
PI MALIET
TOA MAGANDA YA SOYA
2
POK SOYA
ANIKA KWENYE JUA KWA SIKU CHACHE
MO SOYA ECHIENG' KWOM NDALO MATIN
3
KUSAGA UNGA YA SOYA - REGO SOYA
KUPIKA MBOGA NA SOYA
TEDO ALOT GI SOYA
SOYA OKARA
PIKA MBOGA
TEDO ALOT
ONGEZA OKARA AU UNGA YA SOYA
KETIE OKARA KATA MOK SOYA
SOYA UNGA
MOK SOYA
Contact coop: 0722.822.030
TSBF
Oct 2008 Isabelle Vandeplas. In collaboration between the women of Unn Farmer Cooperative society the Tropical Soil Biology and Fertility Institute (TSBF-CIAT) and the Katholieke Universiteit Leuven. Research Funded by a PhD grant of the Flemish Interuniversity Council (VLIR-UOS) and TSBF-CIAT
isaluk@yahoo.com



**Preliminary conclusion**

During the activity a large number of women were reached. The posters allow both literate and illiterate women to learn preparing soybean products at home and are a good basis of teaching from women to women.

| **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 COMPLETED WORK

## NO WORK IN PROGRESS

| **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 COMPLETED WORK

## NO WORK IN PROGRESS

| **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 COMPLETED WORK

## NO WORK IN PROGRESS

| 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 COMPLETED WORK

## NO WORK IN PROGRESS

| 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. |

## COMPLETED WORK

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

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

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

## Farm input marketing in western Kenya: Challenges and opportunities.
*(2008) African Journal of Agricultural Research 3: 167–173*
**Chianu[1], J.N., Mairura[1], F., Ekise[1], I., and Justina[1], N.C.**
[1]*TSBF - CIAT, Kenya*

**Abstract:** Widespread and increasing rural poverty in sub-Saharan Africa has been of great concern to development community. Low use of inputs by farmers, due to market constraints that reduce profitability of input use, is one of the factors responsible for the gap between potential and actual yields. Using questionnaire, this study interviewed 130 agro-input dealers in Kenya to analyze challenges and opportunities in input delivery. Results indicate that there has been a steady annual growth (2–22%, with mean of 16%) in their number. Di-ammonium phosphate fertilizer (stocked by 92% respondents) was most commonly stocked, followed by Calcium Ammonium Nitrate fertilizer (84%), Urea (78%), and NPK (40%). Other services provided by agro-dealers are input information (75% respondents), credit (13%), bulk breaking (8%), and spraying (4%). Inputs selling price increased with distance to markets; long distances to market disconnect villages from input supply chain. High transport cost (53%), low demand (30%), lack of market information (21%), lack of storage facilities (13%), and limited business knowledge (12%) were the most important constraints faced by agro-input dealers. Policies and institutional frameworks suggested by dealers to streamline input trade were associated. The study concludes with suggestions on how to enhance efficiency of agro-dealers in input delivery.

# WORK IN PROGRESS

## An assessment of factors influencing demand for raw materials in food processing firms: A case study of soybeans in Nairobi, Kenya
**L.N. Njaramba[1], R. Atieno[1], P.O. Alila[1], and J. Chianu[2]**
[1]*TSBF - CIAT, Kenya.*

### Introduction

Edible oils and fats are essential in the human diet. Most nutritionists agree that 20–25% of all dietary calories should come from edible oils and fats (FAO, 1989). Nevertheless, under-consumption of proteins, edible oils and fats and related malnutrition are widespread in Kenya (Navarro, 1995). In many developing countries, and Kenya in particular, the diet is low in fat content since oil is one of the most expensive basic foodstuffs (FAO, 1989). The per capita intake of edible oils and fats remains very low especially among the urban poor, rural people and lactating mothers despite its nutritional importance (Mbwika, 1996). Soybean is by far the most important oilseed crop in the world (Ephanto, 1994; Matthews, 1989). In other words, although it is a legume, it contains a higher proportion of oil than most legume seeds. Thus, it is often classified as an oil seed (FAO, 1989). Matthews (1989) argues that flours and concentrates made from legumes other than soybean have had little commercial success. This implies that soybean is a special kind of legume compared to others. Soybean is relatively new in farming systems in many parts of the country (Ephanto, 1994). A report by MED (2004) indicates that soybeans are produced in Western, Rift Valley, Eastern, Central and Nyanza provinces. Western province stands out as the leading area accounting for nearly 50% of total national smallholder planted area and production in 2003. Their development in western Kenya has been linked to the Seventh Day Adventist movement (MED, 2004; Ephanto, 1994). This is followed by Nyanza and Central provinces which in 2003 accounted for 11%-12% of total smallholder production (MED, 2004). Estimates of area potentially suitable for production vary significantly depending on the source of data. Ministry of Agriculture estimates in 1995 was in the order of 157,000 hectares of which Western and Nyanza provinces accounted for 20,000 hectares and 24,000 hectares respectively. Uasin Gishu, Trans Nzoia, Siaya and Bungoma accounts for the largest proportion of land potentially good for soybeans production (MED, 2004). When grown in appropriate soils, soybean seldom requires nitrogen fertilizer; a major cost element in other crops (FAO, 1993). Soybean is used in a wide range of products (animal feed, human food, non-edible products, etc.). The major soybean products include; soy oil, soy meal, soy cake and the full fat soy flour (Ephanto, 1994). As human food, the soybean is superior in protein content to meat, fish, eggs, milk, and other pulses. Compared to other oilseeds, soybean contains about 40% protein. It is more protein-rich than any of the common vegetable or animal food sources available in Africa (http://web.worldbank.org; June 2006). The cost of protein, when purchased as soybean, is only about 10-40% of the cost of protein from fish, meat, eggs, or milk (http://web.worldbank.org; April, 2006). This makes soybean the world's biggest protein reserve. In relation to the cost of production, compared to other major sources of protein and oil, soybeans have low per unit cost of production. Livestock protein and oil sources require higher capital outlay, expansive land, and higher labor inputs. The high cost of production and some risks involved in soybean production imply low profitability, constraining the small-scale farmer (Ephanto, 1994). Large amounts of food are often wasted due to lack of preservation and inadequate processing, contributing to food shortage in developing countries such as Kenya. Improvements in food processing could significantly improve self-sufficiency in food as well as minimize price fluctuations between post-harvest gluts and pre-harvest shortages (Alemayehu, 2000). Processing of soybean is required to preserve products and convert them into usable forms with reasonable shelf lives. A large proportion of soybean processing industries in Kenya rely on imported soybean (MED, 2004). The major sectors utilizing soybeans are the food aid sector, livestock industry and industries involved in the processing of human food, especially those inclined towards dietary habits and hospitals. MED (2004) noted that demand for soybeans for human consumption in Kenya is mainly as food supplements (e.g. unimix) and is largely dependent on relief food requirements, fluctuating over time. The main institutional buyers (e.g., World Food Program, UNHCR, fraternity of NGOs, Prisons, Hospitals, etc.) of various soybean products largely do so for the feeding of refugees. Most African countries and Kenya in particular have gradually lost their capacity to feed their people. With fast growing urbanization (projected to 4.1% during 1995-2015), the urban/rural population ratio is undergoing a rapid change and is expected to reach 47.2% by 2015 (UN, 1996). This means that a third of the population is expected to depend on processed food in the near future and more and more food will have to be processed industrially

(Alemayehu, 2000). However, Kimuyu (1999) argues that processing in Kenya is highly import-dependent and that the greater part of the country's imports are being accounted for by raw materials. In relation to this, the total import bill for edible oils and protein cake/meal was estimated at US$ 88 million in 1995, rising rapidly to reach to an unprecedented level of approximately US$ 172 million in 2002 (MED, 2004). The scenario makes edible oils rank highest as the single commodity under the agricultural import and thus a major concern to our country (Kibuthu, 1996). Dependence on imported soybean and vegetable oils places Kenya in a risky position with respect to food security should international prices rise. Reliance on imports also has foreign exchange implications, hence the need to reverse the trend. At present, Kenya consumes about 400,000 MT of vegetable oils and local production only meets a third of this demand (Jagwe and Nyapendi, 2004). Soybean has been identified as one of the key sources of edible oil but despite its importance, there is evidence that sourcing soybeans is a major problem as majority of soybean processing industries depend on importation (MED, 2004). This has led to low capacity utilization of industries leading to high unit costs of processing, low profitability and poor motivation. This study aims at determining the factors that influence the demand for soybeans by the soybean processing firms. The study will also underpin the constraints these firms face and the types of linkages (e.g., forward, backward) that exist in the soybean processing sector. Demand for raw materials is a major determinant of industry's productivity and production (Jaffee and Morton, 1995).T his study will also give insights on how soybean production and processing could be increased in order to take advantage of its effectives on overall economic development and growth.

**Materials and methods**

*Study Site*
Nairobi city was the site for this study. According to the 1999 population census, the city is home to 2.2 million people with a population density of 3079 people per Km$^2$ (CBS, 2005). Diets in urban areas such as Nairobi are based more heavily on processed foods (http://foodafrica.nri.org, October 2006). Most of the soybean processing firms in Kenya are located and/or headquartered in Nairobi (EPZA, 2005).

*Data Collection, sampling procedure and data analysis*
Both secondary and primary data were collected. Secondary data sources included books, journals and the Internet. Primary data were obtained from the food processing firms, using a semi-structured questionnaire. A cross-section survey was carried out and the basic sampling unit was soybean processing firms. The most recent Kenya Soybean Association's (KESA) list dated 1998 of soybean processing firms and Kenya Directory of Manufacturing Industries from Kenya Industrial Research Development Institute (KIRDI) 3$^{rd}$ edition dated 1997 were used in compiling soybean processing firms operating in Nairobi. KESA has listed 103 firms within the country and KIRDI has listed the firms as food processors but not specifically soybean processors. Kenya telephone directory was used to confirm the addresses. All firms in Nairobi were contacted to find which ones actually process soybeans and the size of their employees. Comparing all available lists, aided by telephone calls led to our confirmation that about 57 firms were

relevant for our purpose. These firms were stratified by their sizes, following Parker and Torres (1993). These authors defined firms as: Micro enterprises (where number of employees is about 10 including the working owner); Small enterprises (where number of are between 10 and 50 employees); Medium enterprises (where number of employees are between 50 and 100); and large enterprises (where number of employees is over 100). The firms were stratified accordingly leading to a total list that comprises micro enterprises (of 16 in number), small enterprises (19), medium enterprises (7), and large enterprises (15). Out of these, 32 firms will be picked using proportionate sampling technique, resulting to 9 micro-enterprises, 11 small-enterprises, 4 medium-enterprises and 8 large enterprises. For the sampling to be proportionate, the sampling fraction (or interval) must be identical in each stratum (http://www.wadsworth.com). Firms from each cluster were listed on a separate piece of paper, folded, put together in a container and then randomly picked at a time. All completed questionnaires were checked (for data integrity, completeness, consistency, etc.), coded and entered into the computer and then finally analyzed. Data were analyzed quantitatively and qualitatively, using SPSS and Microsoft Excel.

*Theoretical framework and variables*

This study was informed by the theory of supply and demand, which describes how prices vary as a result of a balance between product availability at each price and the desires of those with purchasing power at each price (Begg, *et al,* 2005; Mankiw 1998). According to the law of demand, the higher the price of a good, the less the demand for the good and vice versa. Demand is less at a higher price because higher price is also accompanied by a higher opportunity cost of buying the good in question. Theoretically, the factors expected to influemnce the demand for soybean raw material by processing companies include its price, price of its substitutes, availability, size and age of the processing industry, and quality of soybean to mention but a few.

**Preliminary results**

*Ownership and shareholding structure of the firms*

The ownership structure of the firms indicates that while about 25% were sole proprietors, 16% were public limited companies, 34% were private companies, and 25% were family owned. About 78% of the firms were wholly domestic. About 13% of the firms had some domestic shareholders. In about 6% of the firms, ownership was equally shared between domestic and foreign owners. It was only about 3% of the firms that were owned by foreigners alone. Additionally, only about 19% of the firms were multinationals. The balance was local. Company managers comprised about 69% of the respondents. The others were directors (19%), accountants (9%), and supervisors (3%).

*The main products processed using soybeans*

Several products, including flour, soy beverages/tea, spices, cakes, bread, and biscuits, were being processed using soybeans. However, the most popular was soy flour (75% of the companies produced it), followed by soy beverage (9.4%), and spices (6.3 %).

*Determinants of where processors source raw materials*
Different factors determine where (and when) processors source soybean raw material. These include availability and access to soybean grains (according to 32% of the respondents), price of soybean (15%), and quality of soybean grains (6%).

*Constraints faced by soybean processing firms*
Among others, these were evaluated with respect to the sourcing of soybean raw materials. In order of importance, the major snags were related to low domestic production level (17%), price fluctuation (16%), low quality (15%), and high prices (11%). The other constraints include the seasonality of soybean grains and product scarcity, poor road infrastructure, high transport and other transaction costs, lack of information on where to purchase soybean locally, untimely supplies by suppliers, lack of awareness about the economic and nutritional importance of soybean of consumers, low demand for processed products, competition from other suppliers of same or similar processed products, insecurity in the country, natural calamities (e.g., drought), financial constraints and high cost of production. Some processors noted that due to the poor state of roads the raw material (soybean) is not supplied on time, leading to high transaction and production costs. About 34% of the firms found it difficult to pay suppliers due to high prices of soybean grains, price fluctuation and low demand for processed products. Due to the domestic scarcity of soybean grains, almost 100% of the soybean grains processed was imported.

*Steps to address the constraints they face*
The problem of seasonality of soybean grains raw materials was being addressed through bulk purchases during the season. However, the need to create incentives that will lead to increases in domestic production of soybean grains was noted. The need for research into seed quality and high yielding varieties was also noted. It was also observed that processors that producers should be educated and trained on how to grow and utilize soybean in order to arouse and hold their interest in soybean production. Some of the processors would want subsidies and tax incentives and assurance of security. The issue of road infrastructure, market information provision, and irrigation to stabilize production and reduce the effect of seasonality featured prominently.

*Quality of soybean raw materials*
All the respondents were keen on the issue of the quality of soybean grains, especially the protein content, which most of the firms want to be above 38%. Most of the firms that process soy flour prefer the oil content to be below 4%.

Size of grains is important. About half of the firms preferred large-sized grains. Cleanliness of soybean grains was important to about 42% of the firms. They would want the soybean grains to be weevil-free with low moisture content (very dry). Low fiber content was also a desired trait. About 50% of the firms were keen on organic soybean. If given the choice between organic and chemically produced soybean, most of the firms would go for organic soybeans. Many of the firms were ready to pay premium prices for organic soybean if they could see it to buy. However, some of the firms noted that they would pay the same price for organic and non-organic soybeans. About half of the respondents would not bother about how soybeans were produced but would go straight that meet their needs based on other criteria. None of the firms would aspire to buy organic soybeans at a lower price than the chemically produced soybean.

*Strategies for increasing soybean processing in the firms*
Almost all the firms (about 94%) had strategies for increasing soybean processing. Some of the strategies include: aggressive marketing and advertising of their product (indicated by about 27% of the firms), improvement in processing technology (17%), and a push for tax reduction on finished products (to reduce costs) (10%). The other strategies were awareness creation (on economic and nutritional importance of soybean) through education and training of customers, creation of ready market for local farmers (in such a way that producers are informed about the market), own research (to come up with different ways of utilizing soybean and different kinds of products from them) to arrive at new products, persuasion of government on favorable policies (e.g., that will ensure that private firms are contracted to process soybean products for relief food by the UN), push to ban imported cheap processed soybean products (or high tax in the minimum), and a push for government intervention in the soybean sector (e.g., through marketing boards to ease the difficulties in searching for soybeans. Their other strategies were the expansion of their capacity to increase in production, persuasion of the government to improve on marketing infrastructure (e.g., roads, electricity). Some firmed planned to provide storage facilities to the small scale producers to store their produce during on season to ensure there is no loss of produce.

*Strategies for increasing domestic production of soybeans*
The strategies for increasing domestic production of soybeans include educating and training producers on how to grow soybean and on the socioeconomic importance of soybean, availing top quality seeds for planting to soybean farmers, public awareness creation on soybean utilization, and prompt payment to soybean producers when their goods are purchased. The other strategies include effective information dissemination mechanisms, provision of extension services to soybean farmers, ensuring that prices paid for soybean grains adequately cover farmers' cost of production (leaving some reasonable margins), creation of soybean marketing organizations (for collective marketing), and ensuring that soybean producers have access to credit.

*Role of the government on increasing domestic production of soybean*
According to all the firms, the government had an important role to play. These include: incentives (good quality seeds, fertilizers, etc.) to the producers, improvement on road infrastructure, input tax reduction, and provision of ready market for soybeans produced by farmers as well as availing farmers of subsidized inputs. It was also observed that government should start giving priority to soybean production rather than concentrate on traditional food crops such as maize and wheat. This could be achieved through formulation of policies that encourages production of soybean.

*Government's role in increasing soybean processing*

More than 84% of the firms noted that the government had a major role to play in ensuring that soybean processing was increased. The most important roles expected of the government were tax reduction (over 38% of the respondents), followed by soft loans (19%), and imposition of high taxes on imported soybean products (10%). The government's other roles including subsidies to processors, reduction of fuel prices (to reduce production costs), provision of security to the investors, incentives to processors (e.g., through the provision of technical support), helping processors to secure markets both regionally and internationally, and support widespread creation of public awareness on the socioeconomic importance of soybean. Above all, the government should come up with policies that encourages processing of soybean and also improve on the physical infrastructure (e.g., roads, electricity, etc.) in order to reduce cost of production.

## 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.<br>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.<br>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 **(Figure 3)**.

*Major research questions are:*

→ *Which are the most efficient and effective means, e.g., in terms of cost per farmer reached, to scale up ISFM practices throughout the target impact zones?*

→ *What is the specific role of various partners along each step of the value chain in promoting ISFM practices and how important is this role in reaching the end-users?*

→ *How do partnerships evolve as adoption of ISFM practices is moving from a set of principles to be adapted by local communities to a set of proving practices that can move quickly to a lot of farmers?*

| 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. |

# No Completed Work

# Work in Progress

## Comparative analysis of the production potential and efficiency as determinants of investment choice in the production of cotton, maize, soybean and sugarcane in the farming systems of Matungu division, Mumias district, Kenya

**C.C.O. Ogwan'g[1], W.Otieno[1], J. Adari[1], and J. Chianu[2]**
[1]*Maseno University, Kenya;* [2]*TSBF - CIAT, Kenya*

### Introduction

Available resources for agricultural production are limited in relation to the production needs of competing enterprises. As a result, choice of enterprises has to be made on how to allocate these limited resources. Preference and choice in the use of available resources affect the level of agricultural production and total benefits from production. For example, allocation of more resources in the production of cash crops may in the long run lead to food crisis in the society. Some enterprises give more income over time than others. As a result, enterprise selection should be done based on profitability and social benefit. However, a farmer would at times be comfortable with an enterprise that earned him less profit but sustainable rather than a more profitable enterprise with a high degree of income variation. In other words, a farmer who does not want to take a lot of risk may decide to settle for a lower profit. The objective of this study is to conduct economic analysis of cotton, maize, soybean and sugarcane enterprises in order to sharpen related recommendations to farmers with respect to adoption and investment of the limited farm resources.

### Materials and methods

The study area is Matungu division in Mumias district of Western Kenya. Primary and secondary data are being collected on resource allocation to and the production of cotton, maize, soybeans and sugarcane. These crops are clearly competing for the farmers' resources (land, labor, capital and management). Social benefits from each crop are being considered to judge how each benefits the society as a whole. For sample selection, the farmers were, among others, classified on the basis of the crops they grow and their scale of farming. Data are being collected on input uses and costs, production, and output and output prices. Policy issues directly or indirectly affecting the productivity of each crop is being examined in order appropriately inform or make proper good recommendations on enterprise selection. Multi-stage and random sampling methods were used in sample selection. Data collection is through self-administered questionnaires by the principal investigator complemented by on-farm field surveys, internet research, and secondary data exploration. Data collected would be presented in charts, graphs, tables, pictures and other reporting and other means of information communication. Among others, gross margin, cost-benefit, and farm budgeting analyses would be explored. In addition, data for use in running regression analysis on determinants of farmers' decision to allocate various factors of production to the different crops are being collected. By so doing, we shall understand and be able to explain possible disparity in resource allocation to the different enterprises. Relationships among variables will also be ascertained using correlation analysis.

**Preliminary results**

Most farmers in *Matungu* division applied less inputs than the optimum amount required for production of cotton, maize, sugarcane and soybean. This led to low productivity in all the cases. Some farmers ended up making losses due to low productivity. The fear of waiting for up to two years before getting returns on sugarcane farming drove some farmers into selling mineral fertilizers meant for sugarcane in order to meet their immediate household financial needs. Some also diverted mineral fertilizers meant for sugarcane to production of rival crops (especially maize). Most farmers did not use farm budgets as a tool of planning and analysis, ending up in wrong investment avenues.

**Preliminary conclusion**

Limited use of appropriate farm inputs is having a toll on overall farm productivity in the study area and is affecting crops such as soybean much more than the rival crops (maize, sugarcane, and cotton). Farmers constrained with access to mineral fertilizers tend to give special attention to their maize crops. This has adverse implications on the common call for agricultural diversification as a way of reducing rural poverty and attenuating rural-urban migration.

| 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

### Determinants of the decision to adopt integrated soil fertility management practices by smallholder farmers in the central highlands of Kenya. *Expl Agric. (2009), volume 45, pp. 61–75 C- 2008 Cambridge University Press*

**Mugwe[1], J., Mugendi[2], D., Mucheru-Muna[2], M., Merckx[3], R., Chianu[4] J. and Vanlauwe[4], B.**

*[1]Kenya Forest Research Institute, Kenya; [2]Kenyatta University, Kenya; [3]KU Leuven, Belgium; [4]TSBF - CIAT, Kenya*

**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.

## WORK IN PROGRESS

### Bridging the gap between farmers and researchers through collaborative experimentation cost and labour reduction in soybean production in South-Nyanza

**I. Vandeplas [1,2], B. Vanlauwe[1], A.M. Sagwa[3], J.A. Asimba[3], R. Merckx[2] and J. Deckers[2]**

*[1]TSBF-CIAT, Kenya; [2]KU Leuven, Belgium; [3]Uriri Farmers Cooperative Society, Kenya*

TSBF-CIAT introduced dual purpose soybean varieties in south-west Kenya both to improve soil fertility by nitrogen fixation and to provide a source of better food and income. Since the start of the project in 2005, the Uriri Farmer Cooperative Society was successful in spreading of the seeds over the district. Nevertheless, farmers still had problems with soybean agronomy. We therefore started a Collaborative Experiment (CE) Approach in March 2006 to make soybean production more accessible to farmers. The approach consisted of four stages: 1) information sessions; 2) participatory rural appraisal; 3) collaboration in the whole process of experimentation, from problem identification, to the design and analysis; 4) handing over to farmers. In this case study, farmers identified two main constraints to the recommended soybean production methods: 1) high labour requirement 2) lack of income to purchase the inputs. The treatments chosen were: 1) Labour options: point-placing with 2 weedings (recommended), planting in trenches at "correct distance" with 1 or 2 weedings, and broadcasting with one weeding; 2) Inputs: di-ammonium phosphate (DAP) (recommended), ½ DAP and ½ manure, manure, ½ Tithonia and ½ DAP, ashes, ½ ashes and ½ manure, and no input. Statistic analysis of the yields show a significant increase in yields from 586 kg/ha to 756-1047 kg/ha when applying inputs, but no significant differences between the local or mineral inputs. After seeing the harvest results, farmers were interested in using ½ ashes and ½ manure, ½ DAP and ½ manure, full manure or full ashes. Economic analysis confirmed that those were indeed the most beneficial among all inputs. The farmers' preferences amongst the labour treatments, were planting in trenches with one or two weeding, or broadcasting with one weeding, depending on labour availability in their household. Indeed, only 50 kg/ha was gained by planting in trenches rather than broadcasting, although requiring 4 time more labour than broadcasting. Only 75-84 kg/ha were gained by weeding twice rather than once. The results and discussions with farmers during the field days, and short term impact analysis allowed demonstration that the CE approach had been successful on two main aspects. First, CE was successful in defining problems and yield enhancing treatments which are accessible to deprived people. Indeed, farmers ranked low production cost and low labour requirement as more important criteria for treatment choice than even the yields. During field days, all farmers felt there was at least one of the treatments accessible to them. The second main success of the CE process was the increased awareness and interest about soybean. After less than a year of collaboration, farmers drew benefits trees showing that soybean can bring a better life, cash for school fees and better health. The number of farmers registered in the soybean cooperative also increased from a few hundreds to 4500 that year. Several farmers started their own experiments to further adapt the recommendations to their own needs. The CE approach was thus successful in bridging the power-relations and knowledge gap between researchers and farmers and in designing appropriate technologies.

## Scaling-Up and -Out of Fertilizer Microdosing and "Warrantage" or Inventory Credit System to Improve Food Security and Farmers' Income in West Africa

**R. Tabo[1], A. Bationo[2], B. Amadou[3], F. Lompo[4], M. Gandah[5] O. Hassane[1], F. Dougbedji[1], K. Sako[6], J. Ndjeunga[1] and S. Koala[1]**

*[1]ICRISAT, Niger; [2]TSBF - CIAT, Kenya; [3]FAO Projet Intrants, Niger; [4]INERA, Burkina Faso; [5]INRAN, Niger; [6]EUCORD, Mali*

The fertilizer microdosing technology deals with the application of small quantities of fertilizer in the planting hole thereby increasing fertilizer use efficiency and yields while minimizing input cost. In drought years, micro-dosing also performs well, because larger root systems are more efficient at finding water, and it hastens crop maturity, avoiding late-season drought. Recent research also found that solving the soil fertility problem unleashes the yield potential of improved millet varieties, generating an additional grain of nearly the same quantity. Recognizing that liquidity constraints often prevent farmers from intensifying their production system, the warrantage or inventory credit system helps to remove barriers to the adoption of soil fertility restoration. Using a participatory approach through a network of partners from the National Agricultural Research and Extension Systems (NARES), Non-Governmental Organizations (NGOs), farmers and Farmers groups and other International Agricultural Research Centers, the microdosing technology and the warrantage system 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 up to 120 % while farmers' incomes went up by 130 % when microdosing was combined with the warrantage system. This paper highlights the outstanding past results and the on-going efforts to further scale-up the technology using Farmers Field Schools (FFS), capacity and institutional strengthening, private sector linkages and crop diversification amongst other approaches

## Achieving Impacts at Scale with Integrated Soil Fertility Management Innovations in Sub-Saharan Africa: Successes, Lessons and Prospects

**P.C. Sanginga[1], J. Chianu[2], B. Vanlauwe[2], A. Bationo[2], E. Smaling[3], P. Woomer[4], U. Mokwunye[5] and N. Sanginga[2]**

*[1]CIAT-Kabale, Uganda; [2]TSBF - CIAT, Kenya. [3]International Institute for Geo-Information Science and Earth Observation, Netherlands; [4]FORMAT, Kenya [5]United Nations University Institute for Natural Resources, Ghana*

Agropessimism still pervades much of the current initiatives on agricultural development in Sub-Saharan Africa (SSA). Specifically, there is doubt that integrated soil fertility management (ISFM) can achieve impacts at scale, i.e., bringing benefits to more people over wider geographic areas. Based on a number of selected case studies, this paper shows that, there are successful cases across SSA where ISFM has registered considerable impacts at large scales. These include (i) micro-dosing adopted in Sahelian dryland areas; (ii) soil and water conservation; (iii) grain legume-cereal rotation and intercropping systems, and (iv) crop-livestock systems in the east African highlands areas. Using a dynamic analytical framework, the paper attempts to identify key ingredients and critical lessons that contributed to their success. Analysis shows that the main driving forces for success include: (i) technology 'sparks' resulting from improved germplasm and simple technologies that provided additional benefits to yield such as livestock feed and crop residues; (ii) market linkages support ISFM because it performs best where farmers have access to farm inputs, credit facilities, storage facilities, and fair produce markets;(iii) research for development partnerships; (iv) alternative dissemination and extension approaches in different contexts including public sector extension, NGO-led participatory approaches and market-led information services. However, a critical missing element has been the absence of policy support, as well as considerable financial investment in ISFM. The paper delineates the impact zones for intensification where ISFM can make a considerable difference, and suggests a number of investment options to achieve large-scale impacts in a relatively short time.

## Enterprise prioritization and implications for Soil Fertility Management – The case of Kiambu district

**F.W. Maina[1] and S.K. Kimani [2]**
*[1]TSBF - CIAT, Kenya; [2]Kilimo Trust, Uganda*

High potential areas form the major food producing zones in Kenya. However, the small-scale farmers in such areas are not necessary food secure or income sufficient. In these high potential areas several factors, including declining soil fertility, hamper increase in farm household incomes by contributing to low and declining yields. Priority of enterprises selected and the objective of selecting the specific enterprise was hypothesized to influence Soil fertility management (SFM) options the farmers use. The objective of this study was to understand enterprise selection amongst 3 SFM classes (good (1), average (2) and poor (3)) in Kiambu district and its effect on their SFM techniques. The study was conducted amongst 99 farmers in Githunguri division of Kiambu district in AEZ classified as Upper midlands zone. Dairy was ranked highest by 88%, 78% and 60% of farmers in the 3 SFM classes respectively. This was followed by maize and potatoes (65% and 44% of all farmers respectively) as they provide stable food and income source, though lower compared to high value crops like tomato. Tomatoes received on average 85kg/ha N fertilizer followed by potatoes (27kg/ha N) and maize (25kg/ha N). This was supplemented by manure application at 14t/ha on napier, 12 t/ha on tomato, 8 t/ha on potato and 7 t/ha on maize/beans. All rates were lower than recommended. In developing and disseminating SFM techniques, researchers should consider the farmers priority enterprises, reasons for the selection as well as address the conflict between risk and fertilizer use in high value crop production.

## Farmer utilization and perception of herbicide-resistant IR maize

**B. Vanlauwe[1], L. Nyambega[1]**
*[1]TSBF - CIAT, Kenya*

Following installation of the demonstration trials during the long rainy season of 2005, farmer-managed adaptation trials were initiated during the long rainy season of 2006 and 2007 to evaluate the performance of IR maize under farmer management. This activity aimed at achieving deliverable (iv) a strategy for farmers to test and disseminate best-bet options to alleviate Striga-related production constraints. During the long rainy season of 2006, seeds of IR maize were distributed to about 100 farmers per target area (totalling about 1000 farmers). Since the seeds would not be sold, the agreements reached with the participating farmers were that (i) each farmer receiving IR seeds had to include a control plot with a local variety near the plot with IR maize, (ii) each farmer would fill a technology evaluation form, with the help of community facilitators, engaged by the project, (iii) each farmer would allow soils to be taken at the start of the season in order to measure the soil fertility status and the *Striga* seedbank, and (4) each farmer would nominate three other farmers that would be interested in joining these activities during the second rainy season of 2006. While originally it was planned to scale up the testing during the short rainy season of 2006, lack of availability of IR-maize forced this activity to be postponed till 2007. During the long rainy season of 2007, each farmer was invited to identify 2 new farmers that would be interested in testing the IR-maize, totalling 3,000 farmers.

*Evaluation of IR maize during the long rainy season of 2007*

During the long rainy season of 2007, a total of 1040 kg IR seeds were distributed to 3200 farmers and 400 of these are followed in detail to measure the yield of IR versus a local variety, measure *Striga* emergence, and get feedback on problems with the IR technology. This work was done together with IITA. 'Old' farmers were already involved in the IR evaluation during the long rainy season of 2006 while 'new' farmers joined the 2007 activities (**Table 17**). Conditions for involvement in the evaluation were (i) the plots with local and IR maize should be laid out next to one another and have approximately the same size with a minimal size of 10 by 10 m, (ii) although no limits were set on crop management practices (planting density, weeding regime, application of inputs, establishment of intercrops, etc), both plots should be managed in the same way, and (iii) measurements of *Striga* emergence and maize yields should be taken. To implement this work and ensure proper follow up and data collection, 10 facilitators were engaged, each monitoring 20 old and 20 new farmers. Only data from 8 of the 10 facilitators were used in the final analysis because of doubt regarding the quality of the data collected by 2 facilitators (unfortunately, both in Vihiga district). This means that 320 farms were monitored, 160 'old' farmers and 160 'new' farmers.

**Table 17: IR maize seeds distributed during the long rainy season of 2007**

| District | Sub-location | IR seed distributed (kg) | Nr of farmers given seed | Nr of farmers included in the detailed follow-up studies | |
|---|---|---|---|---|---|
| | | | | New farmers | Old farmers |
| Siaya | Sigomere | 80 | 300 | 20 | 20 |
| | Sega | 80 | 300 | 20 | 20 |
| | Kogeyo | 100 | 300 | 20 | 20 |
| Bondo[a] | Hagonglo_1 | 100 | 300 | 20 | 20 |
| | Hagonglo_3 | 100 | 300 | 20 | 20 |
| | Hagonglo_6 | 100 | 300 | 20 | 20 |
| Busia | Bukhalalire | 100 | 300 | 20 | 20 |
| | Funyula | 80 | 300 | -- | -- |
| | Muyafwa | 100 | 300 | 20 | 20 |
| Vihiga | Emusutswi | 100 | 300 | 20 | 20 |
| | Ebunangwe | 100 | 300 | 20 | 20 |
| **Total** | **11 sites** | **1040** | **3200** | **200** | **200** |

[a] In Bondo district, the famer groups, names Hagonglo_1, _3, and _6 have farmers that cut across various sub-locations (including Abom, Ajigo, Mahaya, Memba, Nyabenge, Okola, Siger). Consequently, in the current table, the farmer group names are given, not the sub-locations.

The two varieties used (IR maize and local maize) were evaluated for preference against nine agronomy attributes: maize yield, technical simplicity, cost for management, *Striga* population reduction, and enhancement of soil fertility, vegetative vigor, and ability to withstand abiotic factors, ability to withstand biotic factors and time to maturity. These agronomic attributes were adopted to allow new farmers who were experiencing the IR-Maize technology for their first time to be able to take part into the evaluation of the two types of maize. Each attribute received a score of 1 for the best rank and a score of 2 for the least rank on each attribute. All the households ranked IR-Maize as a better variety compared to the local maize, across gender, district, and time of exposure to the IR technology (**Table 18**), indicating that the IR maize varieties do have a good potential for dissemination in the Lake Victoria basin.

**Table 18: Overall ranking of the IR and local maize varieties based on agronomy attributes (Means of scores).**

| | All[a] | New | Old | Male | Female | Bondo | Busia | Siaya |
|---|---|---|---|---|---|---|---|---|
| Mean score for IR-Maize | 11.5 | 11.4 | 11.5 | 11.3 | 11.7 | 11.8 | 10.9 | 11.4 |
| Mean score for local maize | 15.5 | 15.6 | 15.5 | 15.6 | 15.3 | 15.2 | 15.9 | 15.6 |

Number of respondents All=320, New & Old=160, Male=209, Female=111, Bondo & Siaya=120, Busia=80)

When applying the same scoring approach was to each specific attribute, across all farms, IR-Maize scored high on *Striga* reduction, yield enhancement, soil fertility improvement, vegetative vigor and ability to withstand abiotic performance factors. The local maize scored higher on technical simplicity and time to maturity.

More detailed analysis of the different traits of the IR maize relative to the local maize are revealed that IR-Maize had a number of positive attributes: high yield, high biomass, tasty green maize, ability to disperse *Striga*, resistance to biotic and abiotic stresses, high market returns based on weight, less susceptible to storage pests, and requires less or no post harvest dusting. IR maize was, however, negatively ranked for tasty Ugali, high labor requirement, high input requirement, careful farm management, high management cost and ease of sell based on color. The observations made for the IR-Maize for the general case applies for all the categories of farmers across the districts, gender and new as well as the old

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

## NO COMPLETED WORK

## NO WORK IN PROGRESS

| Output 4. Enabling environment | |
|---|---|
| Output Targets 2010: 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. |

## NO COMPLETED WORK

## NO WORK IN PROGRESS

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

## NO COMPLETED WORK

## NO WORK IN PROGRESS

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

## NO COMPLETED WORK

## NO WORK IN PROGRESS

## 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.<br>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.<br>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 **(Figure 3)**.

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

# COMPLETED WORK

## Report of the Agro-dealer training workshop on Integrated Soil Fertility Management, Kisumu, Western Kenya, 13–15 November 2008

**B. Vanlauwe[1], L. Nyambega[1], M. Chirasha[1]**
*[1]TSBF - CIAT, Kenya*

### Introduction

In the context of the collaboration between TSBF – CIAT and AMARK aiming at enhancing the capacity of agro-dealers in western Kenya to give advice to farmers on Integrated Soil Fertility Management (ISFM), a Training Workshop in Integrated Soil Fertility Management was organized between 13 and 15 November 2008. A total of 56 people attended. The Training workshop was a follow-up on earlier held (June 2008) Exchange Visits to the demonstration plots, established near 42 agro-dealer shops.

### Materials and methods

The Training workshop consisted of a one-day session on Integrated Soil Fertility Management (ISFM). The second day consisted of an exchange visit to 4 demonstration trials while the third day consisted of sessions on Striga management and pest and disease management. The day 1 and day 3 sessions were supported with teaching aids and documents with extra information, given to all participants. During the first day, topics related to ISFM that were covered included: soils and soil fertility (Session 1), soil fertility evaluation (Session 2), fertilizer use and management (Session 3), and organic input use and management (Session 4). During the third day, topics covered included integrated management of Striga (Session 1) and integrated pest and diseases management (Session 2). During the second day, 4 demonstration plots of varying fertility were visited. Individual scoring of the different treatments of the demonstration trials by all participants revealed the following information: (i) maize responded to fertilizer in most sites and differences between DAP and Mavuno were minimal, except at Khwisero where K appeared to be limiting, (ii) top-dressing was only effective in presence of fertilizer application at maize planting, and (iii) differences in performance between the IR and DH04 maize varieties were minimal, and (iv) soybean rotational effects were observed in two of the four sites. In the concluding section, participants were invited to evaluate the training workshop. The most frequently mentioned positive aspects of the training workshop include: the exposure to training on soil fertility management, to fertilizer use and management, to Striga control, and to crop nutrient requirements. Areas that could be improved include: the need to install and visit more demonstration plots, the need to provide soil test kits and the knowledge on how to use these, and the need for more time in the meeting room and the field. The participants were also invited to propose the way forward. In summary, priority follow-up activities should focus on intensifying the initiated activities (more training, more demonstrations also in other areas), providing access to soil test kits and their utilization, and strengthening linkages between the agro-dealers and farmers. A group photograph was taken and certificates of participation were distributed to all participants. The meeting was officially closed by the Provincial Director of Agri-business Development, Kisumu. Some important observations made during the workshop include: (i) the current knowledge on soil and fertilizer management is variable and generally limited, (ii) linkages between input suppliers (seed, fertilizer) are weak and driven by the suppliers with little negotiation power on the side of the agro-dealers, and (iii) there is a genuine interest for agro-dealers to give better advice to farmers. These are some of examples of how crucial the formation and empowerment of agro-dealers will be if they are going to play a major role in providing services to farmers and advancing the African Green Revolution.

**Preliminary conclusions**

The training workshop was revealing in terms of the variability in knowledge on ISFM that currently exists within the agro-dealer community. For example, a large number of participants were not able to calculate recommendations from a specific nutrient rate to a specific fertilizer rate or did not know that nutrient contents indicated on fertilizer bags refer to N, $P_2O_5$, or $K_2O$ and not to N, P, and K as such. Some participants were also surprised to see limited response to fertilizer in the demonstration plots at Khwisero, visited during the field visit. One participant remarked that agro-dealers may have misled farmers unwillingly because of lack of knowledge on their products. Secondly, what was also apparent is the need for closer interaction between the agro-dealers and the input suppliers. The presence of seed companies in the training workshop was acknowledged as good. The lack of negotiation power with importers of fertilizer was also apparent since the type of fertilizer and its price is totally set by the suppliers. In that same context, it was mentioned during the meeting that the agro-dealers should form and association although one could wonder if such association would remain strong since there is some level of competition between the various agro-dealers. Thirdly, there is a strong interest in the agro-dealer community to get closer linkages with farmers which is obviously not surprising since these are their major clients. The need for more demonstrations, covering a wider area was mentioned as was the need to provide test kits for assisting the formulation of appropriate recommendations. They also wanted farmers to be directly involved in the training meetings.

## Strengthening the Technical Capacity of Agrodealers on Integrated Soil Fertility Management (ISFM) in Malawi

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

A multi-thronged approach is required to improve access to agri-inputs by farmers and ensure that that inputs are used appropriately. Collaboration between TSBF-CIAT and CNFA and a consortium of agricultural research and development networks jointly implemented activities to train and promote agrodealers and develop site and crop-specific soil fertility management strategies in the Chinyanja Triangle area covering Malawi, Zambia and Mozambique. A detailed baseline survey was done to capture information on availability and distribution of agrodealers, farmers' access and use of fertilizers and other soil fertility improving technologies. Detailed characterization of soil fertility at the study sites was also conducted to diagnose soil fertility constraints to crop production. In addition, site and crop-specific fertilizer management and ISFM strategies to increase fertilizer use efficiency and enhance economic returns to fertilizer use by farmers have been developed for maize, groundnut and bean taking into account the variability in soil fertility existing across farms.

A baseline survey that gave insights into current access to agro-inputs by farmers, their management and opportunities and challenges for increasing use of soil fertility enhancing technologies. Report of the baseline survey was instrumental in improving targeting of technologies in different sites. A soil fertility database for the intervention sites was developed and used to help agrodealers and development and research partners to diagnose soil fertility constraints to production of different crops. Strategies for fertilizer and soil fertility management were refined for specific sites, including, use of micronutrients in fertilizers, 2) integrated use of manure and fertilizers, 3) fertilizer recommendations for beans and crop rotations, and 4) use of lime to correct soil acidity. Current fertilizer recommendations in all sites were blanket and covered only application of fertilizer N and P, and the new strategies can potentially increase crop productivity and profitability of fertilizer use by 30-60%. These technologies have been widely tested for two years and are ready for transfer. A group of 40 agrodealers and 1000 farmers were trained on principles of ISFM covering:

- Soil variability and fertilizer requirement for different soils
- Nutrients are required by the main crops produced in the different areas
- Types of fertilizer, their formulation and their use
- Advantages and limitations of fertilizer use
- Good soil fertility management, including integrated use of fertilizer and organic nutrient resources such as manure
- Establishment and management of demonstration plot

The training greatly improved agrodealers' knowledge on use of agro-inputs and enhanced their capacity to promote improved seed and fertilizer through demonstrations.

Pilot farmers have reported substantial yield increases through adoption of ISFM technologies.

| **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

### Agricultural intensification in the Sahel - The ladder approach. *(2008) Agricultural Systems, vol. 98, (2): 119-125*

**Aune[1], J.B. and Bationo[2], A.**
*[1]Norwegian University of Life Sciences, Norway; [2] TSBF – CIAT, Kenya*

**Abstract:** Agricultural intensification in the Sahel can be described as climbing a ladder. The capital, labour, management and institutional requirements increase when farmers climb the ladder, but the potential gains are also higher. The first step on this ladder are agricultural practices without any financial outlay but with increasing labour demand, such as organic fertilizer use, seed priming, water harvesting and harvesting grains at physiological maturity to improve fodder quality. The next step on the ladder is the use of micro-fertilizing, popularly known as microdose, at the rate of 0.3 g NPK fertilizer per pocket in sorghum and millet. The following step is the development of improved crop/livestock systems characterized by use of higher rates of mineral fertilizers and manure, increasing cowpea density and improved animal fattening. The last step presented on the ladder is the development of more commercially orientated agriculture characterized by development of cash crops, milk production and/or agroforestry systems. Evidences from the field support the observation that farmers intensify their production in a sequential manner similar to the way described in this paper. The technologies presented can facilitate agricultural intensification by reducing the risks and minimizing the cost in agricultural production.

### Livelihood activities and wealth ranking among rural households in the farming systems of Western Kenya. *(2008) African Journal of Livestock Extension 5: 43 – 52*

**Ajani[1], O.I.Y., Justina[2], N.C., Chianu[2], J.N., and Olayide[1], O.E.**
*[1]University of Ibadan, Nigeria; [2]TSBF - CIAT, Kenya*

**Abstract:** The study examined the relationship between the livelihood activities of rural households in the farming systems of Western Kenya in relation to their wealth. A stratified random sampling procedure was used to select 252 farm households from eight districts in three provinces. Focus group discussions (FGD) were used to collect community-level data which complemented household data. Primary data were collected using structured questionnaire. Results indicate that average household size was seven persons across survey districts. As expected, agriculture (crop and livestock) was the main activity of the farmers. Maize and common beans are the most important staple

food crops and traded food crops. Livestock enterprises are dominated by poultry production. For purposes of diversification for better livelihoods, some farm households engaged in small businesses (especially fish trading), employment and artisanal work. The cropping system is mainly mixed cropping. Lack of cash and limited land availability were the most important factors that constrain agricultural development in Western Kenya. Although most households preferred selling their farm produce in the markets or places where prices were better, many of them not only sold their farm produce but also purchased their farm inputs from the nearest towns due to problems and costs associated with going to where produce prices were better. Our results show a high wealth inequality among farm households in Western Kenya. This was in terms of both household wealth (with a *Gini*-coefficient of 0.52) and per capita wealth (with a *Gini*-coefficient of 0.55). The high level of inequality calls for more attention on proper targeting of development activities to ensure even distribution of resources and economic growth and development.

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

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

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

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

**Chianu[1], J.N., Adesina[2], A., Sanginga[3], P., Bationo[1], A., Justina[1], N.C., and Sanginga[1], N.**

*[1]TSBF - CIAT, Kenya; [2]The Rockefeller Foundation, Kenya; [3]CIAT-Africa, Uganda.*

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

# WORK IN PROGRESS

## 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. Ngoga[4], A. Gahigi[4], S. Kantengwa[5], J.P. Lodi-Lama[6], W. Bimponda[6], J.J. Nitumfuidi[6] and B. Vanlauwe[1]**

*[1]TSBF - CIAT, Kenya; [2]DIOBASS, DR Congo; [3]CIAT, DR Congo; [4]ISAR, Rwanda; [5]CIAT, Rwanda; [6]INERA, DR Congo*

During the 2008 B and 2009 A seasons, a large number of "farmer adaptation trials" were initiated, whereby promising ISFM technologies, previously developed and tested in demonstration trials were evaluated by individual households in their own farms. The participating households received packages of planting materials and fertilizer, a brochure describing the technology and a testing protocol. Training was given, and facilitators and technical teams at the level of the action site or association were identified to assist and monitor participating farmers. Currently, over 1500 households are involved in adaptive testing of new technologies (400 in Rwanda, 795 in Sud-Kivu and 350 in Bas-Congo).

These trials offered an excellent opportunity for promoting new technologies. Exchange visits with the farmer associations within and between sites were conducted in all 4 mandate areas **(Table 19)**. These exchange visits were led by NGO partners: DIOBASS in Sud-Kivu, World Vision, RDO, RHEPI and RWARRI in Rwanda, and APRODEC, BDD and CLD-Nkolo in Bas-Congo. During the visits, farmer associations debated the use of new varieties, the utilization of fertilizer, crop management issues, and other aspects of the new technologies. Associations discussed and decided the location to organize a field day, and the trials to visit during that day. Further details are described in reports with summaries of participatory discussion sessions held between farmer associations, evaluations of the individual trials visited and recommendations for future activities.

**Table 19: Exchange visits organized around the adaptation trials in the mandate areas of the CIAT-TSBF project during the 2008 B season.**

| Dates | Region | Action sites | Participation |
|---|---|---|---|
| 17-18 April | Sud-Kivu | Kabamba + Luhihi | 13 associations (21 participants) |
| 21-22 April | Sud-Kivu | Burhale + Lurhala | 9 associations (16 participants) |
| 6-7 May | Kibungo | Kabare + Gatore | 4 associations (33 participants) |
| 8-9 May | Bugesera | Musenyi + Murama | 2 associations (34 participants) |
| 13 May | Umutara | Nyakigando + Rugarama | 5 associations (22 participants) |
| 14 May | Umutara | Murambi + Kabarore | 2 associations (21 participants) |
| 15 May | Umutara | Nyakigando + Murambi | 3 associations (21 participants) |
| 30-31 May | Bas-Congo | Zenga + Tumba | 14 associations (21 participants) |
| 14-15 June | Bas-Congo | Kanga Kipeti + Mbanza Nzundu | 14 associations (80 participants) |
| 7 June | Bas-Congo | Lemfu | 16 associations (86 participants) |

Subsequently, eight field days were organized, with the objective to promote the new technologies, instigate dissemination through research and development partners, and increase awareness about the CIALCA project activities by local policy makers, and through press agencies **(Table 20)**. Research partners from the national institutes and universities, as well as development partners and interested NGOs attended the field days. Local authorities as well as representatives from the Ministry of Agriculture were present, and press agencies promoted CIALCA and its activities through local radio and television channels. The program of the field days generally consisted of a word of welcome and introductions by the organizing committee (CIALCA representatives and NGO partners), explanations on CIALCA and its activities, a visit to selected fields to demonstrate the new technologies, a plenary discussion and evaluation session, summary speeches by the local authorities and a closure event. Farmer associations involved in seed multiplication took the opportunity to promote their improved legume varieties. In Sud-Kivu, representatives from some associations sold small packs of seed. Press coverage was estimated at least 150,000 persons per mandate area, by involving some of the more popular media. In Rwanda, an article was published in the *New Times* newspaper, and the field days were reported in the newscast on the national television. In

DRC, CIALCA activities were covered by various local radio and television stations in repeated emissions during the weeks following the field days. Full reports are available, in which the participants are listed, the expositions and discussions held are described in detail, and estimates of coverage by the various press agencies are given. A number of DVDs were prepared, which will be posted on the CIALCA website.

**Table 20: Field days organized in the mandate areas of the TSBF-CIAT project during the 2008 B season.**

| Dates | Region | Action sites | Participation |
|---|---|---|---|
| 5 May | Sud-Kivu | Kabamba | 52 key participants + 95 farmers |
| 7 May | Sud-Kivu | Burhale | 30 key participants + 102 farmers |
| 28 May | Rwanda | Kabare | 27 key participants + >500 farmers |
| 29 May | Rwanda | Murambi | 31 key participants + >600 farmers |
| 30 May | Rwanda | Murama | 33 key participants + >600 farmers |
| 6 June | Bas-Congo | Zenga | 14 key participants + 96 farmers |
| 7 June | Bas-Congo | Lemfu | 18 key participants + 86 farmers |
| 14 June | Bas-Congo | Kanga Kipeti | 25 key participants + 46 farmers |

## A comparative economic analysis of maize, soybean, sugarcane and tobacco enterprises in the farming systems of Uriri division, Rongo district, Kenya

**O. S. Bonyo[1], J. Adari[1], J. Chianu[2], and W. Otieno[1]**
*[1]Maseno University, Kenya; [2]TSBF - CIAT, Kenya*

### Introduction

The contribution of agriculture to economic development largely depends on diversification and commercialization of agricultural production. Alternative options are often available for farmers interested in cash income generation. However, the inability of many farmers to use economic techniques and tools in enterprise choice has hindered them from making informed decisions on choices. This study has identified enterprise choice as a problem in farm decisions among farmers in, Kenya. The objective is to carry out a comparative economic analysis of the production of four important cash generating crops (maize, soybean, sugarcane and tobacco) in the farming systems of Uriri division in Rongo district. These four crops are 'cash crops' and have commercial indices (i.e., proportion of total production that is actually sold for cash) compared with the other crops in the farming systems of the study area. The study also plans to investigate the factors that influence farmers' decisions to invest in these crops. The hypothesis being tested is "whether farmers' choice of cash crops is influenced by enterprise profitability". The outcome of the study is expected to benefit farmers in the study area and similar environments through the education that will result from increased farm productivity and profitability as well as the development of appropriate agricultural diversification strategies at policy level.

### Materials and methods

The study area is Uriri division, Rongo district, Western Kenya. Multi-stage sampling procedure was employed in selecting the respondents for the study. Self-administered questionnaires are being used to collect farm and household data. Analysis is planned to be done using SPSS and other relevant data analysis applications. Gross margin analysis will be used to determine and compare the four enterprises under similar conditions. Analysis of the determinants of farmers' decision to invest in the different enterprises as well as the intensity of their investment is planned to be executed using the Tobit regression model. Linear programming is planned to be used to develop optimal farm plans involving all the four crop production enterprises. Results are planned to be presented in text, tables and graphs among others. The study aims at a comparative economic analysis of the production of four important cash generating crops (maize, soybean, sugarcane, and tobacco). It will also investigate the factors that influence farmers' decision to invest in the four crops. The specific objectives are: (i) to carry out comparative analysis of the profitability of maize, soybean, sugarcane, and tobacco enterprises; (ii) to determine the factors that influence farmers' decision to invest in each of the four cash crops; (iii) to study the local marketing systems and strategies for maize, soybean, sugarcane, and tobacco enterprises; and (iv) to understand the promoters of the different crops, their motives, and the strategies they employ in the promotion in order to influence farmers participation in the production of the different crops.

**Preliminary results**

Land ownership among survey farmers ranges from a low value of 0.12 ha to 9.6 ha (with a mean of ~2 ha). While the average land area allocated to maize was 1.15 ha, that allocated to soybean was about 0.41 ha or about 35% of land allocated to maize. Results from technical efficiency calculations [following the formula $TE_{i(k)} = \exp(-u_i) \times 100$] show that sugarcane has the highest mean technical efficiency of ~81±11.361%, followed by maize (~70±11.35%), tobacco (54±31.68%), and soybean (~48±26.22%).

**Preliminary conclusion**

For soybean to successfully become an alternative cash income crop in *Migori* area, the technical efficiency of its cultivation must improve. This calls for further intervention in the areas of soybean agronomy and crop management practices among the smallholder soybean farmers.

## Groups of farmers trained on soybean processing and utilization July 2007-June 2008

| Location/groups | Dates | Number of male farmers | Number of female farmers | Total number of farmers trained |
|---|---|---|---|---|
| Training of trainers at the HAART Nakaseke HIV Group, Luwero, Uganda | 21-26/04/2008 | 14 | 28 | 42 |
| Butere farmers group. Muyundi farmers group. Mumias farmers group | 6th - 10th May 2008 | | | |
| Installation and training of farmers in the operation of the VitaGoat machine in Migori. | 7th and 8th May 2008 | 9 | 6 | 15 |
| Training of farmers in Gingo Young Christian group in Suba | 16th - 17th May 2008 | 14. | 6 | 20 |
| Post test support groups of PLWH in Busia District hospital | 21st - 23rd May 2008 | | | |
| Training of soybean processing and utilization in Samunyi health care | 12th - 13th June 2008 | 15 | 5 | 20 |
| Training of upesi jiko in Red ribbon group in Gingo | 16th - 17th June 2008 | 14 | 6 | 20 |
| Training in collaboration with VACID Africa on soybean utilization and entrepreneurship;<br>Butere farmers' group<br>Mumias farmers' group<br>Migori farmers' Group | 7th – 17th July 2008 | 26<br>33<br>28 | 14<br>7<br>12 | 40<br>40<br>40 |
| Monitoring and evaluation of the, Butere, Mumias, and Migori. | 23rd - 25th Sept 2008 | | | |
| Training of trainers on the soy cow machine utilization and magazine distribution in Suba | 28th Nov – 1st Dec 2008 | 17 | 8 | 25 |

**NB:** FPI- Family Preservation Initiative
DOW- Doctors of the World
AMPATH- Academic Model for the prevention and Treatment of HIV and AIDS

| 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

### Book on 'Innovations as Key to the Green Revolution in Africa: Exploring the Scientific Facts'

**Bationo[1], A. Waswa[1], B.S. Okeyo[1], J. and Maina[1], F.**
[1]*TSBF - CIAT, Kenya*

**Table of Contents**

| |
|---|
| *Atsu E, Tibo I and Sumaila I* |
| Effect of organic inputs and mineral fertilizer on maize yield in a Ferrasol and a Nitisol soil in central Kenya - *Mucheru-Muna M, Mugendi DN, Pypers P, Mugwe J, Vanlauwe B, Merckx R and Kung'u J* |
| Effects of Conservation Tillage, Crop Residue and Cropping Systems on changes in Soil Organic Matter and Maize-Legume Production: A Case Study in Teso District - *Anyanzwa H, Okalebo JR, Othieno CO, Bationo A, Waswa BS and Kihara J* |
| The Dryland Eco-Farm: a Potential Solution to the Main Constraints of Rain-Fed Agriculture in Africa's Semi Arid Tropics - *Fatondji D, Pasternak D, Nikiema A, Senbeto D, Woltering L, Ndjeunga J and Abdoussalam S* |
| Benefits of integrated soil fertility and water management in semi-arid region - *Zougmore R, Mando A, Troosnijder L* |
| Survival and Soil Nutrient Changes during Five Years Growth of Sixteen Faidherbia albida Provenances in Semi Arid Baringo District, Kenya - *Dangasuk OG, Gudu S and Okalebo JR* |
| The "secret" behind the good performance of *Tithonia Diversifolia* on P availability as compared to other green manures - *Ikerra ST, Semu E and Mrema JP* |
| Nitrogen fixation and P uptake by soybean at two low-P soils of southern Cameroon - *Jemo M, Nolte C., and Abaidoo RC* |
| Roles for herbaceous and grain legumes, kraal manure and inorganic fertilizers for soil fertility management in eastern Uganda - *Kaizzi CK, Byalebeka J, Wortmann CS and Mamo M* |
| The Effects Of Integration Of Organic And Inorganic Sources Of Nutrient On Maize Yield In Central Kenya *Kathuku AN, Kimani SK, Okalebo JR, Othieno CO, and Vanlauwe B* |
| Forage Legume-Cereal Double Cropping in Bimodal Rainfall Highland Tropics: The Kenyan Case - *Masinde JK, Mwonga SM, Mumera LM and Nakhone L* |
| Effects Of Conservation Tillage, Fertilizer Inputs And Cropping Systems On Soil Properties And Crop Yield In Western Kenya - *Githinji HK, Okalebo JR, Othieno CO, Bationo A, Kihara J and Waswa BS* |
| Effect of manure application on soil nitrogen availability to intercropped sorghum and cowpea at three sites in eastern Kenya - *Kihanda FM and Warren GP* |
| The Effect Of Organic Based Nutrient Management Strategies On Soil Nutrient Availability And Maize Performance In Njoro, Kenya - *Lelei JJ, Onwonga RN and Freyer B* |
| Using forage legumes to improve soil fertility for enhanced grassland productivity of semi-arid rangelands of Kajiado District, Kenya - *Macharia PN, Gachene CKK and Mureithi JG* |
| Potential of cowpea, pigeonpea and greengram to contribute nitrogen to maize in rotation on Ferralsol in Tanga – Tanzania - *Marandu AET, Mrema JP, Semu E and Nyaki AS* |
| Model Validation through Long Term Promising Sustainable Maize/Pigeon Pea Residue Management in Malawi - *Mwale CD, Kabambe VH, Sakala W.D (Late), Giller KE, Kauwa AA, Ligowe I and Kamalongo D* |
| Use of Tithonia biomass, Maize residues and Inoraganic phosphate on Climbing Bean yield and Soil properties in Rwanda - *Nabahungu NL, Mowo JG, Uwiragiye A and Nsengumuremyi E* |
| The Potential of Increased Maize and Soybean Production in Uasin Gishu District, Kenya, Resulting from Soil Acidity Amendment using Minjingu Phosphate Rock and Agricultural Lime - *Nekesa AO, Okalebo JR, Othieno CO, Thuita MN, Bationo A and Waswa BS* |
| Residual effects of contrasting organic residues on maize growth and phosphorus accumulation over four cropping cycles in savanna soils - *Nwoke OC, Abaidoo RC., Nziguheba G and Diels J* |
| Interactive effects of selected nutrient resources and tied-ridging on plant growth performance in a semi-arid smallholder farming environment in central Zimbabwe *Nyamangara J and Nyagumbo I* |
| *In-Vitro* selection of Soybean accessions for induction of germination of *Striga hermonthica* (Del.) Benth seeds and their effect on *Striga hermonthica* attachment on associated maize - *Odhiambo JA, Vanlauwe B, Tabu IM, Kanampiu F and Khan Z* |
| Effect of nutrient type on chemical composition and dry matter partitioning of cassava (*Manihot esculenta* Crantz*) - Taffouo VD, Tsoata E, Kenne M, Priso RJ Fonkou JT and Akoa A* |
| Simplifying RothC for biomass data assimilation in C sequestration contracts - *Traoré PCS, Bostick WM, Jones JW and Bado V* |
| Grain legume rotation benefits to maize in the northern Guinea savanna of Nigeria: Fixed-nitrogen vs. Other rotation effects - *Yusuf AA, Iwuafor ENO, Abaidoo R, Olufajo OO and Sanginga N* |
| Innovations In Cassava Production For Food Security And Forest Conservation In Western Côte D'Ivoire - *Ayemou A, Tschannen A, Koné I, Allou D, Akpatou B and Cisse G* |

| |
|---|
| Promoting uses of indigenous phosphate rock for soil fertility recapitalization in the Sahel: state of the knowledge on the review of the rock phosphates of Burkina Faso - *Bonzi M, Lompo F, Ouandaogo N and Sedogo MP* |
| A study of the agronomic efficiency of human stool and urine on the production of maize and egg plant in Burkina Faso - *Bonzi M, Lompo F, Kiba ID, Kone A, Ouandaogo N and Sedogo MP* |
| Using the crop simulation model APSIM to generate functional relationships for analysis of resource use in African smallholder systems: aggregating field-scale knowledge for farm-scale models - *Chikowo R, Corbeels M, Tittonell P, Vanlauwe B, Whitbread A and Giller KE* |
| Selecting indigenous P solubilizing bacteria for cowpea and millet improvement in nutrient deficient acidic soils of southern Cameroon - *Fankem H, Abba M, Ngo Nkot L, Deubel A, Merbach W And Etoa F-X And Nwaga D* |
| Evaluation of Human Urine as a Source of Nitrogen in the Co-Composting of Pine Bark and Lawn Clippings - *Fatunbi AO and Mnkeni PNS* |
| Extractable Bray-1 Phosphorus and Crop Yields as influenced by Addition of Manure Integrated with Phosphatic Fertilizers of Various Solubilities in an Acid Soil - *Gikonyo EW, Zaharah AR, Hanafi MM and Anuar AR* |
| Seedbed Types and Integrated Nutrient Management Options for Cowpea Production in the Southern Rangelands of Semi-Arid Eastern Kenya - *Githunguri CM, Esilaba AO, Kimotho LM and Mutuku LM* |
| Land and Water Management Research and Development in Arid And Semi-Arid Lands Of Kenya - *Itabari JK, Kwena K, Esilaba AO, Kathuku A N, Muhammad L, Mangale N and Kathuli P* |
| Breeding Common Bean for Tolerance to Low Fertility Acid Soils in East and Central Africa - *Kimani PM, Lunze L, Rachier G and Ruganzu V* |
| Evaluation of establishment, biomass productivity and quality of improved fallow species in a ferralic arenosol at coastal region in Kenya - *Kiraithe C, Kamiri N, Kirongo B, Oeba OV and Welimo M* |
| Assessment of potato bacterial wilt disease status in North Rift Valley of Kenya: A Survey - *Kwambai TK, Omunyin ME, Okalebo JR, Kinyua ZM and Gildemacher P* |
| Soil fertility variability in relation to the yields of maize and soybean under intensifying cropping systems in the tropical savannas of north-eastern Nigeria - *Kwari JD, Kamara AY, Ekeleme F and Omoigui L* |
| An evaluation of Lucerne varieties suitable for different agro ecological zones in Kenya - *Lukuyu BA, Methu JN, Mwangi D, Kirui J, Mwendia SW, Wamalwa J, Kavatha A, Ngae GN and Mbure GN* |
| Water Harvesting And Integrated Nutrient Management Options For Maize-Cowpea Production In Semi-Arid Eastern Kenya - *Miriti JM, Esilaba AO, Bationo A, Cheruiyot HK, Kathuku AN and Wakaba P* |
| The potential of Ipomoea stenosiphon as a soil fertility ameliorant in the semi-arid tropics - *Mombeyarara T, Murwira HK and Mapfumo P* |
| Increasing productivity through maize-legume intercropping in Central Kenya - *Mucheru-Muna M, Mugendi DN, Pypers P, Mugwe J, Vanlauwe B, Merckx R and Kung'u J* |
| Effect of Al concentration and liming acid soils on the growth of selected maize cultivars grown on sandy soils in Southern Africa - *Musharo C and Nyamangara J* |
| The role of Biological Technologies in Land Quality Management: Drivers for Farmer's Adoption in the Central Highlands of Kenya - *Mutegi JK, Mugendi DN, Verchot LV and Kung'u JB* |
| Biophysical characterization of Oasis soils for efficient use of external inputs in Marsabit District: Their potentials and limitations - *Muya EM, Lelon JK, Shibia MG, Esilaba AO, Okoti M, Gachini GN and Chek AL* |
| Use of Tithonia biomass, Maize residues and Inorganic phosphate on Climbing Bean yield and Soil properties in Rwanda - *Nabahungu NL, Mowo JG, Uwiragiye A and Nsengumuremyi E* |
| Multi-functional properties of mycorrhizal fungi for crop production: The case study of banana development and drought tolerance - *Nwaga D, Tenkouano A, Tomekpe K, Fogain R, Kinfack D.M, Tsané G and Yombo O* |
| Effect of Phosphorus Sources and Rates on Sugarcane Yield and Quality in Kibos, Nyando Sugar Zone - *Omollo JO and Abayo GO* |
| Assessment of soil management practices in East African highland cooking banana (Musa spp. AAA-EA) systems in Uganda - *Wairegi LWI, van Asten PJA, Kiwanuka C, Tenywa M and Bekunda M* |
| Natural and antropic determinants of soil carbon stocks in two agro-ecosystems in Burkina Faso - *Youl S, Hien E, Manlay RJ, Masse D, Hien V and Feller C* |
| Integrated Soil Fertility Management Involving Promiscuous Dual-purpose Soybean and Upland NERICA Enhanced Rice Productivity in the Savannas - *Oikeh SO, Houngnandan P, Rahimou I, Touré A, Niang A, Abaidoo RC and Akintayo I* |
| Nitrogen Use in Maize (*Zea Mays*) –Pigeon pea (*Cajanus cajans*) Intercrop in Semi- arid Conditions of Kenya - *Wanderi SW, Mburu MWK, Silim SN and Kihanda F* |

| |
|---|
| Measured N and P capture and recovery efficiencies for rainfed cereal crops in sub-Saharan Africa: A review - *Chikowo R, Corbeels M, Mapfumo P, Tittonell P, Vanlauwe B and Giller KE* |
| Greenhouse Evaluation Of Agronomic Effectiveness Of Unacidulated And Partially Acidulated Phosphate Rock From Kodjari And The Effect Of Mixed Crop On Plant P Nutrition - *Compaore E, Fardeau J-C and Morel J-L* |
| Effect Of Continuous Mineral And Organic Fertilizers Inputs And Plowing On Groundnut Yield And Soil Fertility In A Groundnut – Sorghum Rotation In Central Burkina Faso - *Compaore E, Cattan P And Taonda J-BS* |
| Soil Inorganic N and N uptake by maize following application of legumes biomass, tithonia and manure, and inorganic fertilizer in central Kenya - *Mugwe J, Mugendi DN, Mucheru-Muna M and Kungu J* |
| Changes in $\delta^{15}N$ and N nutrition in nodulated cowpea (Vigna unguiculata L. Walp.) and maize (Zea mays L.) grown in mixed culture with exogenous P supply. *Ndakidemi PA and Dakora FD* |
| Cation flux in incubated plant residues and its effect on pH and plant residue alkalinity - *Sakala GM, Rowell DL and Pilbeam CJ* |
| Combining Field and Simulation Studies to Improve Fertilizer Recommendations for Irrigated Rice in Burkina Faso - *Segda Z, Haefele SM, Wopereis MCS, Sedogo MP And Guinko S* |
| Some facts about fertilizer use in Africa: the case of smallholder and large scale farmers in Kenya - *Okoth PF, Murua E, Sanginga N, Chianu J, Mungatu JM, Kimani PK and Ng'ang'a JK* |
| Potential for Reuse of Human Urine in Peri-Urban Farming - *Semalulu O, Azuba M, Makhosi and Lwasa S* |
| Towards sustainable land use in Vertisols in Kenya: challenges and opportunities - *Ikitoo EC, Okalebo JR and Othieno CO* |
| Influence of Agro-ecology on the Efficiency of Nitrogen Utilization by Maize in Western Cameroon - *Meppe PF, Tchuente F, Bilong P and Nwaga D* |
| Potential Nitrogen Contribution of Climbing Bean to Subsequent Maize Crop in Rotation in South Kivu Province of Democratic Republic of Congo - *Lunze L and Ngongo M* |
| Investigation on the Germination of *Zanthoxylum Gilletii* Seeds (De Wild) Waterm (East African Satinwood) - *Okeyo MM, Ochoudho JO, Muasya RM and Omondi WO* |
| Combining ability for Grain Yield of Imidazolinone Resistant-maize inbred lines under Striga (*Striga hermonthica*) infestation - *Rwiza IH, Mwala M and Diallo A* |
| Identification of plant genetic resources with high potential contribution to the soil fertility enhancement in the Sahel with special interest in fallow vegetation - *Tobita S, Shinjo H, Hayashi K, Matsunaga R, Miura R, Tanaka U, Abdoulaye T and Ito O* |
| Within-farm variability in soil fertility management in smallholder farms of Kirege location, Central Highlands of Kenya - *Muthamia JM, Mugendi DN and Kung'u JB* |
| Residual Effects of Applied Phosphorus Fertilizer on Maize Grain Yield and Phosphorus Recovery from a Long-Term Trial in Western Kenya - *Wangechi H, Pypers P and Vanlauwe B* |
| Nitrogen and carbon mineralization patterns of indigenous legumes as influenced by their chemical composition - *Nezomba H, Tauro TP, Mtambanengwe F, and Mapfumo P* |
| Interactive effects of selected nutrient resources and tied-ridging on plant growth in a semi-arid smallholder farming environment in central Zimbabwe - *Nyamangara J and Nyagumbo I* |
| Potential of combined effect of organic and inorganic fertilizers on crop productivity - *Mukuralinda A, Tenywa, J S, Obua J and Verchot L* |
| Effect of Organic Inputs on Phosphorus Sorption and Chemical Properties of Some Acid Soils of Zambia - *Phiri LK, Malama C and Mwale M* |
| Phenotypic Characterization Of Local Maize Landraces For Drought Tolerance In Kenya - *Tabu IM, Munyiri SW and Pathak RS* |
| Targeting resources within diverse, heterogeneous and dynamic farming systems: towards a 'uniquely African green revolution' - *Tittonell P, Vanlauwe B, Misiko M and Giller KE* |
| Analysis of Spatial Variation of Soil Fertility Gradients in Smallholdings in Tropical Africa Using Geostatistical Techniques: Case Studies from Vihiga and Siaya Districts of Western Kenya - *Okeyo JM, Shisanya CA, Wamicha WN and Shepherd KD* |
| Effect of long term application of organic and inorganic resources on soil properties and maize yield at Kabete, Kenya - *Waswa BS, Bationo A, Mugendi D, Okeyo JM, Kimetu J* |
| Responses of indigenous legumes species to mineral P application for soil fertility restoration in smallholder farming systems of Zimbabwe - *Tauro TP, Nezomba H, Mtambanengwe F, and Mapfumo P* |

| |
|---|
| Formulating crop management options for Africa's drought-prone regions: Taking account of rainfall risk using modeling. - *John Dimes* |
| Residue quality does not influence long-term C and N stabilization. - *Gentile R, Kavoo A, Chivenge P, Vanlauwe B and Six J* |
| Interaction between Resource Quality, Aggregate Turnover, Carbon and Nitrogen Cycling in the Central Highlands of Kenya - *Kavoo A, Vanlauwe B, Six2J, Gentile R, Mugendi DN, Muluvi G and Wangechi HK* |
| Performances of Cotton-Maize Rotation system as Affected by Ploughing Frequency and Soil Fertility Management in Burkina Faso - *Ouattara K, Nyberg G, Ouattara B, Sédogo PM, Malmer A* |
| Spatial patterns of soil properties as influenced by soil fertility management in small-scale maize farms in Njoro, Kenya. - *Mungai NW, Bationo A and Waswa BS* |
| Developing Standard Protocols for Soil Quality Monitoring and Assessment - *Moebius BN, Idowu OJ, Schindelbeck RR, van Es HM, Wolfe DW, Abawi GS and Gugino BK* |
| Prioritizing research efforts to increase on-farm income generation: the case of cassava-based farmers in peri-urban southern Cameroon - *Duindam JW and Hauser S* |
| Gender differentials in adoption of soil fertility management technologies in Central Kenya - *Kirumba EG, Mugendi DN, Karega R and Mugwe J* |
| Stakeholder characterization of the biophysical and socio-economic potential of the desert margins in Kenya. - *Onyango JW, Esilaba AO and Kimani PK* |
| Community Soil Fertility Management in the Region of Gourma, Burkina Faso -West Africa - *Traoré M, Ouattara TG, Zongo E and Tamani S* |
| Policy framework for utilization and conservation of below-ground biodiversity in Kenya - *Achieng' C, Okoth P, Macharia A and Otor S* |
| Understanding Cassava Yield Differences at Farm Level: Lessons for Research - *Babirye A and Fermont AM* |
| Organic Matter Utilization And The Determinants Of Organic Manure Use By Farmers In The Guinea Savanna Zone Of Nigeria - *Bala A, Osunde AO and Odofin AJ* |
| Innovativeness Of Common Interest Groups In North Rift Kenya: A Case Of Trans Nzoia District - *Mauyo LW, Wanyama JM, Lusweti CM. and Nzomoi JN* |
| Economic analysis of improved potato technologies in Rwanda - *Mugabo RJ, Mushabizi D, Gafishi M, Chianu JN and Tollens E* |
| Policy Issues Affecting Integrated Natural Resource Management and Utilization in Arid and Semi Arid Lands of Kenya - *Munyasi, JW, Esilaba AO, Wekesa L and Ego W* |
| Assessment of Occupational and Environmental Safety Concerns in Pesticide Use among Small-scale Farmers in Sagana, Central Highlands, Kenya - *Mureithi P, Waswa F and Kituyi E* |
| Variation in socio economic characteristics and natural resource management in communities with different potato market linkages in the highlands of southwestern Uganda - *Muzira R, Vanlauwe B, Rwakaikara SM, Basamba T, Chianu J and Farrow A* |
| Crop Rotation Leguminous Crops as Soil Fertility Strategy in Pearl Millet Production Systems - *Ndinelao HL and Eligaus AT* |
| Impact of different market types on investment in soil management technologies: A case study of Ugandan cotton - *Pali PN, Delve RJ, Kaaria, SK and Freyer B* |
| Participatory variety selection of pulses under different soil and pest management practices in Kadoma District, Zimbabwe - *Rusinamhodzi L and Delve RJ* |
| Economic Returns Of The 'Mbili' Intercropping Compared To Conventional Systems In Western Kenya - *Thuita MN, Okalebo JR, Othieno CO, Kipsat MJ and Nekesa AO* |
| Bio-Socio-Economic Factors Influencing Tree Production in South Eastern Drylands of Kenya - *Wekesa L, Mulatya J and Esilaba AO* |
| Economic Evaluation of the Contribution of Below Ground Biodiversity: Case Study of Biological Nitrogen Fixation by Rhizobia - *Chianu J, Huising J, Danso S, Okoth P and Sanginga N* |
| Farm input market system in Western Kenya: constraints, opportunities and policy implications - *Chianu JN, Mairura F and Ekise I* |
| Enhancing Agricultural Production Potential through Nutrition and Good Health Practice: The Case of Suba District in Kenya - *Ohiokpehai O, Hongo T, Kamau J, Were G, Kimiywe J, King'olla B, Mbithe D, Oteba L, Mbagaya G and Owuor O* |
| Cost-effectiveness of fertilizer use in the production of main crops in Cameroon - *Meppe FP, Ndioro M, Mala D,* |

| |
|---|
| *Amougou R and Bilong P* |
| Farmers' Perceptions and its Influence on Uptake of Integrated Soil Nutrient Management Techniques: Evidence from western Kenya - *Odendo M, Obare, G and Salasya B* |
| Taking Soil Fertility Management Technologies to the Farmers' Backyard: The Case of Farmer Field Schools in Western Kenya - *Odendo M and Khisa G* |
| Status And Trends Of Technological Changes Among Small Scale Farmers In Tanzania - *Maeda J Elizabeth* |
| Opportunities for sustainable crop production: Contributions from organic resource quality and quantity - *Yeboah E, Abekoe MK, Dowuona, GNN, Adiku SGK, Vanlauwe B, Saran SP and Six J* |
| The dilemma of using fertilizer to power the green revolution in Sub-Saharan Africa - *Musembi DK* |
| Overcoming market constraint to pro-poor agricultural Growth in the Eastern of DR. Congo, South Kivu - *Njingulula MP and Kaganzi E* |
| Constraints in Chickpea Transportation in the Lake Zone of Tanzania - *Babu A, Hyuha T, Nalukenge I* |
| Linking policy, research, agribusiness and processing enterprise to develop Mungbean (*Vigna radiata*) production as export crop from Senegal River Valley - *Cisse M, Diouf M, Gueye T And Alioune* |
| Enterprise prioritization and implications for Soil Fertility Management – The case of Kiambu district - *Maina FW and Kimani SK* |
| Effect of Zai soil and water conservation technique on water balance and the fate of nitrate from organic amendments applied: A case of degraded crusted soils in Niger. - *Fatondji D, Martius C; Vlek P; Bielders CL and Bationo A* |
| Soil organic inputs and water conservation practices are the keys of the sustainable farming systems in the Sub-Sahelian zone of Burkina Faso - *Hien E, Masse D, Kabore W.T, Dugue P and Lepage M* |
| Intercropping Grain Amaranth (*Amaranthus Dubius*) With Soybean (*G. Max*) For Sustainability And Improved Livelihoods In Western Kenya. - *Ng'ang'a MN, Ohiokpehai O, Muasya RM and Omami E* |
| Micro-dosing as a pathway to Africa's Green Revolution: Evidence from broad-scale on-farm trials - *Twomlow S, Rohrbach D, Dimes J, Rusike J, Mupangwa W, Ncube B, Hove L, Moyo M, Mashingaidze N and Putso M* |
| Soil conservation in Nigeria: Assessment of past and present initiatives - *Junge B, Deji O, Abaidoo R, Chikoye D and Stahr K* |
| Effect of farmer resource endowment and management strategies on spatial variability of soil fertility in contrasting agro-ecological zones in Zimbabwe - *Masvaya EN, Nyamangara J, Nyawasha RW, Zingore S, Delve RJ and Giller KE* |
| Empowering Farmers in Monitoring and Evaluation for Improved Livelihood: Case Study of Soil and Water Management in Central Kenya - *Matiri FM and Kihanda FM* |
| Counting eggs? Smallholder experiments and try-outs as success indicators of adoption of soil fertility technologies - *Misiko M and Tittonell P* |
| Effectiveness Of "Prep-Pac" Soil Fertility Replenishment Product On Performance Of The Diversified Maize-Legume Intercrops In Western Kenya - *Ruto EC, Okalebo JR, Othieno CO, Kipsat MJ and Bationo A* |
| Risk Preference And Optimal Crop Combinations For Small Holder Farmers In Umbumbulu District, South Africa: An Application Of Stochastic Linear Programming - *Kisaka-Lwayo M* |
| Scaling Out Integrated Soil Nutrient and Water Management Technologies through Farmer Participatory Research: Experiences from Semi-Arid Central Zimbabwe - *Nyagumbo I, Nyamangara J and Rurinda J* |
| Reducing the Risk of Crop Failure for Smallholder Farmers in Africa through the Adoption of Conservation Agriculture - *Thierfelder C and Wall PC* |
| Dissemination Of Integrated Soil Fertility Management Technologies Using Participatory Approaches In The Central Highlands Of Kenya - *Mugendi D, Mugwe J, Mucheru-Muna M, Karega R, Muriuki J, Vanlauwe B and Merckx R* |
| Adoption Potential of Legumes, Cattle manure, Tithonia and Inorganic fertilizer in the Central Highlands of Kenya - *Mugwe J, Mucheru-Muna M, Mugendi DN, Kung'u J and Mairura F* |
| Success Stories: A Case Of Adoption Of Improved Varieties Of Maize And Cassava In Kilosa And Muheza Districts, Eastern Tanzania. - *Mkangwa CZ, Kyakaisho PK and Milaho C* |
| Using spatial analysis for targeting research and scaling-up opportunities- *Farrow A, Sonder K, Delve, RJ, Risinamhodzi K and Njuki J* |
| Millennium Villages in Malawi: an integrated approach to achieving a 'green revolution' - *Harawa R, Denning G, Wangila J and Palm C* |
| Upscaling Best-Bet Technologies In Arid And Semi-Arid Lands In Kenya - *Esilaba AO, Okoti M, Keya GA,* |

| |
|---|
| *Miriti JM, Kigomo JN, Nyariki D, Olukoye G, Wekesa L, Ego EW, Muturi GM and Cheruiyot HK* |
| Micronutrient fertilizers for fighting household food insecurity and malnutrition: a case from semi arid Tigray Plateau, Ethiopia - *Kebede Fassil* |
| The role of forest resources in the strategies of rural communities coping with the HIV/AIDS epidemic in sub Sahara Africa - *Kung'u B James and Oto Samuel* |
| Farmer managed natural regeneration in Niger: A key to environmental stability, agricultural intensification and diversification - *Larwanou M and Reij C* |
| Achieving a Green Revolution in Southern Africa: Role of Soil and Water Conservation in Enhancing Agricultural Productivity and Livelihoods in Semi-Arid Areas of Malawi - *Kabuli A and Phiri MAR* |
| Managing Soil and Water through Community Tree Establishment and Management: A Case of Agabu and Kandota Villages in Ntcheu District, Malawi - *Kabuli HJ and Makumba W* |
| Adoption and up scaling of water harvesting technologies among small scale farmers in Northern Kenya - *Shibia MG, Mumina GS, Ngutu M, Okoti M and Recke H* |
| Social and Economic Factors for the Adoption of Agroforesry Practices in Lake Victoria Catchment, Magu, Tanzania - *Tenge AJ, Kalumuna MC and Shisanya CA* |
| Improving smallholder farmers' access to information for enhanced decision making in natural resource management: Experiences from South Western Uganda. - *Masuki KFG, Mowo JG, Sheila R, Kamugisha R, Opondo C and Tanui J* |
| Market Access: Components, Interactions and Implications in Smallholder Agriculture In The Former Homeland Area Of South Africa - *Obi A, Pote P and Chianu J* |

## The handbook of Tropical Soil Biology: Sampling and characterization of Below-ground Biodiversity (Book)

**Moreira[1], F.M.S. Huising[2], E.J. and Bignell[3], D.E.**

*[1]Universidade Federale de Lavras, Brazil; [2]TSBF - CIAT, Kenya; [3]University of Malaysia, Malaysia*

The Project has just published a handbook of tropical soil biology sampling and characterization of below ground biodiversity. This book describes method for BGBD inventory in tropical climates. It has 218 pages and published by Earthscan publishers, ISBN No. 978-1- 84407-593- 5, 2008.

The chapters in the book include:-

Chapter 1: The inventory of soil biological diversity: concepts and general guidelines
Chapter 2: Sampling strategy and design to evaluate below ground biodiversity
Chapter 3: Macro fauna
Chapter 4: Soil collembola, Acari and other Mesofauna – The Berlese method.
Chapter 5: Soil nematodes
Chapter 6: Nitrogen fixing leguminosae - nodulating Bacteria (LNB)
Chapter 7: Arbuscular mycorrhizal fungi (AMF)
Chapter 8: Saprophytic and plant pathogenic soil fungi
Chapter 9: Sampling, conservation and identifying fruit flies
Chapter 10: Entomopathogenic Fungi and nematodes
Chapter 11: Description and classification of land use at the sampling locations for the inventory of below ground biodiversity.

# WORK IN PROGRESS

## Analysis of labor productivity and economic returns under alternative soil fertility management options in different cropping systems in Chuka, Central Kenya

**J. Chianu[1], D. Lesueur[1], B. Vanlauwe[1], L. Chibole[1], F. Mairura[1]**

[1]TSBF - CIAT, Kenya

## Introduction

Scientists working in sub-Saharan Africa are often concerned about the continuing farm-level low agricultural productivity and the attendant rural poverty that is common among smallholder farmers in the region. They, therefore, engage themselves in searching for plausible and sustainable solutions that can help to pull farm families out of poverty. Micro-organisms play key roles in engendering increased agricultural productivity. However, whether advantage would be taken of this attribute of soil micro-organisms depends, among others, on three factors. First is the soil and land management system since this affects the prevalence of soil fertility enhancing micro-organisms. Second is factor (e.g., land, labor, capital) productivity (in terms of consumable food products) under different soil fertility management options. Third is system's profitability and farmer adoption of the different soil fertility management alternatives which in many cases are prerequisites to the appropriation of the beneficial effects of the existence of soil micro-organisms. In view of the foregoing, an experiment was designed by a team of biophysical scientists and socio-economists in order to not only investigate the effect of different soil management options on different soil micro-organisms but also compare the treatments in terms of both factor (e.g., land, labor, capital) productivity and potential farmer adoption of the different options. This paper compares the treatments in terms of factor productivity, net returns, and potential farmer adoptability. This focus was based on the premise that the benefits of engendering an increase in the soil micro-organisms and whatever attributes associated with it can only become real in the livelihoods of farm families if the associated technologies are accompanied by increase in factor productivity and financial returns to the smallholder farmers. It is then and only then that the farmers can make enough profit from their farms to attend to other important family needs such as sending their children to school and providing them with better healthcare and diet. Such impacts make a difference in the lives of the poor who represent about 70% of the population in the study area. The data used for the analysis presented here were obtained from the first cropping season of an experiment and serves as a benchmark upon which progress will be measured in future when it would have been clear that the treatments have influenced the prevalence of the target soil micro-organisms and that the effects of these would have also clearly been transferred to the crops.

## Materials and methods

### *Study area*

The study was carried out in Chuka, located approximately 150 km northeast of Nairobi. Chuka lies in the Upper Midland zone 2 and 3 (UM2–UM3) at an altitude of about 1500 m above sea level. The annual rainfall, bi-modally distributed (with the short rain SR and the long rain LR seasons falling annually from March to June and from October to December, respectively), ranges from 1200 to 1400 mm (Jaetzold and Schmidt, 1983). The farming system is dominated by steep slopes (sometimes up to 60%) and competing (and sometimes complementary) crop-livestock enterprises that are often intensively managed (Warner, 1993; Lekasi et al., 2001). The soil type is mainly Humic Nitisol

(Jaetzold and Schmidt, 1983). Chuka was chosen for the experiment because the farming systems here are representative of the farming systems of East and Central provinces of Kenya. Besides, Chuka has a high agricultural potential with favorable socio-economic conditions including good market access.

*Test crops and cropping system*

Maize (variety H513) and soybean (variety SB3, an early maturing variety) constituted the test crops. Both crops are important for both food and cash in the study area. Cropping systems (Soybean-Maize intercrop, Sole Maize crop, Sole Soybean crop, and Maize followed by Soybean in a rotation) constituted the main plots under which the four treatments (see below) were evaluated.

*Experimental design, treatments and plot size*

A split-plot design was used. Cropping systems (Soybean-Maize intercrop, Sole Maize crop, Sole Soybean crop, and Maize followed by Soybean in a rotation) constituted the main plots. There were four sub-plots or treatments (with four replicates articulated in 4 blocks) and included +N, -R-N, +N+R, and +R (where +N refers to the application of Nitrogen fertilizer sourced from Calcium Ammonium Nitrate and applied at the rate of 230.6 kg/ha, +R refers to the application of crop residues, -R-N refers to where neither Nitrogen fertilizer nor crop residues was applied). Each treatment received a basal Triple Super phosphate (TSP) application at the rate of 130.3 kg/ha. The size of the experimental plot was 6 m by 5 m or $30m^2$. However, yield data were taken from a plot size of $18m^2$ at the centre of the experimental plots. These crop yields were later extrapolated to per hectare basis.

*Data collection and analyses*

Seed (maize and soybean) and fertilizer (CAN and TSP) inputs were recorded by the research technician responsible for the day-to-day management of the experiment. The quantities of seeds planted per experimental plot were 60 grams of maize in both the Sole Maize cropping system and the Maize followed by Soybean rotation, 49 grams of soybean in the Sole Soybean cropping system, and 54 grams of maize and 40 grams of soybean in Maize-Soybean intercrop. The costs of seeds were KShs. 120/kg for maize and KShs. 60/kg for soybean seed. The price of both CAN and TSP fertilizers was KShs.33/kg.

Data on labor use (measured in minutes and later converted in Person days using simple arithmetic) for different farm operations (top dressing, first weeding, second weeding and harvesting) were collected by a trained technician that directly observed and recorded the data. The research technician responsible for the day-to-day management of the experiment also collected data on crop (maize and soybean) yields. Output (maize and soybean) price data were collected from the local market in Chuka. Wages (KShs. 80/Personday of 8 hours) for farm operations labor were market-determined and represent the actual cost of labor in the study area.

Data were entered and transformed using Microsoft Excel. Analyses were carried using both GenStat and the Statistical Analysis System (SAS). The Mixed Model procedure in SAS was used to compute the least square means for arriving at the standard errors.

**Preliminary results**

*Labor use (Person days/ha)*

The result of total labor use for crop production under different treatments in the different cropping systems is presented in **(Table 21)**. It shows that overall labor use ranges from about 34 Person days/ha to about 63 Person days/ha. Among the cropping systems, labor use was generally highest in the Soybean-Maize intercrop (AS), ranging from about 55 to 63 Person days/ha. This must have been accounted for by the labor requirements to harvest two different crops (maize and soybean). As expected, among the treatments labor use was highest in all cases, except one, where nitrogen fertilizer was used for topdressing.

**Table 21: Total labor use across all farm operations (Person days /ha)**

| Cropping system | Treatment | | SED |
|---|---|---|---|
| | +N | -R-N | |
| Soybean-Maize intercrop (AS) | 63.01 | 55.03 | 4.20 |
| Sole Maize crop (MC) | 46.35 | 37.15 | 3.83 |
| Sole Soybean crop (ML) | 53.99 | 50.00 | 2.25 |

P-cropping systems <0.001, SED=.2.09

***Labor cost (KSh ./ha)***

The result of total labor cost for crop production is presented in **(Table 22)**. The overall labor cost ranges from about 2694 KShs./ha to about 5041 KShs./ha. Among the cropping systems, labor cost was generally highest in the Soybean-Maize intercrop (AS), ranging *from about* KShs.4402/ha to about KShs.5041/ha. Again, this must have been accounted for by the labor requirements and costs to harvest two different crops (maize and soybean). As expected, among the treatments labor cost was highest in all cases, except one, where nitrogen fertilizer was used (and hence cost incurred) for topdressing.

**Table 22: Total labor cost across all farm operations (KShs /ha)**

| Cropping system | Treatment[@] | | Mean |
|---|---|---|---|
| | +N | -R-N | |
| Soybean-Maize intercrop (AS) | 5041 | 4402 | 4722 |
| Sole Maize crop (MC) | 3708 | 2972 | 3340 |
| Sole Soybean crop (ML) | 4319 | 4000 | 4160 |
| **Mean** | 4356 | 3791 | |

[@] US$1 = KShs.66.00

[&] Data reported is only for maize

*Total cost of operations (KShs /ha)*

The total cost of all inputs (labor, seeds, and fertilizer) is presented in **(Table 23)**. It ranges from a low value of KShs.8871/ha to a high value of KShs.19910/ha. As expected, across the cropping systems, the total costs of operations were highest where, in addition to seeds, inputs such as nitrogen fertilizers are used for topdressing.

**Table 23: Total costs across all inputs (labor, seeds, fertilizer) (KShs/ha)**

| Cropping system | Treatment[@] | | SED | Mean |
|---|---|---|---|---|
| | +N | -R-N | | |
| Soybean-Maize intercrop (AS) | 19910 | 11660 | 376 | 15785 |
| Sole Maize crop (MC) | 17218 | 8871 | 336 | 13045 |
| Sole Soybean crop (ML) | 17210 | 9279 | 307 | 13245 |
| **Mean** | 18113 | 9937 | | |

P value (cropping systems, -<0.001), (treatment <0.001)
[@] US$1 = KShs.66.00

*Gross returns (KShs ./ha)*

The result of gross returns across all outputs (maize and soybean) under different treatments in the different cropping systems is presented in **(Table 24)**. It was highest under the maize-soybean intercrop, followed by sole maize (represented by both MC and RO), and lastly by sole soybean. Overall gross returns ranges from a low value of KShs.19241/ha to a high value of KShs.71364/ha.

**Table 24: Gross revenue across all outputs (Maize and Soybean) (KShs /ha)**

| Cropping system | Treatment[@] | | SED | Mean |
|---|---|---|---|---|
| | +N | -R-N | | |
| Soybean-Maize intercrop (AS) | 67176 | 55089 | 11397 | 61133 |
| Sole Maize crop (MC) | 63028 | 35062 | 6048 | 49045 |
| Sole Soybean crop (ML) | 24246 | 13347 | 4271 | 18797 |
| **Mean** | 51483 | 34499 | | |

[@] US$1 = KShs.66.00

*Gross margin (KShs /ha)*

The result of gross margin (income above variable cost) analysis under different treatments in the different cropping systems is presented in **(Table 25)**. It shows that although no loss was incurred in any of the treatments across the cropping systems, the profit or net returns level was clearly variable, ranging from a very low level of KShs.4067/ha to a very high level of KShs.53389/ha.

**Table 25: Gross margin (KShs /ha)**

| Cropping system | Treatment[&] | | SED | Mean |
|---|---|---|---|---|
| | **+N** | **-R-N** | | |
| Soybean-Maize intercrop (AS) | 47266a | 43429a | 11248 | 45348 |
| Sole Maize crop (MC) | 45810a | 26191ab | 4552 | 36001 |
| Sole Soybean crop (ML) | 7036a | 4067a | 4193 | 5552 |
| **Mean** | 33371 | 24562 | | |

P value (cropping systems, -<0.001), (treatment <0.007)
[&] Means followed by the same letter are not significantly different.

*Net labor productivity*

The result based on net labor productivity is presented in **(Table 26)**. Across treatments, net labor productivity was generally low, ranging from KShs.81/Person day to KShs.1233/Person day. Across treatments, it was lowest under the sole soybean cropping system, ranging from KShs.81/Person day to KShs.227/Person day with a mean of about KShs.147/Person day.

Table 26: Net labor productivity (KShs /Person day)

| Cropping system | Treatment[@] | | Mean |
|---|---|---|---|
| | +N | -R-N | |
| Soybean-Maize intercrop (AS) | 750 | 789 | 770 |
| Sole Maize crop (MC) | 988 | 705 | 847 |
| Sole Soybean crop (ML) | 130 | 81 | 106 |
| **Mean** | 623 | 525 | |

[@] US$1 = KShs.66.00

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

**J.K Onyango[1], O.L.E. Mbatia[1], J.J Okello[1], and J.N. Chianu[2]**
[1]*University of Nairobi, Kenya;* [2]*TSBF - CIAT, Kenya*

### Introduction

The improvement of agricultural productivity is vital to achieving the Millennium Development Goals (Kimaru and Jama 2006). Kenya's economy relies on agricultural sector for export earnings and employment generation (Ministry of agriculture 2006). The sector provides employment to 70% of the Kenyan labor force, generates 60% of the foreign exchange, provides 75% of raw materials for industry, and provides 45% of total revenue (Central Bureau of Statistics 2005). The challenge lies with improving factor (labor, land, etc.) productivity in Kenyan agriculture, which has not reached optimal level (Nyangito and Odhiambo 2003, Ministry of Agriculture, 2006). Many factors are contributing to this, including soil fertility decline, poor infrastructure, inefficient marketing system, insecure land tenure, and unpredictable and erratic rainfall (Jayne and Nyoro, 2000). This means that year round household food security will increasingly depend on maximizing productivity and incomes from limited available land (Strasberg *et al.*, 1999). It is a key challenge to identify technologies that meet both agricultural productivity and sustainability goals. Presently, most smallholder farmers continuously plough small parcels of land with sub-optimal or without application of fertility replenishing inputs (Jayne *et al.*, 2005; Jayne and Nyoro 2000; Ministry of Agriculture 2004), leading to cycles of the mining of essential soil nutrients, with minimal replacement. A study on soil nutrient balance in Kenya indicates that nitrogen outputs exceeded inputs by 25 $kg^{-1}ha^{-1}yr^{-1}$, representing an annual depletion of 0.4 – 0.5% across farming systems (Jager *et al.*, 2001). Phosphorus depletion from the soils in Kenya has also been estimated at 3 $kg^{-1}$ $ha^{-1}$ $yr^{-1}$ **(Table 27)**. The negative trend in fertility is aggravated by declining fallow periods due to population pressure, soil erosion, deforestation, and crop production on steep slopes with limited investments erosion control measures such as terraces. Poverty and other socioeconomic factors also constrain effective soil conservation practices (Ministry of Agriculture, 2004).

**Table 27: Farm Level Soil Nutrient Balances in Kenya, 1996 (kg/ha/year)**

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

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

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

## Materials and methods

### *Research Design*

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

### *Study Area*

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

*Sampling technique*

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

*Data collection*

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

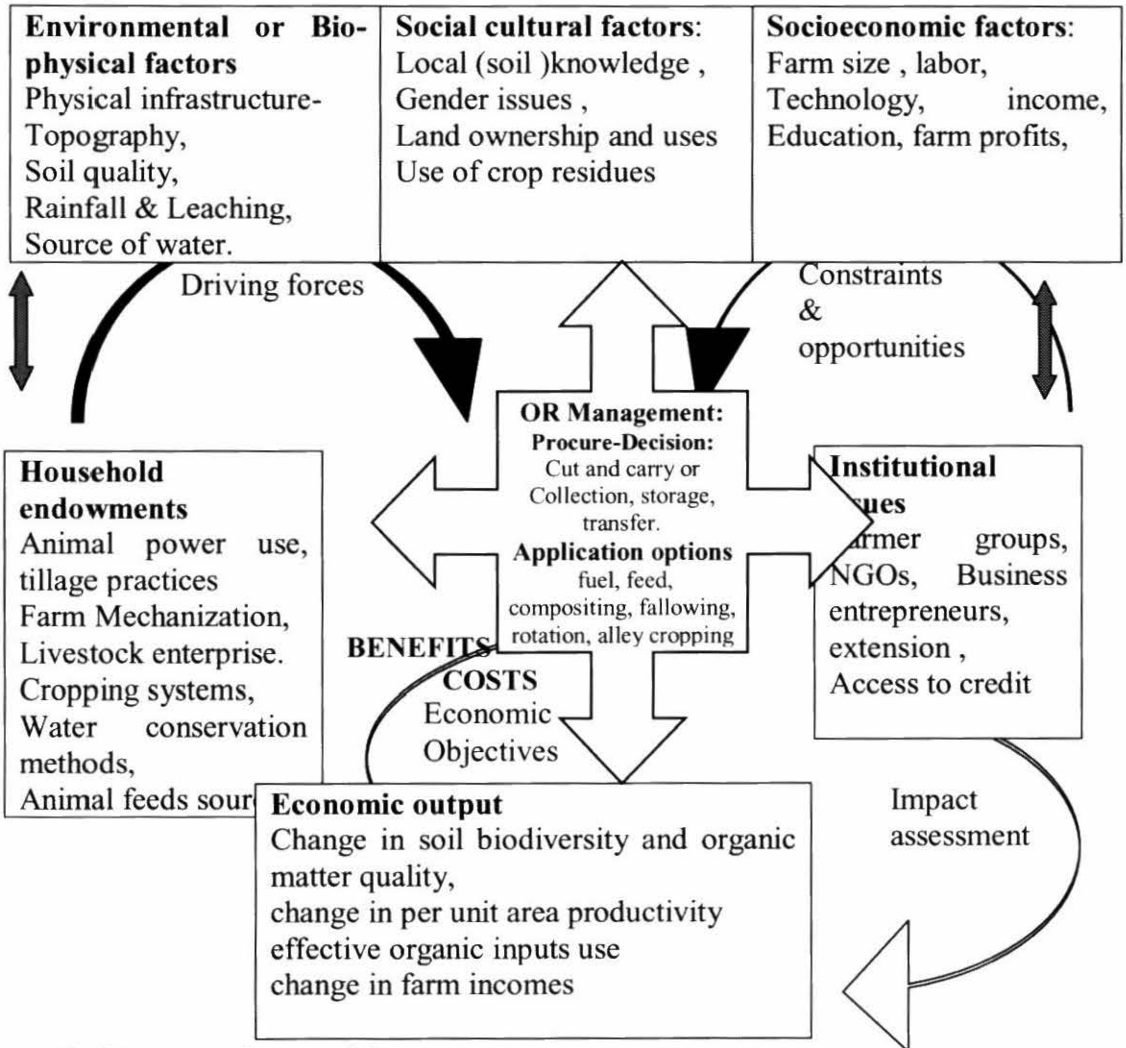



**Figure 60: Structure of the model**

**Preliminary results**

Data analysis is still ongoing.

## Lessons learned from Long-term Soil Fertility Management Experiments in Africa

**Bationo et al (eds.)**

*TSBF - CIAT, Kenya*

Long term trials hold the key to understanding the processes and functioning of many of the cropping systems in tropical Africa. These trials could be used especially by researchers and higher education students interested in basic research about the various systems. Data from these trials can be used for simulation and prediction of potential changes in production or soil properties thus improving on decision making in light of changing biophysical and socio-economic conditions. The book will document information and lessons learned from long-term experiments being undertaken in East, Southern and Western Africa.

**Contents**



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

## No Completed work

## No Work in progress

| **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

## Strengthening Agro-dealer Technical Capacity in Integrated Soil Fertility Management in Western Kenya

**Vanlauwe[1], B.**
*[1]TSBF - CIAT, Kenya*

The Citizens Network for Foreign Affairs (CNFA) and the Tropical Soil Biology and Fertility Institute of the International Center for Tropical Agriculture (CIAT-TSBF) have recently explored potential joint activities to strengthen the technical capacity of agro-dealers by introducing Integrated Soil Fertility Management (ISFM) practices under the Kenya Agro-dealer Strengthening Program (KASP). ISFM is defined as the application of soil fertility management practices, and the knowledge to adapt these practices to local conditions, which optimize fertilizer and organic resource-use efficiency and crop productivity. Complete ISFM comprises the use of improved germplasm, fertilizer, appropriate organic resource management and adaptations to local conditions and seasonal events. Local adaptation adjusts for variability in soil fertility status and recognizes that substantial improvements in use efficiency can be expected on responsive soils while on poor, less-responsive soils, application of fertilizer alone does not result in improved use efficiency and is better applied in combination with organic resources. CNFA, through its affiliate, the Agricultural Market Development Trust (AGMARK), is implementing a three-year program aimed at improving farmer incomes and productivity by increasing smallholder access to improved agricultural inputs and better production practices through a strengthened rural agro-dealer network.

In the context of above collaboration, ISFM training workshops will be organized. During a field visit for agro-dealers, organized in June 2008 in Western Kenya, 6 general topics were proposed for inclusion in such training workshop: (i) soil testing and evaluation, (ii) fertilizer management, (iii) alternative methods for soil fertility restoration, (iv) soil conservation, (v) pest and disease management, and (6) striga and weed management **(Table 28)**

The current manual was developed to support training for agro-dealers and other extension personnel on the first three topics: (i) soil testing and evaluation, (ii) fertilizer use and management, and (iii) organic matter use and management, after a general introduction to soils and soil fertility. Additional training materials on these and other topics are also available. The manual contains theoretical background information and practical sessions on these topics and finishes with a session on installation and management of demonstration plots.

**Table 28: Prioritization of topics for the ISFM workshop**

| **Issues that received widespread support** |
|---|
| Soil testing and evaluation: Soil evaluation, soil type, missing elements; presence of soils in different districts; value of the soil; how to manage it well (farmer-oriented); what is affecting soil quality; soil sampling technique; soil testing; soil composition; soil organisms |
| Fertilizer management: Fertilizer rates and seed rates; proper application of fertilizer, early planting and proper seeds; different types of fertilizer and their use; evaluation of seeds adapted to different soils/areas |
| Alternative methods for soil fertility restoration: Crop rotations; other modalities for soil fertility restoration besides soybean and fertilizer (eg improved fallows, manure, compost); methods for preparing farm manure; use of organic matter; organic fertilizer (HB101 from Japan); agro-forestry; management of non-responsive soils |
| Soil conservation: Soil erosion control; intensifying soil conservation measures; methods of soil conservation; soil and water conservation; water harvesting/minimum tillage; early soil preparation and deep tillage |
| Pest and disease management: Crop pest diseases and control; advantage/disadvantage of using herbicides and other chemical applications; how to safely use herbicides; safe use of chemicals (fertilizer, chemicals) (e.g. IR maize) |
| Striga and weed management: Striga and weed management (other weeds: couch grass); varieties to suppress striga; legumes for striga suppression |
| **Other Issues** |
| Horticulture: Horticultural crops (sukuma wiki, fruits, etc) besides maize (eg foliar feeds for s. wiki) |
| Information management: Information packaging and dissemination |
| Fallow management: Shifting cultivation; natural fallow management (egg some areas) |
| Soybean processing: Utilization of soybean (processing); varieties of SB; soils that are appropriate for different varieties |
| Access to markets: Preservation of farm produce; cereal banking |

# Work in progress

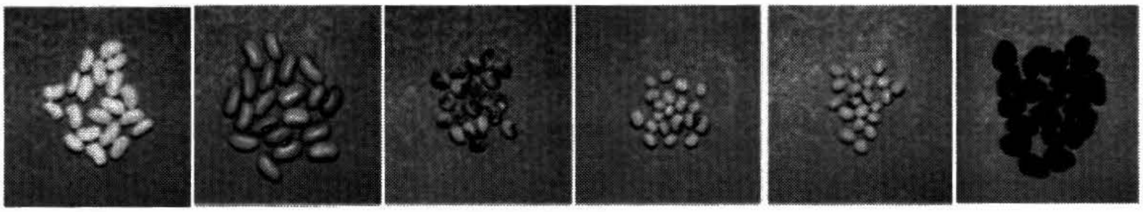
## Adapted and preferred legume germplasm

**P. Pypers[1], A. Chifizi[2], S. Mapatano[2], J.M. Sanginga[3], K. Bishikwabo[3], T. Ngoga[4], A. Gahigi[4], S. Kantengwa[5], J.P. Lodi-Lama[6], W. Bimponda[6], J.J. Nitumfuidi[6] and B. Vanlauwe[1]**

*[1]TSBF - CIAT, Kenya; [2]DIOBASS, DR Congo; [3]CIAT, DR Congo; [4]ISAR, Rwanda; [5]CIAT, Rwanda; [6]INERA, DR Congo*

Improved legume germplasm is taken as an entry-point to improve agriculture-based livelihoods, and is used to increase soil fertility, income and nutrition. A number of characteristics are sought in newly introduced varieties. Firstly, varieties should be beneficial for soil fertility, and therefore produce high amounts of biomass, nodulate promiscuously, fix large amounts of atmospheric N, and have low harvest indices. Secondly, varieties should be high-yielding, resistant to diseases and environmental stresses, produce on poor soils and respond to input application, in order to obtain high returns. Varieties should be farmer-preferred, and favoured on local and regional markets. Highest prices are given for grains characterized by the preferred colour, size, density, taste, cookability, etc. Finally, the produce should be beneficial for human nutrition, and therefore rich in protein, micronutrients and other nutritious compounds.

Details on testing and selection of improved varieties of bush beans, climbing beans, soybean, groundnut, cowpea and pigeon pea are explained in detail in the CIALCA 2007 annual report. The yield potential and characteristics related to N fixation were evaluated on-station for a large number of varieties. Selected varieties were then tested by minimally two farmer associations in each action site, and yields, as well as biomass production, and resistance to diseases and environmental stresses were assessed. Farmer associations evaluated and selected varieties based on their own and researcher-defined criteria. A number of varieties were identified which were high-performing and preferred for large regions or an entire mandate area (e.g., varieties presented (**Photograph 1**) for the Bas-Congo mandate area). Farmer associations were then trained in seed multiplication, and are now producing large amounts of selected varieties.

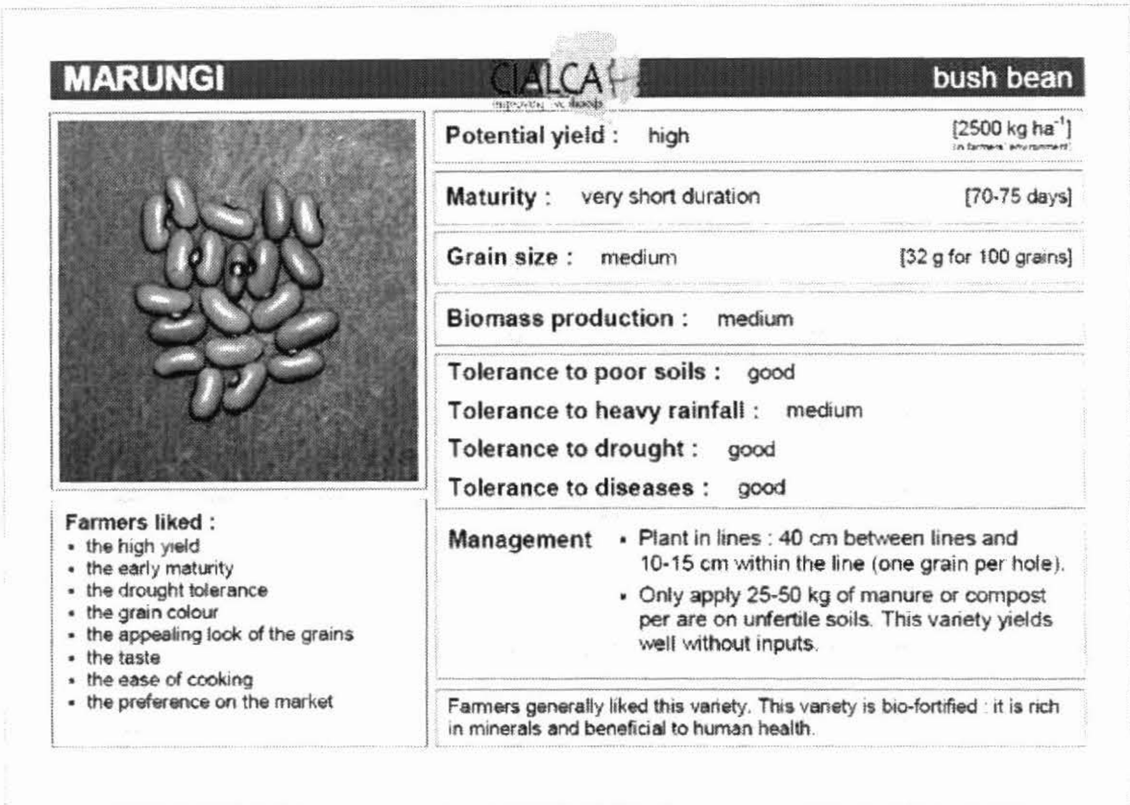


**Photograph 1: Selected legume varieties promoted in Bas-Congo, DRC. From left to right: climbing beans Tuta, bush beans Lola, cowpea Diamant, soybean SB19, soybean Vuangi, groundnut CG7.**

Details on all selected varieties are summarized in legume variety cards, which are available on the CIALCA website (www.cialca.org) (**Photograph 2**). A number of hard-copy cards were also distributed among key research and development partners, community workers and agronomists, and to the representatives of the various farmer associations involved in seed multiplication. The cards were produced in English, French and local languages. Following information can be found on the cards:

| | |
|---|---|
| • Potential yield<br>• Maturity period<br>• Biomass production<br>• Resistance to poor soils, heavy rainfall, drought and diseases | • Grain size and colour<br>• Recommendations for management (spacing and input application)<br>• Nutritional aspects<br>• Farmer-preferred traits |

Potential clients (individual farmers, NGOs, seed producers, and national seed systems) can obtain seed of the varieties through the farmer associations involved in seed multiplication, or through the national research institutes. Contacts and details are provided through the CIALCA offices.




**Photograph 2: legume variety card for an improved, bio-fortified bush bean variety.**

| 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 trainings

**Participatory Approaches to Research and Scaling up Training Workshop**
21st April - 2nd May 2008, UNEP, Gigiri, Nairobi

**The objectives of the workshop** were to ensure that after the training, the participants would be better able to:

(i) Diffuse successful technologies and approaches rapidly to more farmers within more localities and to more institutions and stakeholders.
(ii) Communicate research findings more effectively to farmers.
(iii) Understand the policy implications of the research activities
(iv) Understand value chain analysis and innovation platforms and its relevance to participatory research
(v) And overall to increase the relevance and impact of their research on integrated soil fertility management

**Topics covered**

**Participatory approaches to research**

→ Basics of participatory approaches to research.

This included concepts and methodologies used in participatory research. During this session, the participants also got to share their experiences in participatory research and scaling up using different methods and methodologies. During this session, the basic communication facts identified that limit success of participatory research were

(i) How to ensure that people/farmers do not become more dependent in the process of development, rather than autonomous?

(ii) How to avoid their performance becoming contingent upon 'external clappers'? - dependent development

(iii) How to ensure targeted persons/farmers becoming participants rather than spectators - Since we define the problem, we also define a role for ourselves as problem solvers i.e., outsiders' participation being institutionalized but not vice versa. The nature of outsiders participation determines the level of empowerment of the targeted and other communities

(iv) People cannot just be the clappers since when to clap and when not to, is as important as the question of whether to clap at all.

(v) It is often easier starting from what is known (by the community) and moving gradually to the unknown – it is however, not cheaper!

→ Designing and planning participatory research work.

→ Data analysis, interpretation and farmer options in participatory experiments.

→ Structural change in fertilizer procurement method: Assessment of impact in SSA.

**Markets and Agro-enterprise development in participatory research**

Under this, discussions were held on identification of market opportunities and agro-enterprise development and how to link this to research; Moving from Research Outputs to Outcome and Impact; Market-led hypothesis on investment in NRM. All this was in the face of how agricultural markets can improve livelihoods in sub-Saharan Africa.

**Policy issues in research**

Under policy issues, in groups and in plenary, issues discussed ranged from the innovativeness of policies in making agricultural research successful by understanding the research - policy link. This was discussed from policy analyst as well as agricultural research perspectives.

**Scaling up and out**

Inter-disciplinarity in scaling up and out was discussed and some examples of how some policies that affect scaling-Up/Out of Technologies. A case study of a scaling up and out approach used by the Kenya Agricultural Research Institute was also discussed based on its merits and de-merits. This was used as an example to learn lessons

## Capacity building, training and dissemination

**Okoth[1], P., Huising[1], J. and Etyang[1], B.**

*[1]TSBF - CIAT, Kenya*

***In Brazil*:** About 100 students (Ph.D., M.Sc., undergraduate) have been trained in Brazil including field Technicians and laboratory attendants. Brazil has participated in various side events related to below ground biodiversity (BGBD) including: Seminars, symposia, congresses, etc. In addition Brazil has trained farmers on the use of biological indicators of soil quality, Organized/participated in training courses across countries, made booklets and folders (on sustainable management and conservation of BGBD) and disseminated the importance of BGBD and its management to farmers and other stakeholders.

***In Kenya*:** A total of 16 MSc/MA and 5 PhD students are currently collecting field data, 26 Post graduate and 2 undergraduate students have graduated with written thesis. 10 scientific papers have been published. *Trichoderma, Acari, Collembolla, Rhizoctonia*, earthworms, Nematodes, Nematophagus fungi and Mycorrhizae isolates have been preserved at the University of Nairobi and the national Museums of Kenya.

***In Uganda*:** A scientist and laboratory technician have been trained on AMF techniques and methods; a biometrician has also been trained in multivariate statistical analysis. Scientists have been trained in data analysis techniques. 8 internship students from Makerere University have been admitted and currently attached to different scientists. 3 BSc, 4 Msc and 6 PhD students are at different levels of their pursued degrees. Furthermore, Efforts to improve BGBD research and management capacity in the country have been started. Sensitization workshops have been conducted at the benchmark area to improve capacity of farmers, extension workers and NGOs to interpret and apply information on BGBD, as a collaborative effort of stakeholders.

***In Mexico*:** Research themes for post-doctoral and undergraduate students have been identified, several public publications have been planned and proposal content was elaborated. The farmers are continuously trained as the experiments are being carried out as a joint learning strategy.

Thirteenth meeting of SBSTTA FAO, Rome, Italy, 18-22 February 2008: Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA)

## NO WORK IN PROGRESS

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

## COMPLETED WORK

### AfNet Research Highlights from West Africa

Since 2001, AfNet has continued to support network experiments in West Africa using commonly developed research protocols. The research activities in West Africa are conducted under a memorandum of understanding between TSBF institute of CIAT and ICRISAT. Collaborative research is being undertaken with researchers from Niger, Burkina Faso, Nigeria, Ghana, Senegal etc. The themes which are investigated are 1) Water harvesting and nutrient management 2) Combining organic and inorganic nutrient sources; 3) use of different cropping systems; 4) On-farm evaluation of soil fertility restoration technologies; 5) Optimum management of organic resources and inorganic nutrient sources, 6) conservation agriculture, and 7) use of phosphate rock in crop production. In Niger (West Africa), several sites have been established since 2001 and being continued in 2008. **(Table 29)** below shows a list of Network collaborative trials in Niger, 2008 giving the type of trial and sites located.

**Table 29: Network collaborative trials indifferent sites in Niger (West Africa), 1999-2008**

| Type of Trials | Site | Started | End |
|---|---|---|---|
| Long-term operational scale research | Sadore | 1986 | On going |
| Long-term cropping system | Sadore | 1993 | On going |
| Long-term crop residue management | Sadore | 1982 | On going |
| On-farm evaluation of cropping systems technologies | Sadore, Karabedji, Gaya | 2003 | On going |
| Placement of phosphorus and manure | Karabedji | 1999 | On going |
| Placement of phosphorus and PUE | Karabedji | 2000 | On going |
| On-farm evaluation of cropping systems technologies, KKM project | Maradi | 2008 | On going |
| On-farm evaluation of soil fertility restoration technologies | Karabedji, Gaya | 1999 | On going |
| Comparative effect of mineral fertilizers on degraded and non degraded soils | Karabedji | 1999 | On going |
| Fertilizer equivalency and optimum combination of low quality organic and inorganic plant nutrients | Banizoumbou, Karabedji, Gaya | 2001 | On going |
| Optimum combination of phosphate rock and inorganic plant nutrients | Banizoumbou, Gaya, Karabedji, Sadore | 2005 | On going |
| Corral experiment (demonstration) | Sadore | 1988 | On going |

**Long-term management of manure, crop residues and fertilizers in different cropping systems**

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. For pearl millet dry matter, the application fertilizer, manure, crop residue and cropping systems together account for 35% (56% in 2006) of the total variation. The data in **(Figures 61 and 62)** illustrates the response of pearl millet grain yield and total dry matter respectively to the application of different input combinations of organic and inorganic fertilizers.

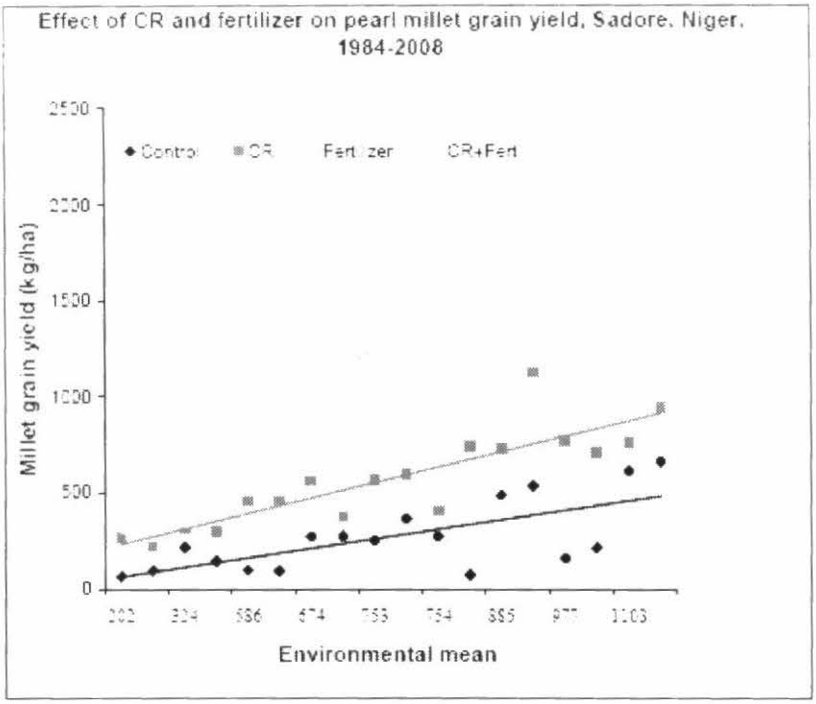



**Figure 61: Effect of Crop residue and Fertilizer on pearl millet grain yield, Sadore, Niger, 2008 rainy season.**

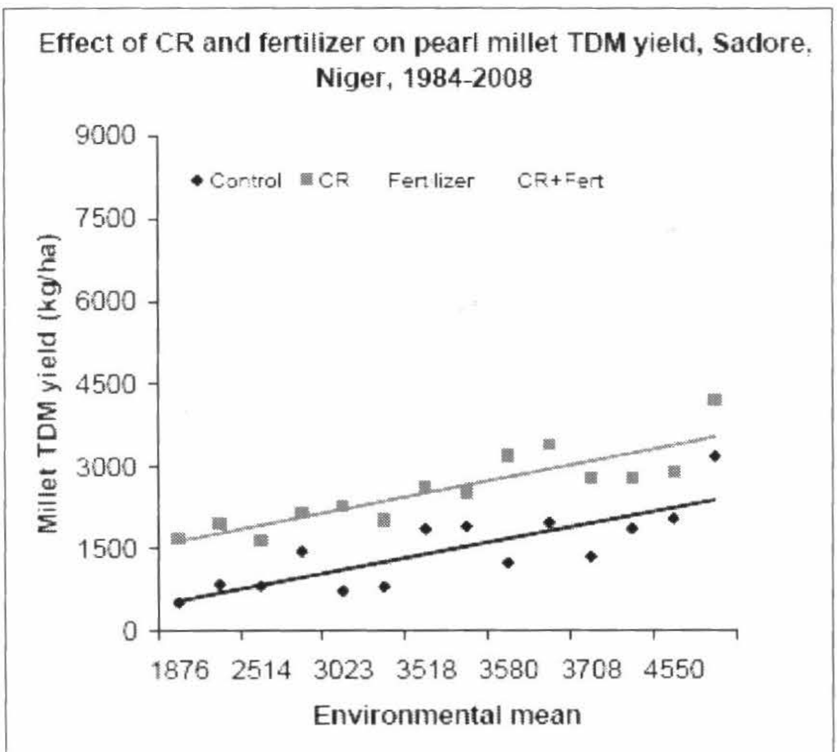



**Figure 62: Effect of Crop residue and Fertilizer on pearl millet total dry matter, Sadore, Niger, 2008 rainy season.**

## AfNet Research Highlights from Eastern Africa

AfNet research activities continued to be implemented in several sites in Kenya, Uganda and Tanzania during the year 2008. AfNet continued to support several experiments in this region as indicated in the table below.

**Table 30: AfNet Trials in Western, Central and Eastern Regions of Kenya, Eastern Uganda and Eastern Tanzania.**

| Experiment | Location |
|---|---|
| Integrated Nutrient Management Trials (IN2 and INM3 | Maseno, Western Kenya |
| Conservation Agriculture research trials (CT Trials) - 4 sites | Nyabeda, Mathayos and Teso, Western Kenya |
| Rock phosphate trial in Maseno | Nyabeda, Western Kenya |
| Fertilizer Equivalency Trial (N1- Kabete) | NARL, Kabete, Central Kenya |
| Long-term experiment, Kabete | NARL, Kabete, Central Kenya |
| Hedge-row Intercropping Trial- Embu | Embu, Eastern Kenya |
| ISFM Trials in Eastern Kenya | Kirege, Eastern Kenya |
| IFS Machanga trial | Machanga, Eastern Kenya |
| Water and nutrient management research in the drylands of Eastern Kenya | Emali, Eastern Kenya |
| AfNet-ERI-IDRC Project Sites | Eastern Uganda and Eastern Kenya |
| Improving and Strengthening Rural Community Access to Agricultural and Soil Fertility Information in Korogwe District, Tanzania | Korogwe District, Tanzania |

**Soil, water and nutrient management in Western Kenya**

Integrated Nutrient Management (INM) and conservation tillage trials have been running in western for the last seven years.

**Microbial diversity and composition**

Tillage influenced composition of bacteria and fungi populations similarly in Matayos and Nyabeda in western Kenya **(Figure 63)**. Fungal populations from treatments within each tillage system were highly correlated ($P<0.01$), but there were no significant correlations across the tillage systems. The results indicate shifts in the composition of bacteria and fungal populations due to tillage. Soil disturbance (conventional tillage) was accompanied by slightly lower bacteria diversity, relative to reduced tillage. Thick dark bands for DGGE bands observed in reduced tillage support greater fungal abundance than conventionally tilled plots. The two principal components in Figure 1 constituted 66% of the total variance.

**Nitrogen fixation in Nyabeda**

The practice of reduced tillage plus surface application of crop residue offers farmers an opportunity to maximize on BNF. A significant tillage x crop residue interaction on %NDfA was observed ($P<0.05$) **(Table 31)**. Application of CR in conventional tillage decreased %NDFA from 57 to 45%, whereas under reduced tillage, crop residue application increased %NDfA from 49 to 65%. Reduced tillage plus crop residue yielded during the short rains of 2007 and long rains of 2008 under the collaboration among the DMP research scientists from collaborating institutions that included the TSBF Institute of CIAT, KEFRI, KARI, extension staff from the line ministries, NGOs and community based organizations from the DMP sites. Rainwater harvesting using tied ridges and open ridges are some of the cheap methods of mitigating dry spells in areas where farmers have inadequate resources to invest in irrigation. The on-going DMP field trials in Makueni District and other studies have indicated that tied ridges increase maize yields by more than 50% above the conventional flat tillage practiced by farmers. There were significant increases in maize yield when tied ridges are combined with integrated nutrient management. The research hypothesis was that combining water harvesting techniques with improved soil fertility will result in higher efficiency of resources and increase in crop yields in the ASALs. Water harvesting methods consisted of tied-ridging and open furrows while the INM treatments were: (1) manure (10t/ha), (2) manure (5 t ha), (3) manure (10t/ha) + 20kg N/ha+ 20 kg $P_2O_5$, (4) manure (5t/ha) + 20kg N/ha+ 20 kg $P_2O_5$, (5) control (farmers practice with no fertilizers). On-farm studies have shown that tied ridges, when combined with fertility management, have the advantage of increasing crop yields by more than 50% when compared to yields from flat planting. The conclusion was that water harvesting and INM strategies will increase crop production in ASALs while conserving the environment. This will lead to improved food security and increased household incomes.

In extension of sustainable natural resource management, two types of scaling-up strategies were used: (i) strategies for the promotion of readily available technologies and (ii) approaches for participatory learning and innovation on knowledge-based issues including NRM. Open field days continue to be the most preferred methods of disseminating information especially on the water harvesting and INM technologies being demonstrated in the different sites in Eastern rangelands of Kenya.

## AfNet Research Highlights from Southern Africa

Field research activities in the Southern Africa region continued in Zimbabwe and Malawi under the AfNet-ERI-IDRC Project. Other collaborative research activities were implemented between AfNet and the University of Zimbabwe especially on water harvesting technologies and adaptation to climate change by smaller farmers in Africa. In addition, AfNet launched a new project in Malawi in collaboration with the Bioforsk Soil & Environmental Division, Norway and the Department of Agricultural Research and Technology, Malawi, on eempowering farmers with soil, water and nutrient enhancing technologies for increased productivity. This is expected to continue for the next 2 ½ years.

### Information Dissemination - The Essential Electronic Agricultural Library

A major constraint faced by many national scientists and students in Africa is limited access to current research publications. This has often led to difficulties especially when undertaking literature searchers for writing papers and research proposals as well as for students at different levels in the universities. Over the years, the AfNet Co-ordination Unit has been receiving numerous requests for agricultural literature from its members. In an effort to satisfy the research information needs, AfNet in collaboration with the University of Kassel, Germany, under the Volkswagen Project, installed The Essential

Electronic Agricultural Library (TEEAL) at the AfNet coordination unit in Nairobi. The LanTEEAL contains full-text and graphics of 115 of the world's best journals in agricultural and environmental issues. The TEEAL is updated annually. Students and researchers based in Sub-Saharan Africa can send search requests to AfNet Unit and quickly receive full papers of the papers requested.

**Networking and Inter-institutional Teams**

Recognizing the benefits of networking, AfNet has continued to promote strategic linkages with several partners across the research and development continuum. AfNet teamed up with ICRISAT and the CPWF Theme 2 to organize several training workshops. Most of the research activities undertaken in the different benchmark site have been through a strong collaboration with researchers from national agricultural research organizations, CG centres and challenge programmes. Joint research, proposal writing and training initiatives have also been promoted through collaboration with advanced research organizations (JIRCAS, JORDFORSK, ISRIC, ETC,), local and foreign universities (Wageningen University, Hohenheim university, Kiels University, Kassel University and Witzenhausen/Göttingen, Kenyatta, Moi, Nairobi and Egerton Universities in Kenya, National University of Rwanda among others) as well as national agricultural research systems. AfNet has also continued to strengthen linkages with IFS for research support towards upcoming African scientists. AfNet has also strengthened linkages with regional agricultural bodies and networks as strategy of benefiting from synergies of networking.

**Preliminary conclusion**

AfNet successfully implemented its research and development, capacity building and information dissemination activities in the sub regions in line with its strategy. The Network recognizes the importance of collaboration as basis for sharing information and resources and for avoiding duplication of effort. As a result the Network will continue to support and strengthen such collaboration not only with other CG centres and advanced research organizations but also more importantly with national agricultural research systems. With its network of able and successful researchers and the wealth of knowledge and experience, at the moment, AfNet is positioning itself to work in partnership with AGRA and other partners to restore soil health in Africa in order to contribute in revitalizing African agriculture in International levels

# WORK IN PROGRESS

## Improving Soil Fertility Recommendations to Smallholder Farmers in Africa through the Use of Decision Support Tools

**Bationo et al (eds.)**

[1]*TSBF - CIAT, Kenya*

The book will contain a total of 16 chapters focusing on the use of decision support tools to model different agro-ecological phenomena. The themes that are being addressed by different scientists include: Tillage and Nitrogen applications, Soil conservation practices, Phosphorus and maize productivity; Genetic Coefficients and yields of different Soybean cultivars; Long-term soil fertility management technologies in the drylands; Microdosing; Manure and nitrogen effects in drylands of Kenya; Optimization of nitrogen * germplasms*water on maize and sorghum in Ghana; Adoption of agricultural decision support systems; Zai technology; Spatial analysis of water and nutrient use efficiencies with selected cultivars in the Volta basin; Tradeoff analysis.

The chapters of the book include the following:

1. Building capacity for modeling in Africa
   *Bationo A., Tabo R. and Kihara J.*
2. The concept of Decision Support Systems
   *Jim Jones and Gerrit*
3. Effects of tillage on rain water productivity in Nyabeda, western Kenya
   *Kihara J. and Bationo A., and C. Martius*
4. Intensification of Phosphorus Management Strategies for Maize Production in Western Kenya Using DSSAT Simulation Model
   *Wangechi, H., Pypers P and Vanlauwe, B.*
5. Determination and Evaluation of Genetic Coefficients of Dual Purpose Soybean Varieties Using Field Trials and Crop grow Model
   *Nyambane, A., Tittonell, P., Corbeels, M., Wasike, V, Vanlauwe, B.*
6. Effect of integrated soil fertility management technologies on the performance of millet in Niger: Understanding the processes using simulation
   *Adamou A.; R. Tabo; D. Fatondji; O. Hassane; A. Bationo; T. Adam*
7. Long-term effects of fertilizer microdosing on millet performance and on water and nutrient use efficiency in the Sahel: Understanding the processes using simulation
   *Hassane Ousmane; Ramadjita Tabo; Ibrahim Maikano; D.ougbedji Fatondji; Adamou Abdou and Andre Bationo*
8. Evaluation of the effects of manure and nitrogen fertilizers on maize production in semi-arid eastern Kenya using DSSAT model
   *Miriti J.M., A.O. Esilaba, A. Bationo, H. Cheruiyot[2], J.Kihumba*
9. Soil conservation and decision support Systems
   *Marc Corbeels*
10. Optimization of nitrogen, germplasms, water on maize in Ghana
    *Mathias Fosu*
11. Adoption of agricultural decision support systems
    *Carlos Quiros*
12. Integrated soil fertility management on sorghum productivity in Burkina Faso sudanian zone
    *TRAORE Karim, SAWADOGO Seraphine, BONZI Moussa*
13. Water use and yield of millet under the Zai system: Understanding the processes using simulation models.
    *Fatondji, D.; A. Bationo; R. Tabo; A. Adamou; O. Hassane*
14. Modeling nutrient and water productivity of sorghum (sorghum bicolor (L.) Moench) in smallholder farming systems in a semi-arid region of Ghana using DSSAT
    *Dilys Kpongor, Paul L.G. Vlek, Andrea Bationo and R. Tabo*
15. Spatial analysis of water and nutrient use efficiencies with selected cultivars in the Volta basin
    *Fatondji D*
16. Prediction of potential yields of new rice varieties in the Senegal River Valley using simulation models
    *Michiel E. De Vries, Bado B. V. Sakané N. Sow A*

| 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 COMPLETED WORK

## NO WORK IN PROGRESS

| 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 the belowground biodiversity project

**Okoth[1], P., Huising[1], J, and Sakalian[2], M.**
*[1]TSBF - CIAT, Kenya; [2]UNEP, Rome*

Side event during SBSTTA 13
The side event was hosted by UNEP/DGEF. Its objective was to present the outcomes, information generated and technical assistance provided to developing countries by UNEP GEF projects on conservation and sustainable use of agricultural biodiversity. The side event was addressed by UNEP's Executive Secretary of the CBD. About 40 people attended the meeting. The meeting included three presentations on: (i) Contribution to in-situ conservation of crop genetic diversity on farm and in the wild, (ii) Contribution to the International Pollinator Initiative, (iii) Contribution to the Soil Biodiversity Initiative through the conservation and sustainable management of below ground biodiversity (CSM- BGBD) project. The main focus of the presentations was on the conservation impact of the projects, benefits to local communities and on the ways in which agricultural biodiversity can contribute to global challenges including climate change. The CSM- BGBD project was represented in the side events by the projects information Manager Dr. Peter Okoth.

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

## NO WORK IN PROGRESS

# III.6. 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 agroforestry 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

**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 agroforestry 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.

**International Agricultural Research Centres:** IITA, Uganda, RF project on ISFM for bananas; DGDC project on banana management in Central Africa; IITA, Nigeria (Alene Arega, David Chikoye, Robert Abaidoo); ICIPE and CIMMYT Kenya, DfID project on striga management in the Lake Victoria Basin; CIMMYT, Kenya, AATF project on striga management in Western Kenya; IFDC, Togo, WOTRO project on soil fauna and soil aggregation; INIBAP, Uganda, DGDC project on banana management in Central Africa; ICRAF, Kenya, RF project on soil fertility gradients and site-specific soil fertility management; ICRISAT (Niger); Centre d'Etude Régional pour l'Amélioration de l'Adaptation à la Sécheresse (CERAAS/ISRA); West African Rice Development Authority (Patrick M. Kormawa); African Highlands Initiative, Ethiopia; Millennium Project – Dr P. Mutua; World Economic Forum-Business Alliance to Reduce Chronic Hunger; International Centre for the Improvement of Maize and Wheat – Hugo de Groote; West Africa Rice Development Authority – Rita Agboh-Noameshie; International Institute for Tropical Agriculture – Dr Hell and Busie Dixon; World Fish Centre, Cairo – Simon Heck; ICRISAT – Richard Jones; International Centre for underutilized Crops – Hannnah Jaenicke

**International and Regional Agricultural Research Centers:** CIMMYT, Kenya: Hugo de Groote, Mirjam Pulleman; CIP, Kenya: Charles Crissman; ICRAF, Kenya: Frank Place, Steve Franzel, Noordin Qureish, Bashir Jama, Richard Coe, Keith Shepherd; ICRISAT, Kenya: Ade Freeman; ICRISAT, Mali: Tabo; ICRISAT, Niger: Abdoulaye and Mahamane; ICRISAT, Zimbabwe: John Dimes; IITA Ibadan, Nigeria- Abdou; IITA Uganda: Piet van Asten, Cliff Gold, Suleiman Okech; ILRI, Kenya: Patti Kristjanson, Steve Staal, Philip Thornton, Mario Herrero, Dannie Romney; ICIPE: Zia Khan; AATF: Mpoko Bokanga; West African Rice Development Authority – S. Oyke; International Institute for Tropical Agriculture – Alene Arega, David Chikoye, Robert Abaidoo

**NGOs:** FIPS, Kenya, RF project on soil fertility gradients and site-specific soil fertility management; SACRED-Africa, Kenya, RF soybean project; Diobass and Food for the Hungry, D R Congo, DGDC project on legume integration in systems in Central Africa; DGDC project on banana management in Central Africa; UR2PI, Congo ,ANR/MICROBES project on microbial observatories for the management of soil ecosystem services in the tropic; Hunger Project/Burkina Faso; Groupe d'Action pour le Développement Communautaire (GADEC); Tambacounda / Senegal; Union des Groupements Paysans de Mekhe (UGPM/ Senegal); Projet Intrants/Niger; Groupement Nabonswendé de Tougouri / Burkina; Entente des Groupements Associés de Toubacouta (EGAT) / Senegal;Caritas-Kaolack/Senegal; AfriAfya (Caroline Nyamai-Kisia); CRS (Tom Remington); Farmers' Own Trading Company (Tony Margetts)
Africa2000 Network, UEEF, Africare (Uganda)

**The Private Sector:** TSBF-Africa is also working with a wide array of private sector and farmers associations. Some of those involved in Kenya as an example 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;

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, Kenya). AMFRI farms (Uganda), Olivine Industries, Harare, Reapers (Pvt) Ltd, Harare