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

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Rationale

Strategic and component research to date has been conducted largely at the plot or field scale, where interactions among various agricultural enterprises are seldom considered. Although TSBF-CIAT's strength remains at the plot level, the diversity of forces impinging on the plot naturally draws attention towards a hierarchical systems-based approach. The next generation of work will be at higher scales, particularly the farm and landscape scales. The rationale for working at the farm scale is the need to improve nutrient use efficiency through better allocation of the limited organic and inorganic resources among different enterprises, taking into consideration inherent soil variability within the farming system. Inadequacies in supplies of both organic and inorganic nutrients have created strong fertility gradients even within the smallest farms. Smallholder farmers typically remove harvest products and crop residues from their food producing 'outfields' and devote their scarce soil inputs to their smaller market 'infields', resulting in large differences in soil productivity over time between these two field types. Understanding how to manage the limited nutrient supplies across such fertility gradients is a key component in raising productivity in fields of staple crops.

Interest in the quality and health of soil has grown with the recognition that soil is vital not only to production of food and fiber, but also the smooth functioning of the ecosystem, and overall environmental stability. Agriculture needs economically viable and ecologically sound soil management practices that provide sufficient food and yet maintain environmental stability, ecological integrity, and the quality of essential resources. Strategies for sustainable management include conserving essential soil components, minimizing erosion, balancing production with environmental needs, and making better use of renewable resources. In this regard, soil health is a major indicator of sustainable management. Criteria for indicators of soil health are useful in defining ecosystem processes and sensitivity to managements and climatic variations and in integrating physical, chemical and biological soil properties. Numerous experts *e.g.* agricultural specialists, producers, conservationists, and policy makers, etc might extensively need those criteria and data for sustainable management practices. Although soils gain certain biological, chemical and physical properties within a given ecosystem, the ultimate determinant of soil productivity, sustainability and health is the land manager. The assessment of health and quality of soil is the primary indicator of sustainable management and environmental remediation. Examples given include approaches for assessing soil health, defining the economic and environmental sustainability of land management practices, and translating our science into practice.

Environmental services, particularly hydrological response and soil erosion control, can be managed effectively only at larger landscape scales. Research at the watershed scale is critical in the tropical regions, and given that projections indicate that eastern and southern Africa, and Central America will be critically short of water in the coming decades, extending TSBF-CIAT's research agenda into this area is warranted. Research projects funded by the Water and Food Challenge Program for the Volta in West Africa basins and on the Quesungual systems in Central America offer the opportunity to address constraints related to water and its interaction with soil fertility and other environmental challenges. Research conducted with partners in regional networks and consortia and the GEF-UNEP funded BGBD project will contribute to development and promotion of sustainable land management (SLM) practices.

To see ISFM principles applied by a wide variety of actors at scales ranging from the farm level to the national or continental levels means addressing the problems of how to use knowledge gained at one scale to interpolate or extrapolate knowledge for decision making at another scale.

In recent years TSBF and other natural resource management programs have confronted the challenge of extending their research findings for successful impact on farm. Conveying the numerous components and complexity of interactions involved in natural resource management is very different from the extension of new crop varieties through demonstration plots. In the latter, the results are quick and easy to see, whereas the results and possible benefits of natural resource management strategies may not be readily apparent and often take time to manifest themselves. The rise of the participatory movement in agricultural research has also emphasized the importance of responding to farmers' perceptions and needs rather than assuming that formal science provides solutions in its own right.

Key research questions

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

Output target 2008

- ***Methods for socio-cultural and economic valuation of ecosystem services developed and applied for trade-off and policy analysis used in at least in 2 humid and 2 sub-humid agroecological zones***

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]

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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 47)**. 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 47: Total labor use across all farm operations (Person days /ha)

	Treatment		
Cropping system	+N	-R-N	**SED**
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 (KShs./ha)

The result of total labor cost for crop production is presented in **(Table 48).** 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 48: Total labor cost across all farm operations (KShs./ha)

	Treatment[@]		
Cropping system	+N	-R-N	**Mean**
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 49).** 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 49: Total costs across all inputs (labor, seeds, fertilizer) (KShs./ha)

Cropping system	**1.**	**Treatment[@]**			**2.**		**4.**	
	6.	+N	7.	-R-N	**3.**	**SED**	**5.**	**Mean**
Soybean-Maize intercrop (AS)	8.	19910	9.	11660	10.	376	11.	15785
Sole Maize crop (MC)	12.	17218	13.	8871	14.	336	15.	13045
Sole Soybean crop (ML)	16.	17210	17.	9279	18.	307	19.	13245
Mean	20.	18113	21.	9937	22.		23.	

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 50).** 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 50: Gross revenue across all outputs (Maize and Soybean) (KShs./ha)

	Treatment[@]			
Cropping system	+N	-R-N	**SED**	**Mean**
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 51)**. 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 51: Gross margin (KShs./ha)

Cropping system	Treatment[&] +N	-R-N	SED	Mean
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 52)**. 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 52: Net labor productivity (KShs./Person day)

Cropping system	Treatment[@] +N	-R-N	Mean
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

Output target 2008

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

Work in progress

African regional workshop on sustainable use of Agricultural Biodiversity was held in December 2006. in which the CS-BGBD project participated and gave a presentation in relation to the sustainable use of the soil biological resources. CBD/FAO published the report in 2007. News bulletins were issued by IISD that extensively covered the regional workshop. The meeting aimed at adopting an agenda for the sustainable use of Agro-biodiversity and the aim of CSM-BGBD was to get soil biodiversity explicit recognized as an important component of agro-biodiversity. In the end recommendation will find their way into official text and action programs adopted by the parties of the CBD. In a number of countries CSM-BGBD project participants are member of the national committees on BGBD and or are being consulted by these committees and play an actively role in workshops and events organized at national level in relation to CBD related issues.

Output target 2009

- ***30% of partner farmers in pilot sites used SLM options that arrested resource degradation and increased productivity in comparison with non-treated farms***

- ***75% of stakeholders in target areas have an improved capacity for collective action and local policy negotiation and implementation of integrated land use practices using integrated agricultural research for development***

- ***The benefits of community-based watershed management innovations quantified and disaggregated by wealth and gender***

Output target 2010

- ***Scale-up research on soil fertility gradient to farm and landscape levels by conducting one or two carefully designed, integrated studies in collaboration with other CIAT scientists***

Completed work

The Impact of Land Tenure on Maize Crop Response under Small-scale Farming Systems in North-east Zimbabwe: Paper presented at "Utilization of diversity in land use systems: Sustainable and organic approaches to meet human needs", Tropentag, October 9-11, 2007, Witzenhausen.

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After Zimbabwe's independence in 1980, the land owned by white farmers was soon started to be seized by the rural population. In 1997, a land reform was instituted, and nowadays most of the "white" farm land is redistributed and parcelled into many smallholder farms. However, due to continuous crop cultivation without adequate fertilization and limited soil conservation, crop yields abruptly declined in Zimbabwe, leading to reduced food security at national level. The objective of the present study was to identify which factors are limiting maize productivity at village level along three different land tenure classes, i.e. Communal Area (Kanyera), Old Resettlement Areas (Chomotumora) and New Resettlement Areas (Hereford), in North-East Zimbabwe. The study focused on maize, the main staple crop in the region, and further consisted of two main phases: (i) Soil sampling and grain yield assessment in fields from the three villages and, (ii) Questionnaires regarding land use and, input use. Nine farmers were selected in each village according to wealth status and production objectives. These twenty seven farmers were interviewed to carry out an analysis of the main variables affecting maize production according their land tenure systems. Detailed information was collected regarding farm household, soil characteristics, field management and maize productivity. Data retrieved during these two phases were evaluated by a multiple regression analysis showing the main factors influencing maize production.

In the communal areas of Kanyera, the main factor was the inputs of organic and mineral P fertilizer. In addition, as soil organic matter and available P decreased with distance from homestead most of the time. In the new resettlement areas of Hereford, the main factor controlling maize productivity was the amount of organic and mineral N and P fertilizers applied according the farmer income. In the old resettlement areas of Chomotumora, the main factor affecting productivity was soil degradation due to soil management during the last 20 years. The study aimed to provide a basis to develop a methodological tool to assess, improve soil quality, land use and management of the newly established smallholder farms in Zimbabwe, in the future.

Work in progress

Managing soil fertility diversity at farm and village scales to enhance resource use efficiencies in smallholder farming systems: a case from Murewa District, Zimbabwe.

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In sub-Saharan Africa smallholder farming systems, differences in soil fertility brought about by inherent factors and differential resource management by farmers have led to considerable variability in crop yields and nutrients use efficiencies. Therefore, resource allocation strategies appropriate for different zones of fertility are required to increase overall crop production and resource use efficiency at farm and village levels. We applied a simple dynamic model (FIELD) to explore short- and long-term consequences of different strategies for use of limited nutrient resources (mineral N and P fertilizers and cattle manure) available to farmers in a case study village in Murewa District, Zimbabwe. Simulations were done for farms with different access to resources for crop production on each of the two main soil types found in the area: granitic sandy and dolerite-derived red clay soils. Wealthy farmers were identified as those who owned cattle and had large farms (>2.5 ha). FIELD simulated a rapid decline in soil organic C (SOC) and maize yields when native woodlands were cleared for maize cultivation without fertilizers inputs coupled with removal of crop residues. This is typical management on depleted plots belonging to poor farmers and plots distant from homesteads on wealthy farms, covering 55% of the area under cultivation in the village. On each soil type under study, long-term (>30 years) application of manure at 5 and 3 t ha-1 led to the creation of existing high and medium soil fertility zones respectively. On the sandy soil, analysis of different resource allocation strategies showed that nutrient resources on wealthy farms were used most efficiently in the short-term when manure was applied to plots with medium fertility and mineral fertilizers to the most fertile plots (FZ1 and FZ2). This strategy however, resulted in a decline of aggregate farm maize production by 1.4 t after 5 years, as yield gains with manure on the FZ3 were not able to compensate for yield decreases with mineral fertilizers alone on FZ1 and FZ2. Maize response to addition of N and P fertilizers was poor on the depleted soil fertility and at least 5 t manure ha-1 yr-1 was required over several seasons to restore productivity. Redistribution of the 305 t of manure available per year in the village to the depleted soil fertility zone led to an increase of maize yields by 40 t above the current management, mainly due to increased productivity on medium and high soil fertility zones with mineral. The high fertility zone contributed most to maize production at the village level, although it was <25% of the cultivated area.

The poor farmers on the sandy soil were the only group that could not produce sufficient maize for household consumption, due to a combination of poor soils and small farm sizes. Model results applied at the farm and village level indicated that variability in soil fertility due to management history (linked to wealth status of households), the type of soil cultivated, and farm size are key factors that affect resource use efficiencies and the livelihoods of farmers.

Sustainable soil fertility management in small holder farming systems in Murewa District, Zimbabwe: fitting soil fertility technologies and socioeconomic niches within farms and villages.

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Recent studies have established strong gradients of decreasing soil fertility with increasing distance from homesteads in intensive smallholder cropping systems. There still remains a gap in knowledge scaling out implications of soil fertility gradients from the farm to landscape level, and assessing their impact on food security and income. Multi-locational experiments have been established to assess the effects of soil type, distance from the homestead and socio-economic wealth status of the farmers on response of maize (Zea Mays L.) and soyabean (Glycine Max (L) Merr) to phosphorus, calcium, magnesium and micronutrient fertilization at the landscape level. Results from this study will be used to develop soil fertility management strategies targeting different scales, ranging from farm to the landscape level

Progress towards achieving output level outcome

- *Principles of sustainable land management integrated in country policies and programs*

This output is aimed at restoring degraded agroecosystems to economic and ecologic productivity, while recovering the function of such lands as providers of a range of ecosystem goods and services. Tools developed over the past few years are starting to be used by farmer associations to better plan the use of their land. An example is the use of NUANCES.

The interactions between the policy environment and the socio-cultural and economic condition have been addressed through studies that look for enabling environments. By this the support systems are meant to address financial and technological infrastructure as well as the extension services for scaling out win-win land use and management alternatives. Research showed that specific strategic alliances are required for the poorest farmers to benefit from financial mechanism that would allow them to adopt new technologies.

Progress towards achieving output level impact

- *Reversing land degradation contribute to global SLM priorities and goals*