4.4 OUTPUT 4. Improved rural livelihoods through profitable, diverse and intensive agricultural production systems

Rationale

Intensification and diversification of smallholder agricultural production is needed to meet the food and income needs of the poor and cannot occur without investment in natural resource management, especially soil fertility. Investing in soil fertility management is necessary to help households mitigate many of the characteristics of poverty, for example, by improving the quantity and quality of food, increasing income, and resilience of soil productive capacity. Access to multiple stress-adapted and improved crop varieties and multi-purpose legume species, improved soil and water conservation practices and improved targeting to different categories of farmers, are a few examples of existing interventions.

Investment in improving soil fertility is not constrained by a lack of technical solutions *per se* but is more linked to lack of access to; information for improved decision making and analyzing trade-offs; inputs (e.g. fertilizers, credit and improved germplasm) and profitable markets.

Technical innovation to improve poor people's agricultural productivity can link the goals of improving small farm competitiveness, increasing assets, nutrition and income to the sustainable management of the natural resource base.

Milestones

- By 2006, cereal-legumes and livestock systems, with nutrient use efficiency as an entry point, tested and adapted to farmer circumstances.
- By 2006, Quesungual and other related agroforestry systems, with water conservation as entry point, including crop diversification strategies, tested and adapted to farmer circumstances.
- By 2006 increase farm income and production in at least 20 pilot sites in at least 6 countries.
- By 2007, banana and cassava based systems, with the relation between pest, diseases and ISFM as entry point, including novel cropping sequences, tested and adapted to farmer circumstances.
- By 2008 improved production systems have triple benefits of food security, income and environmental services.
- By 2008, farmers are testing and adapting improved production systems in at least 15 sites in 5 countries.
- By 2010, validated intensive and profitable systems are being demonstrated, promoted by partners and adopted by farmers in 10 countries.

Highlights

TSBFI-Africa

- Bananas in central Kenya and Uganda are a cash crop and most bunches are transported out of the region (mostly to Nairobi and Kampala respectively), with probable enhancements in soil nutrient depletion as bananas move away from a food security towards a cash crop.
- Dual purpose, promiscuous soybean varieties, produced in West Africa, retained these traits under Western Kenya conditions as shown by increases in nodulation, biomass production and grain yield but only after application of P fertilizer. Such varieties have great potential to enhance the soil fertility status when included in rotations as they contribute to an increase in net amount of N in the soil.
- The local demand for soybean in Uganda is estimated at about 100,000 MT most of this being consumed in the animal feed sector and oil extraction with little utilization in the food industry. The regional demand for soybean from Uganda is estimated at 150,000 MT annually most of which being

utilized in Kenya for animal feeds and oil extraction. Growth in demand of soybean is positively correlated to growth in consumption of livestock products such as meat, eggs and milk for which feeds are manufactured.

TSBFI-Latin America

- Fertilizer N equivalency of Cowpea, Mucuna and Vigna surface legume mulches was at least 67 kg N ha^{-1} in a maize-based experiment planted in San Dionisio, Nicaragua.
- Short-term tangible benefits, innovative technology, leadership and community participation are the most important drivers influencing in the development of Bright Spots of improved land and water management.

4.1 Evaluate system productivity using participatory approaches

TSBFI-Africa

Completed Work

Improving soil fertility through the use of organic and inorganic plant nutrient and crop rotation in Niger

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Niger is one of the poorest countries in the Sahelian zone of West Africa where soil fertility and rainfall are the most limiting factors for crop production. The majority of the people in this region depend on subsistence agriculture for their livelihood. The population pressure has decreased the availability of arable land and the use extended fallow periods to restore soil fertility is not possible. There is therefore a need to address these constraints through research on long-term soil fertility improvement to ameliorate the farmers' livelihood. Research results have shown that yields can be increased up to five times with the improvement of soil fertility using a combination of soil tillage, organic and inorganic fertilizers than under traditional practice. Crop yields have also been shown to increase substantially using rotation of cereals with legume or intercropping. Yields of pearl millet can be doubled following cowpea as compared to continuous pearl millet cultivation. These combinations can improve soil properties such as Organic carbon content, Cation Exchange Capacity (CEC) and pH. There is however a constraint to the applicability of combining inorganic and organic fertilizers due to the high costs of inorganic fertilizers and the low availability of organic fertilizers at the farm level. But this constraint can be addressed by incorporating grain legume production such as cowpea into the cropping system. The grain, which has high market value, can be sold for buying external inputs such as fertilizer and fodder used for animal feeding. The use of external inputs will result in an increasing biomass at farm level, which increases the crop residue for mulching to mitigate land degradation and increase productivity.

On-going Work

Evaluation of general characteristics of banana production systems in Kenya and Uganda through participatory rural appraisal

J Jefwa and B Vanlauwe

Banana production in Kenya and Uganda has not been matched by corresponding interventions in post harvest and marketing. To bridge the gap between production and markets, the capacity of farmers to access and produce bananas for specialty markets has to be improved. Major concerns in banana production systems are yield declines, reduced plantation life and shifts to annual crops, hence raising concerns in food security and sustainability in the region. Pests and diseases and soil fertility are cited as the main contributing factors in yield decline. Little progress has been made on Integrated Soil Fertility Management (ISFM), yet there is growing evidence that the extent of damage caused by pests and diseases is influenced by soil fertility.

The current project is implemented in the main banana growing region in Uganda in Mujwa and Mugwanjura cells (smallest administrative unit equivalent to sub-locations in Kenya) in Butare Parish, Ntungamo district. The two cells are major producers of cooking and desert bananas, main banana collecting centres to Kampala and Kabale, pests and disease constraints are prevalent, decline in production and has soil related problems such as soil runoff. The target site in Kenya is Maragua district, the leading banana producer in the central province. Both Desert and cooking bananas are grown with approximately 20% of bananas grown from tissue cultured materials. The study is being undertaken in four sub-locations (smallest administrative unit), Gakoigo, Ichagaki, Mbugwa and Kianjiru-ini.

A PRA survey was undertaken (i) to introduce the project to the target farming communities, (ii) to collect data and research information that is consistent with community needs and preferences as well as scientists, (iii) to gather information on farmer perception that will be used to increase understanding by following up with scientific analysis, and (iv) to collect data that will guide into the collection of baseline data, during a site characterization work, on the role, production level and constraints of banana within the farming systems that will finally be used in selecting representative farms for detailed monitoring.

The PRA data showed that banana was ranked as the most important food and also cash crop in Kenya (Table 36). Banana was sold for food (cooking and desert) and as beer. In Kenya, maize and bean farming was ranked first by all the community members because of its perceived importance as a staple food for the people of the area while banana farming was ranked second due to its significance in providing family income as well as meeting food needs of the community.

Table 36. Ranking of the most important food and cash crops.

	Kenya		**Uganda**	
	Food	Cash	Food	Cash
Bananas	4	2	1	2
Sweet potatoes	--	--	2	--
Beans	2	5	3	3
Finger millet	--	--	4	--
Maize	1	3	--	--
Tomatoes	3	4	--	--
Coffee	--	--	--	1
Tea	--	1	--	4

Framers mentioned road network, marketing, declines in yield which they attributed to pests and diseases and soil related problems (Table 37). In Kenya Lack of credit to purchase manure and fertilizer was a major constraint. Soil fertility and pest and diseases were also major constraints in Kenya.

Table 37. Production constraints of banana in Uganda and Kenya

Rank	**Uganda**	**Kenya**
1	Infrastructure	Lack of credit
2	Pests and diseases	Pest and diseases
3	Marketing	Soil fertility
4	Land availability	Water stress
5	Technical advice	Lack of planting materials
6	Human diseases	Lack of technical skills
7	Labour	Poor prices
8	Tools	Poor infrastructure
9	Seed (planting materials)	Exploitation by middlemen
10	Yield decline	Theft of bunches
11	Declining soil fertility	Difficult bolting

In Kenya, soil fertility (declining or poor) was consistently ranked as being among the top five constraints to banana production (Table 37). In most cases lack of capital or credit was ranked highest because farmers need money in order to eliminate production constraints with soil fertility being one of the most prominent along with lack of water, and diseases and pests. The farmers in Kenya had a very clear perception of the fertility problem as demonstrated by the indicators of declining soil fertility listed during the survey. The following were used as indicators of declining soil fertility (1) declining yields (2) change in soil color (3) breakdown of soil structure (4) shift in weed species composition (5) surfacing of banana corms on the soil surface and (6) other indicators being stunted growth, smaller bunches, yellowing of leaves and production of fewer suckers. In Uganda farmers were aware of soil related problems but could not directly link them with soil fertility. Although ranked last, it is evident from soil management measures such as application of manure and mulch and contour terracing that there are soil related constraints.

Strategies as adopted by farmers for the control of pests and diseases (Table 38) in Uganda are: (i) banana wilt disease attacks desert bananas and is controlled by uprooting and chopping the infected banana and replacing it with another cultivar, (ii) Kiriro attacks all cultivars and is controlled by uprooting and destroying the infected plant, (iii) banana weevils attacks plantains and is managed through de-trashing (60 cm radius from the base), chopping pseudostem, uprooting old corms and weeding, and (iv) the toppling disease attacks all bananas and is controlled by propping (bunch support) and application of manure. Strategies as adopted by farmers for the control of banana weevil and nematodes in Kenya: application of ash, trapping, rouging removal of infected plants, burning around the plant, application of detergents (omo), chemical (Furadan), application of green or animal manure, kerosene, change of cultivar, application of hot water, application of hot pepper and field sanitation.

Table 38. List of diseases named by farmers.

Kenya		**Uganda**	
Pests	Diseases	Pests	Diseases
Slugs	Panama	Weevils	Banana wilt
Banana weevils	Sigatoka	Nematodes	Kiriro
Banana beetle	Cigar-end rot		
Thrips			
Nematodes			
Birds			
Aphids			

In both countries, it was observed that the export of nutrients in banana parts from the farms was more intensive. Banana in central Kenya and Uganda is a cash crop and most bunches are transported out of the region (mostly to Nairobi and Kampala respectively). The pseudostems are also used as fodder mostly for zero-gazed cattle. Even though the resultant manure is predominantly used to fertilize bananas, a significant part of the nutrients ends up in milk and meat. This means that the region can benefit from a well designed fertilization regime based on scientific data, taking into consideration the loss of nutrients from the farm with each harvest. This observation will hopefully be addressed in the nutrient omission experiments.

The data from the PRA survey is being used to characterize farming systems and collect baseline data on the role, production levels and constraints of banana within the farming systems. The site characterization data will finally be used to select representative farms for detailed monitoring. There is still a gap on fertilizer application in banana production; hence a nutrient omission trial is being established to identify the nutrients limiting banana production, the nutrients required, the critical and optimum nutrient concentrations and the potential production and recovery rates of fertilizers. Arbuscular Mycorrhizal Fungi have potential to improve performance and control diseases and pests of tissue culture bananas in poor soils. A green house mycorrhizal dependency experiment is in progress to evaluate the response of different banana cultivars to different AMF isolates.

Evaluation of the most limiting nutrients for banana production in Kenya and Uganda
J Jefwa and B Vanlauwe
Although much soil fertility related studies in EA highland banana systems have been conducted, there is a lack of basic knowledge on how much nutrients the AAA-EA banana plant requires, what its potential production is under well fertilized conditions, what nutrients are limiting plant growth in different areas, and what how much fertilizer needs to be applied to achieve the economic optimum for a certain target yield (i.e. target yield will largely depend on pest and disease pressure) and market price. The objectives of the current work are (i) to identify what nutrients are limiting highland banana production on the trial sites, (ii) to determine what the nutrient requirements are of highland bananas, (iii) to identify/confirm what the critical and optimal nutrient concentrations are in different plant parts of highland bananas, (iv) to estimate potential production of highland cooking banana, and (v) to determine recovery rates of fertilizers in highland cooking bananas, in order to allow the calculation of cost-benefits of different fertilizer recommendations.

The trials will be implemented in two sites in Uganda (Ntungamo and Kawanda) and one site in Kenya (Maragua). The treatment structure of the trial is presented in Table 39. While most of the treatments aim at determining the most limiting nutrients and responses to applied nutrients, 2 treatments (9 and 10) are investigating in a preliminary way how pest status affects nutrient uptake.

Table 39. Treatment structure of the on-station limiting nutrient trials for bananas.

Treatment:	1	2	3	4	5	6	7	8	9	10
N	X	-	-	½	X	X	X	X	-	X
P	X	-	X	X	-	X	X	X	-	X
K	X	-	X	X	X	-	½	X	-	X
Micronutrients	X	-	X	X	X	X	X	-	-	X
Pesticide	X	X	X	X	X	X	X	X	-	-

The objectives of T1-T8 are (i) to determine soil nutrient supply, (ii) to determine limiting nutrients, and (iii) to determine slope of the steep part of the response curve for N and K. The objective of T9-T10 is 9i0 to determine how nutrient uptake/recovery is affected by pests and (ii) to see how fertilizers affect plant pest status. The trials have been established during the short rainy season of 2004 and are expected to run for at least 3 ratoon crops.

TSBFI-Latin America

Completed Work

Yield response to fertilizer N and legume cover crops
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During the short rainy season of 2003/2004 an N fertilization and cover crop experiment was conducted at the Calico watershed in Nicaragua. The experiment contained 10 treatments with 3 replications: 6 rates of urea-N (0 - 200 kg ha^{-1}), split-applied in two equal applications at 25 and 55 days after planting, and 4 legume cover crops (cowpea, mucuna (*Mucuna pruriens*), rice bean (*Vigna umbellata*) and common bean), grown for 75 days and cut for surface mulch before planting corn. A uniform rate of fertilizer P was applied at planting of legumes and all fertilizer N plots.

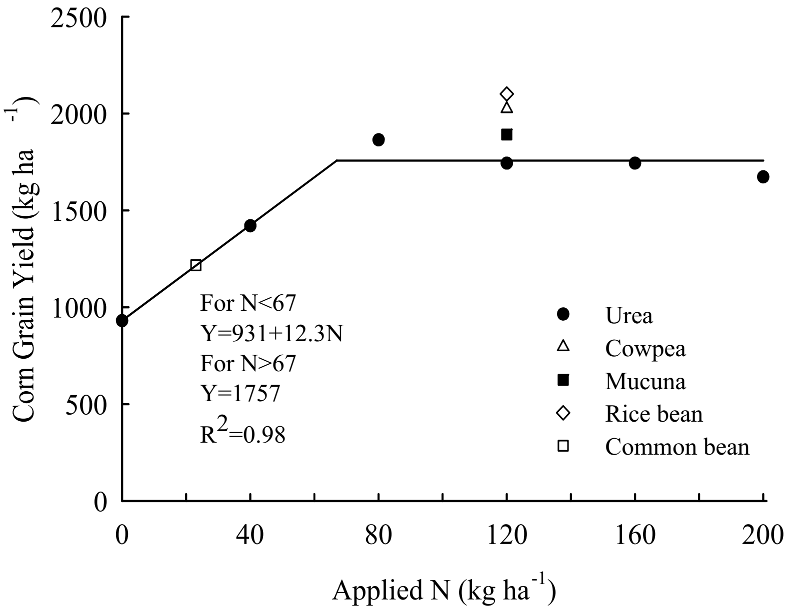

Figure 32. Yield response of corn to nitrogen applied as urea or through plant residues of five legume cover crops in an Inceptisol of San Dionisio, Nicaragua.

Corn grain yield increased with fertilizer N up to 67 kg ha^{-1} (Figure 32). The low yield plateau of 1.8 t ha^{-1} is attributed to limited rainfall during the September-January secondary growing season. Corn yields with 3 of the legumes (cowpea, mucuna and rice bean) exceeded the yield plateau by 0.1to 0.3 t ha^{-1}. Thus fertilizer N equivalency of these surface legume mulches is at least 67 kg N ha^{-1}. Corn yields with the surface mulch of post-harvest common bean residues was 1.2 t ha^{-1} and the urea-N equivalency was estimated as 23 kg ha^{-1}.

On-going Work

4.2 Develop profitable agro-enterprises linked to identified market opportunities (contribute production technologies/backstopping to agro-enterprise development within ERI project)

TSBFI-Africa

Detailed reporting of activities relating to the work of TSBFI in linking to the projects of the Enabling Rural Innovation team in support of activities in management of natural resources, farmer experimentation etc are highlighted in the IPRA Annual Report.

Published Work

Smallholder Farmers to Markets in East Africa: Empowering Mountain Communities to Identify Market Opportunities and Develop Rural Agroenterprises.
Sanginga, P.C., Best, R., Chitsike, C. Delve, R.J., Kaaria, S., and Kirkby, R. 2004.
Linking Mountain Research and Development 2004 24 (4) 288–291
The livelihoods of mountain farmers are often constrained by poor access to markets and limited entrepreneurial skills for adding value to produce. Research and development organizations have now recognized that improving market access and enhancing the ability of resource-poor mountain farmers to diversify their links with markets are among the most pressing challenges in mountain agriculture. What

is not so obvious is how to link small-scale farmers in marginal areas to growth markets, and how to develop methods and approaches that effectively integrate research, market access and development of community agroenterprise. The present article highlights the key steps and procedures in building capacity among farmers, farmers' groups, and communities, to identify and evaluate market opportunities, develop profitable agroenterprise, and intensify production, while sustaining the resources upon which livelihoods depend. This approach, known as Participatory Market Research (PMR) a component of the Enabling Rural Innovation (ERI) initiative is being implemented and further refined by the International Center for Tropical Agriculture (CIAT) in collaboration with research and development partners in Uganda, Malawi, and Tanzania.

Completed Work

Legume management: From process to market-led research
R. Delve.
A paper presented at the Rockefeller Soils Grantees Workshop 2004, Nairobi, Kenya
The paradigm of involving farmers in research is based on strong evidence that enhancing farmers technical skills and research capabilities, and involving them as decision-makers in the technology development process results in innovations that are more responsive to their priorities, needs and constraints. Linking process research and the technology development process to market opportunities has the potential to promote links between investment in natural resources, markets, and adoption of technologies. Market orientated agriculture for reducing poverty and environmental degradation needs to centre on three related paradigms; strengthening biological processes in agriculture (to optimize nutrient cycling, minimize external inputs and maximize the efficiency of their use); building farmer's capacities (to learn and innovate focused on improving livelihoods through market opportunity identification and the management of natural resources); and developing forward and backward linkages (between natural resources, production and markets). Examples of TSBFs and CIATs legume research in understanding processes, targeted germplasm development, adaptive testing of technologies and dissemination strategies will be used to show the evolution of legume research for ISFM and how increased market orientation can lead to increased adoption of improved technology options, investment in natural resource management strategies and provide valuable feedback for the research process.

Adding Value to Soil Fertility Research with Participatory Market Opportunities Identification: A Framework for Mainstreaming Market-led ISFM Research for Development
Sanginga, P.C., Kaaria, S., Muzira, R., Delve, R.J., Kankwatsa, P., Kaganzi, E., Sangole, N. and Pali, P.
Nutrient Cycling in Agroecosystems(in review)
The paper examines four hypotheses underlying market-led integrated soil fertility management (ISFM) research: (i) that linking smallholder farmers to profitable market opportunities will provide incentives for the adoption of ISFM technologies; and (ii) that the use of ISFM technologies will improve the competitiveness and profitability of agro-enterprises. Alternative hypotheses are that (iii) market orientation will lead to further depletion of soils; and that (iv) small-scale African farmers will not use mineral fertilizers. Results from case studies in Malawi, Uganda and Tanzania provide evidence that better market opportunities provide incentives to farmers to invest in replenishing soil fertility. But they need research and development to build their capacity to experiment and innovate to make agriculture more productive and competitive. The paper outlines a novel approach for demand-driven and market-led ISFM research. This approach termed the Resource-to-Consumption (R-to-C) offers a practical framework to link ISFM research to market opportunities identification in a way that empowers farmers to better manage their resources and offers them incentives to invest in soil fertility improvement. The R-to-C approach uses participatory processes to build the capacities of farmers, farmers' groups and communities to identify and evaluate market opportunities, develop profitable agroenterprises, intensify production through experimentation that create a demand for ISFM technologies. Mainstreaming market-

led ISFM requires significant changes in scientist's roles and approaches to research. These should include building and managing effective partnerships, linking technology development to market opportunities, stimulating farmers' experimentation, supporting efficient input markets, building capacity at different scales, and influencing policy change.

Soybean varieties, developed in West Africa, retain their promiscuity and dual-purpose nature under Western Kenyan conditions

B Vanlauwe, J Mukalama, R Abaidoo and N Sanginga

Entry points that give farmers immediate benefits are required to reverse the ever-declining soil fertility status of a substantial area in sub-Saharan Africa. In West Africa, dual purpose, promiscuous soybeans that produce a substantial amount of grains and leafy biomass and do not require inoculation with specific *Rhizobium* (rhizobia) strains were developed and have increased resilience of farming while providing income to farmers. These crops could be a potential entry point for soil fertility improvement in Western Kenya, provided they retain their promiscuity and dual-purpose character in this new environment. The major objective of this work was to quantify nodulation, biomass production and grain yield characteristics of a set of best-bet dual purpose varieties relative to a locally available variety at two sites (Vihiga and Siaya Districts) in Western Kenya. In presence of P, most promiscuous soybean varieties showed substantial improvements in nodulation (19 to 165 nodules per 0.5m of soybean) than the local variety (3 to 13 nodules per 0.5m of soybean). While grain yield was for all but one variety as good as the local control (845 kg ha^{-1}, on average), nearly half of the varieties produced significantly higher amounts of biomass at 50% podding than the local variety (865 kg ha^{-1} in Siaya and 1877 kg ha^{-1} in Vihiga). Increases in nodulation, biomass production and grain yield were mainly observed after application of P fertilizer; in absence of P almost none of the varieties performed better than the local control for any of the measured characteristics. To fully exploit the potential soil fertility improving characteristics of these varieties, it will be necessary to facilitate availability of P fertilizer and to foster demand at the farm, community, and national level.

On-going work

Enabling rural innovation in Africa: An approach for integrating farmer participatory research and market orientation for building the assets of rural poor

Sanginga, P.C., Best, R., Chitsike, C. Delve, R.J., Kaaria, S., and Kirkby, R.

To be submitted to Agricultural Systems

Agricultural research and development organizations are increasingly under pressure to shift from enhancing productivity of food crops to improving profitability and competitiveness of small-scale farming, and linking smallholder farmers to more profitable markets. What is not obvious however, is how to make small-scale farming more market orientated, and how to effectively integrate participatory research approaches to marketing and agroenterprise development. This paper outlines an integrated approach for demand-driven and market-orientated agricultural research and rural agro-enterprise development. This approach termed Enabling Rural Innovation (ERI) offers a practical framework to link farmer participatory research and market research in a way that empowers farmers to better manage their resources and offers them prospects of an upward spiral out of poverty. ERI uses participatory processes to build the capacities of farmers' groups and rural communities in marginal areas to identify and evaluate market opportunities, develop profitable agroenterprises, intensify production through experimentation, while sustaining the resources upon which their livelihoods depend. The approach emphasizes integrating scientific expertise with farmer knowledge, strengthening social organization and entrepreneurial organizations through effective partnership between research, development and rural communities. By strengthening human and social capital, ERI encompasses effective and proactive strategies for promoting gender and equity in the access to market opportunities and improved technologies, and in the distribution of benefits and additional incomes.. Results of action research applying the ERI approach in pilot sites in Malawi, Uganda and Tanzania show that small-scale farmers are not always attracted by higher economic returns. Rather they use a range of economic and non-economic criteria for selecting their existing crops and livestock for new markets, as well as new crops for new markets. Evaluation of market opportunities stimulates farmers' experimentation to reduce risks, access new technologies, and improve the productivity and competitiveness of the selected enterprises. Lessons learned suggest that building and sustaining quality partnerships between research and development organizations, government, private agribusiness sector; and building necessary amount of human and social capital over a certain period of time are critical for achieving success in small- scale agroenterprise development. This however, requires that an explicit scaling up strategy be mapped out to link successful community processes to meso and macro level market institutions at the national and regional levels.

Evaluating the marketing opportunities for soybean and its products in Kenya, Uganda, and Tanzania

J Jagwe, B Vanlauwe

A regional soybean market study that includes Uganda, Tanzania, and Kenya has been implemented by Foodnet during June – September 2004. The purpose of the study is provide information that would benefit private sector stakeholders with the intention of investing in the soybean sub sector. To achieve this, the study reviews the various options for utilising soybean and the requirements for scaling up its production and utilisation in the target countries. The study also explores the market opportunities that can be seized by these countries in regards to its competitiveness in soybean production in the East African region.

The Ugandan study comes at a time when there is increasing quest for information by the private sector on soybean production, utilization and market opportunities and this has been very much championed by a group of stakeholders. These include researchers from NARO and Makerere university faculty of Agriculture, private sector partners from Mukwano Industries Ltd., which is very interested in oil seeds, animal feeds and nutritive foods, the vegetable oil development project and a private soybean farmer association known as the National Soybean Network based in eastern Uganda. The methodology employed by the study was based on a rapid assessment technique using primary and secondary data. Primary data has been obtained through interviews with producers, traders, retailers and exporters. Secondary data was acquired by literature review and the collection of available statistics. Fare scrutiny of secondary data sources ascertains the current level of soybean production in Uganda to be 187,000 MT having risen steadily from 101,000 MT in 1999. The yield has remained more or less constant ranging between 1.0 MT to 1.2 MT per Ha. The production methods remain crude characterised by poor seed, no use of fertiliser, no use of chemicals and poor crop husbandry practices.

Findings from this study reveal that most soybean production in Uganda occurs in the East and northern parts of the country and the cost of production estimates range between US$ 168 to US$ 184 per MT with current production methods. It is believed that with better crop husbandry practices and better utilisation of production inputs, the cost is likely to come down significantly. A comparison with United States soybean producer prices which range between US$ 160 and $ 180 per MT indicates that soybean production in Uganda is quite competitive. The local demand for soybean in Uganda is estimated at about 100,000 MT most of this being absorbed in the animal feed sector and oil extraction and little utilisation in the food industry. The regional demand for soybean from Uganda is estimated at 150,000 MT annually most of which being absorbed into Kenya for animal feeds and oil extraction. Growth in demand of soybean is positively correlated to growth in consumption of livestock products such as meat, eggs and milk for which feeds are manufactured. This growth is conservatively estimated at 5% annually depending on growing urbanisation and change in consumer habits. Oil extraction is a possible option for soybean utilisation but the method of extraction is vital given that soybean has an oil content of only 19%. Solvent extraction is the most recommended method yet it requires high capital investments that cannot be justified by small volumes processed. Findings from the study reveal that oil is currently being extracted using mills and presses and only 10% level can be achieved. Recommendations highlight the importance of bringing together stakeholder in soybean sector to explore opportunities of utilisation of soybean given the latest innovations that have resulted into the release of better varieties.

4.3 Evaluate system resilience of improved production systems (processes)
Work Completed

TSBFI-Africa

Published Work

Improving the productivity of sorghum and millet and farmers income using a strategic application of fertilizers in West Africa

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Poor soil fertility is the most limiting factor to cereal production in West Africa. The situation has worsened in recent years as increasing population pressure led to shortened fallow periods and expansion of agriculture onto marginal lands. As a consequence of this, crop productivity continues to decline. Although soil fertility enhancing technologies are available, they are not being adopted by farmers due to the high costs and unavailability of inputs, and the inappropriateness of the fertilizer recommendations. Recently, ICRISAT and its research and development partners have developed strategies to improve soil fertility on smallholder farms. This strategic application of fertilizers consists of applying small doses of fertilizer in the planting hills of millet and sorghum. The combination of the strategic point application of fertilizer with complementary institutional and market linkages , through an inventory credit system (also known as 'Warrantage') offers a good opportunity to improve crop productivity and farmers income. In the past two years, ICRISAT, in collaboration with other International Agricultural Reseacrh Centers, National Agricultural Research and Extension Systems and NGOs have been evaluating and promoting this point application of fertilizer along with the inventory credit system in three countries in West Africa, namely Burkina Faso, Mali and Niger. Results showed that, on average, in all the three countries grain yields of millet and sorghum were greater by 43 to 120 % when using the hill application of fertilizer than with earlier recommended and the farmers practice. Substantial net profits were obtained by farmers using the inventory credit system.

Long-term effects of crop rotations with groundnut and fallow on soil mineral N, nitrogen recovery, soil properties and crop yields in the Guinean zone of West Africa

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The effects of annual fallow and groundnut (*Arachis hypogea*) on soil N, N fertiliser recovery and subsequent sorghum (*Sorghum bicolour*) and cotton (*Gossypium sp*) yields were studied using a 10-year (1993-2003) old field. The experiment was carried out on the agronomic research station of Farakô-Ba (4^{o} 20' West, 11^{o} 6' North and 405 m altitude), located in the Guinean zone of Burkina Faso. A factorial 4x8 design in a split plot arrangement was used. Three sequences of rotation were used as first factor. Cotton-Groundnut-Sorghum and Fallow-Sorghum rotations were compared to mono cropping of sorghum. Each main plot was split into 8 sub plots and 8 fertilizer treatments (mineral NPK fertilizer, NPK+Crop

Residues, NPK+Dolomite, PK+Crop Residues, PK+Manure, PK+Compost, PK and Control) were applied as second factor. Crop yields were significantly affected by fertiliser and crop rotations but interaction was not observed between the two factors. Mean annual yields of succeeding sorghum increased from 547 kg ha^{-1} in continuous sorghum to 912 and 1021 kg ha^{-1} in Fallow-Sorghum and Cotton-Groundnut-Sorghum rotations respectively. Soils of Fallow-Sorghum and Cotton-Groundnut-Sorghum rotations released more mineral N at sowing and increased fertilizer N use efficiency from 13 and 32 units respectively compared to continuous sorghum. Soil organic carbon increased from 0.36% in continuous sorghum to 0.39 and 0.54% in Cotton-Groundnut-Sorghum and Fallow-Sorghum rotations respectively. Compared to original soil, continuous sorghum and Cotton-Groundnut-Sorghum rotations decreased soil organic carbon. Only Fallow-Sorghum rotation maintained soil organic carbon, exchange acidity and base saturation at same levels like those of original soil. Unlike organic C and total N, highest quantities of available P (P-Bray I) were observed in soils of mono cropping of sorghum and lowest quantities were observed in Fallow-Sorghum rotation. Manure applications increased soil organic carbon, total N and available P. Except for Fallow-Sorghum rotation, all rotations increased aluminium saturation and decreased soil pH compared to original soil. Manure or dolomite applications decreased exchange acidity and maintained soil pH and base saturation at same levels like those of original soil.

Millet yield and water use as affected by amendment type in a traditional land rehabilitation technique – zai

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Due to the increased population pressure and the limited availability of fertile land, farmers in the desert margins increasingly rely on marginal or even degraded land for agricultural production. The farmers rehabilitate these lands with different technologies for soils and water conservation. Among these is the zai, an indigenous technology for land rehabilitation, which combines water harvesting by means of small pits and hill-placed application of organic amendments. To study the resource use efficiency of this technique in the context of the Sahel of Niger, an experiment was conducted at two locations on degraded bare lands in a farmer field from 1999 to 2000. In these experiments, the effect of organic amendment type (millet straw and cattle manure, 3 t ha^{-1}) and water harvesting (with and without water harvesting pit) on millet grain yield, dry matter production and water use were compared. The results revealed that on soil with moderate native fertility, with non-amended zai holes, it was possible to produce 400 kg ha^{-1} of millet grain yield compared to the average yield of Niger of 300 kg grain ha^{-}1, whereas on highly degraded soils with low native fertility, only 20 kg ha^{-1} were produced. In consequence under such conditions, addition of good quality organic amendment is prerequisite for the success of the technology. Grain yield amounting to 900 - 1100 kg ha^{-1} were produced in zai amended with cattle manure compared to 450 to 700 kg ha^{-1} with traditional flat planting with the same amendment. High drainage occurred in the zai treated plots particularly when amended with crop residue. On cattle manure treated plots, the wetting front remained at shallow depth suggesting high water use probably resulting from higher evapotranspiration. Here plant available water was often exhausted throughout the cropping period particularly on plots without zai treatment. On average 1.6 kg grain was produced per unit rainfall in the zai compared to 1 kg for planting on flat. The extra yield is an indication of a better use of the limited rain available in the sahelian conditions.

Stochastic Dominance Analysis of Soil Fertility Restoration Options on Sandy Sahelian Soils in Southwest Niger

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Poor fertility of sandy Sahelian soils remains one of the major constraints to pearl millet (*Pennisetum glaucum* L.) production in West Africa. On-farm trials under farmers' management were conducted in two rainfall zones of Niger in 1996 and 1997 to evaluate the risk characteristics of 6 soil fertility restoration options. Stochastic dominance analysis was used to compare fertilizer treatments tested. Results show that farmers' traditional method (no fertilizer control), Tahoua phosphate rock (TPR) alone applied at 13 kg P ha-1 broadcast, and a combination of TPR broadcast at 13 kg P ha-1 and single super phosphate (SSP) hill placed at 4 kg P ha-1 had the most desirable risk characteristics and are acceptable to risk averse decision makers in both rainfall zones. At current input-output price ratio, most fertilizer-using farmers would choose the combination of TPR broadcast and SSP hill placed. If the availability of single super phosphate was limited, some farmers would use Tahoua phosphate rock alone. The demand for risk efficient alternatives could significantly increase if farmers could bear less than half the fertilizer costs at current output price.

4.4 Identify drivers of farmer innovation for adaptation and adoption of technologies

TSBFI-Africa
Published Work

The adoption potential of biomass transfer and improved fallow practices in eastern Uganda: Determining profitable and feasible options from a farmer perspective
Pali, P.N., Delve, R.J. and White, D.
NARO conference paper, published in Uganda Journal of Agriculture, In press
Many advocate for the use of organic and inorganic fertilizers to restore declining soil fertility. However, most farmers cannot afford to purchase inorganic fertilizers because they are beyond the budgets of most households. Limited access to both credit and markets prevent their use. Organic fertilizers are also a difficult option as small farm size and insufficient labor availability often hinder their production. To estimate the adoption potential of integrated fertilizer options by smallholder farmers, on-farm maize productivity trials were conducted with 10 farmers. The study contrasted twelve treatments of different levels of inorganic fertilizer with improved fallow (IF) species (*Mucuna pruriens* and *Canavalia ensiformis)* and the biomass transfer (BT) species (*Tithonia diversifolia).* Analysis identified optimal combinations of organic and inorganic soil improvement options at varied price levels of inputs and outputs to assess the sensitivity of outputs to price fluctuations. Profitability and associated required investments (capital, labor, and land) of the options within a farm context (labor and capital availability) were assessed using a linear programming model. Tororo district in eastern Uganda served as a case study where farms have on average 2 ha of land in 2 enterprise scenarios. All IF and BT treatments are profitable and were sensitive to labor and maize price fluctuations. The optimal treatment for the farmers scenario was found to be the farmer's practice for the Tithonia treatment and 1.8 t ha^{-1} of Tithonia on 1.9 ha of land, whilst for the proposed practice scenario, with all labor activities costed and a high value of maize used, the optimal mix was found to be the integrated use of Tithonia (0.9 tha^{-1}) and 30 kg inorganic nitrogen on 0.42 ha and N-P-K inorganic fertilizer on 0.495 ha of land. The optimal net benefit in each case could be US $780.1 and US $713.5 respectively. The result showed that a soil improvement practice could be incorporated into the farmer's field using the farmers' usual farming practice with a higher net benefit and if using the integrate approach, the land size should be reduced for economical reasons.

How can smallholder farmer-market linkages increase adoption of improved technology options and natural resource management strategies?
Robert J. Delve and Ralph L. Roothaert
NARO conference paper, published in Uganda Journal of Agriculture, In press
The paradigm of involving farmers in research is based on strong evidence that enhancing farmers technical skills and research capabilities, and involving them as decision-makers in the technology development

process results in innovations that are more responsive to their priorities, needs and constraints. Linking the technology development process to market opportunities has the potential to promote links between investment in natural resources, markets, and adoption of technologies. Market orientated agriculture for reducing poverty and environmental degradation needs to centre on three related paradigms; strengthening biological processes in agriculture (to optimize nutrient cycling, minimize external inputs and maximize the efficiency of their use); building farmer's capacities (to learn and innovate focused on improving livelihoods through market opportunity identification and the management of natural resources); and developing forward and backward linkages (between natural resources, production and markets). In a multi-stakeholder coalition, CIAT and its partners are working in Malawi, Mozambique, Tanzania and Uganda to explore and understand how market orientation leads to improved NRM at the farm level. This paper uses case studies from Uganda to highlight and discuss examples where identifying potential markets for existing and new products have led to increased investment in NRM.

TSBFI-Latin America

Completed work

Analysis of drivers associated with the development of Bright Spots: Are there key factors that contribute to the development of Bright spots and their sustainability?

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Final draft Report, Bright Spots Project-Comprehensive Assessment Program

Individuals and communities have developed ways of coping with and reversing natural resource degradation. There are numerous isolated examples around the globe of interventions that have been effective in reversing the continuous downward spiral of poverty and hopelessness wit positive impacts on land and water resources. These are often termed "Bright Spots" and can be defined as individuals, small communities and households that have adopted innovative practices and strategies to reverse degradation in a sustainable manner whilst maintaining or enhancing food security. In this study an assessment of the key drivers that influence the development o f Bright Spots was evaluated through a questionnaire survey of existing examples. Analysis of data indicates that depending on the form of Bright Spot development specific drivers were observed to have important role. In the case of community based projects (i. e., watersheds development projects) leadership, social capital and community participation were the three most important elements effecting the development of the Bright Spot whilst innovation ranked fourth. Contrasting to this, in the case of the 204 respondents that have implemented new improved methods of growing rice and wheat in south India and the Punjab, innovative technology, aspirations for change and short-term tangible benefits were the key elements associated with the development of the Bright spot.

Drivers effecting the development and sustainability of the Quesungual Slash and Mulch Agro forestry System (QSMAS) in hillsides of Honduras

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The Quesungual Slash and Mulch Agroforestry System (QSMAS) is a bright spot of improved land and water management for sub-humid hillside agroecosystems suffering severe seasonal drought periods. This system has contributed to improve livelihoods of more than 6,000 farmer households in the Lempira Department, Honduras. It is based in the management of dispersed native trees in cropping fields through periodic pruning. Competition is kept low while provision of plant residues for soil cover and nutrient cycling is maintained favorating soil moisture conservation and fertility maintenance. Annual crops and pastures are planted on no-burned fields with zero tillage/direct planting operations. This system enabled farmers to increase crop yields and reduce labor for weed control. Besides gains in crop improvement, the widespread adoption of the system is associated to an strong participation of the community in the development of the system and the implementation of local policies to avoid use of fire for agricultural purposes and incentives to promote overall welfare of the community. In this paper, we analyze the role of these factors behind the social acceptance of the system and make an attempt to derive lessons that could be considered for the extrapolation of the system to similar regions in Latin America and Africa.

Drivers affecting development and sustainability of no-till systems for smallholders at watershed level in Brazil

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The no-till system in Brazil can be considered as a bright spot of improved land and water management for tropical soils prone to soil and water losses under conventional land preparation methods. This system has contributed to enhancing the productivity and sustainability of annual cropping systems in both large and small farming units of the southern and cerrados regions of the Brazil. Smallholders adopting the system have benefited through reductions in labor and increased profits produced by the system. Widespread adoption of no-till in Brazil is associated to an strong participation of farmers in the development and implementation of the system and to policies and incentives to improve environmental land and water quality at the watershed level. The case study included in this paper ilustrates the positive linkages that were developed between farmers, local goverment and the private sector to improve public health, control soil erosion and reduce water pollution at the watershed level

4.5 Investigate alternate production options using trade-off and scenario analysis tools

TSBFI-Africa

Published Work

Pathways for fitting legumes into the farming systems of East African Highlands: A Dual approach

Tilahun Amede
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In: Waddington, S. 2003. Green legumes and Green manures for soil fertility in Southern Africa. Taking Stock of Progress. Proceedings of a Conference held 8-11 October, 2002. Leopard Rock, Vumba, Zimbabwe. Soil Fert Net and CIMMYT, Harare, Zimbabwe. 246pp.

Food legumes remained to be important components of various farming systems of Eastern Africa, while the attempt to integrate fodder legumes and legume cover crops (LCCs) became unsuccessful. Despite recognising their benefits as soil fertility restorers and high quality fodder, farmers remained reluctant to integrate legumes mainly due to community/farmer specific socio-economic determinants. This paper is written based on the experiences of the African Highlands Initiative that has striven to integrate legumes in Ethiopian Highlands, Areka, and also understand the processes of integration of legumes of different use through participatory research. Areka had an altitude of 1990 masl, and rainfall amount of 1300mm, which is characterised by mixed subsistent farming systems, poor access to resources, intensive cropping, land shortage and soil degradation. Participatory evaluation was conducted on the agronomic performance and adaptability of eight legumes for three consecutive years during the main and small growing seasons, accompanied by extensive data collection on socio-economic determinants. PR experiences showed that the selection criterion of farmers was far beyond biomass production. The major biophysical traits are performance of the species under that specific agroecology, which was characterised by yield, disease and pest resistance, effect on soil fertility and the succeeding crop and its compatibility into the existing cropping system. Specifically, farmers identified firm root system, early soil cover, biomass yield, decomposition rate, soil moisture conservation, drought resistance and feed value as important criteria. The total sum of farmers' biophysical criteria showed that Mucuna followed by Crotalaria could be the most fitting species, but farmers finally decided for Vetch, the low yielder, due to its fast growth and high feed value. Farmers' priority was livestock feed over soil fertility. The final decision of farmers for integrating a food legume into their temporal & spatial niches of the system is dictated by the food habit while for non-food legume it depended on land productivity, farm size, land ownership, access to market and need for livestock feed. The potential adopters of LCCs and forage legumes were less than 7%, while 91% of the farmers integrated the new cultivars of food legumes. Strategic combination of biophysical and socio-economic determinants in the form of decision guides was suggested to facilitate the integration of legumes to help farming communities, development agencies and researchers to easily identify potential adopters, learn about the criteria of choice and suggest an improved system management. Moreover, it may also help them to identify niches and/ or create niches, modify the existing systems and promote the technology for wider use.

Multiple models to enhance farmer innovation in sustainable nutrient management: AHIs' experience

Tilahun Amede

Tropical Soils Biology and Fertility Institute of CIAT/ African Highlands Initiative

In: German, L. and Stroud, A., 2004. Integrated Natural Resource Management in Practice: Enabling Communities to Improve Mountain Landscapes and Livelihoods. AHI Conference, 12-15 October, 2004. Nairobi, Kenya.

Continual food insecurity and deteriorating livelihoods of millions in East Africa is highly related to long standing decline in soil and human nutrient budget and poor distribution among system components and sub-units. Even with in the crop sector there are mixed enterprises variably attached to specific farm units, namely the house, homestead, mid field, outfield and pasture land and wood lots. Various participatory tools and models were used to increase nutrient enrichment, to minimize trade-offs in nutrient budget between various farm enterprises, to reduce mining of nutrients of specific farm units, to reduce excessive accumulation of nutrients of certain farm units at the expense of other farm units, and also optimize the nutrient budget of the people without mining the land based resources, which could be extrapolated to other communities and higher scales. Although a U-form relation between population pressure and nutrient management is needed to feed the ever growing population it became elusive to achieve it due to multiple causes. This paper will present potential tools and models to intensify the existing systems, namely:

1) DSS to identify spatial and temporal niches to increase organic biomass production of the system as increased use of chemical fertilizers may not compensate for the organic matter-related processes, particularly in the far out fields.
2) Designing strategies that could encourage farmer innovations to minimize nutrient mining of some farm units to enrich other enterprises
3) Fitting technologies with win-win benefits to attract collective interest of farming groups and communities to manage nutrients better
4) Models to design nutrient management in systems perspective with various scenarios considering socio-economic differences so as to minimize resource degradation while maximizing benefits that comes out of the system as food, feed and cash
5) Develop policy suggestion for system shift and nutrient input enrichment through bottom-up negotiations at individual farmer, community and district levels. Increasing awareness of the communities on nutrient cycles and disorders and its implication on human and system health.

Implementation of these innovations demanded a mix of technological & institutional interventions. The immediate impact will be improving the nutrient recycling of the system through manipulation of the existing household resources, which will have a considerable implication on soil and human health. Local institutions could be benefited by getting knowledge and methodology on how to quantify and optimize nutrient recycling of the current production systems to possibly minimize nutrient mining but reversing the current trends using the existing local resources. Strategies are suggested to enhance local innovation in improving sustainable nutrient recycling. This paper would present case studies where the above mentioned strategies have been tested in a participatory research frame work at plot, farm and higher levels in Ethiopia and Kenya.

Intensification Pathways from Farmer Strategies to Sustainable Rural Livelihoods: AHIs' Experience

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In: German, L. and Stroud, A., 2004. Integrated Natural Resource Management in Practice: Enabling Communities to Improve Mountain Landscapes and Livelihoods. AHI Conference, 12-15 October, 2004. Nairobi, Kenya.

Subsistence farmers in Eastern Africa face serious decline in soil productivity. They categorized themselves in relation to number & composition of animals, perennial crops, land productivity and size, health and social positions. General strategies towards sustainable livelihoods were to enable children to have thorough education, introduce family planning and improve agricultural productivity. The last had proven elusive, with few innovations being adopted despite various R&D attempts of governmental and non governmental institutions. AHI teams across the region tested various scenarios of participatory and integrative ways to enhance integration of technologies. Farmer research committees (FRC), planning with development agents and scientists, initially focused conservatively on crop varieties. Members now supply seed of selected varieties to others, while researchers learned their selection criteria. With growing confidence, farmers embarked on more complex issues. Multipurpose elephant grass on contours was enthusiastically taken up, followed by farmer experiments with herbaceous and agroforestry legumes. Farmers describe interacting effects: new fodder sources improved dairy production; maize stover is retained for soil fertility; mixing early- and late-maturing maize varieties opened a niche for a legume relay. Some farm-level constraints provoked border conflicts (e.g Construction of soil bunds), which demanded collective management and negotiation of waterways towards developing initial confidence to address higher community issues. The FRC's vision changed to self-reliance through enhanced local innovation, to placing technical demands on the public sector, and to assisting other communities. Lessons learned across AHI sites about systems intensification scenarios, FRCs and FFCs and the role of research are discussed.

On-going work

Use of a decision support tool (DST) for evaluation of trade-offs and scenario analysis, results of a collaboration between ILRI, ICRISAT, TSBF and national partners

This project used benchmark sites in Ethiopia, Tanzania and Zimbabwe to test and evaluate the DST and to conduct trade-off and scenario analysis.

Incorporating farmers perceptions, farmer production objectives and the farmers perceptions of risk and vulnerability into the modeling work was critical to enable the partners to refine their thinking and review the initial researcher based scenarios and develop farmer criteria based scenarios for crop-soil-livestock systems. Case study farmers were chosen to represent different farm types in each country, in terms of land size, wealth category, number of livestock, access to labor etc. Individual interviews were used to elicit information on seasonal calendars, labor allocation throughout the year, farm enterprises, production objectives and possible new enterprises. Also data on perceptions of risk and vulnerability and the trade-off between growing for food security and market orientation was investigated. Following these field trips, the data was input in to the DST and scenarios and trade-off analyses conducted. Return trips will be made to these same farmers to discuss the implication and projections of the DST results, to further refine the scenarios with farmers and re-run the DST though focus group and individual farmer discussions. The incorporation of farmers perceptions, farmer production objectives and perceptions of risk and were essential to generate relevant and realistic scenarios.

Areka, Ethiopia example

Tables 40-42 give an example of this process for a farmer in the highlands of Areka, Ethiopia. The initial situation of the land management of their farm is given in Table 40. In the present situation the farmer grows a mixture of crops and enterprises for food security and income generation and makes 2,381 Birr (approx. USD280).

Table 40. Existing land management for a medium wealth category farmer in Areka, Ethiopia.

Plot	Enterprise
Homestead	Enset, coffee, kale, sweet potato, maize
Mid field 1A	Maize
Mid field 1B	Sweet potato, wheat
Mid field 2A	Maize
Mid field 2B	Sweet potato
Mid field 3	Barley
Outfield A	Maize
Pasture	Unimproved pasture

Using the IMPACT DST to optimize the farm for income generation the farmer can make a total of 3,300 Birr (approx. USD388) but as you would expect from an optimization model it chooses the most profitable crop and turns the whole farm over to this enterprise, in this case maize (Table 41). Whilst this was known before running the DST, this was done with the farmer group to show them what would happen if is this was their only production goal. The idea was not to suggest this to them but to start discussions, and as expected this started lots of discussion, once the farmers had stopped laughing at the researchers for suggesting such an impractical future scenario.

Table 41. Income optimized scenario of the medium wealth category farmer in Areka, Ethiopia.

Plot	Enterprise
Homestead	Potato, wheat
Mid field 1A	Maize
Mid field 1B	Maize
Mid field 2A	Maize
Mid field 2B	Maize
Mid field 3	Maize
Outfield A	Maize
Pasture	Potato, wheat

The discussion that followed was then about which crops were needed for food security, which for producing livestock feed, which would generate income and in which plot on the farm to grow these crops (Table 42). At the end of the discussion the agreed future scenarios would produce food security and an income of 2,700 Birr (approx. USD318). Whilst this was less than the optimal scenario, this resulted in increased income and maintained many of the food security and livestock options.

Table 42. Farmer optimized production preferences for the medium wealth category farmer in Areka, Ethiopia

Plot	Enterprise
Homestead	Enset, coffee, kale, sweet potato, maize
Mid field 1A	Maize
Mid field 1B	Maize
Mid field 2A	Potato, wheat
Mid field 2B	Maize
Mid field 3	Potato, wheat
Outfield A	Potato, wheat
Pasture	Pasture

Testing and development of prototype DS tool on-farm in East and Southern Africa by project partners (NARES, NGO's, IARC's, farmers)

As mentioned previously this project built on existing work by ILRI that had gone a long way to developing the DST. This project focused on improving this and linking in the soil-crop simulation modeling component. The DST was completed after the first 18 months of this project.

Once it was completed the DST was tested in preliminary meetings with researchers and farmers in Tanzania, Ethiopia and Zimbabwe, as well as in Kenya and Ghana, through existing funded projects to ILRI. An example of its testing and development follows:

Lushoto, Tanzania example

The first visit to the farmer groups in Lushoto collected the data required to parameterize IMPACT and the household model. Three wealth categories had been previously identified in on-going work and data for each wealth group was collected and entered into the DST. A follow-up visit then presented their data back to the group, including their current production enterprises, food security situation, nutrient balance and income (Photo 5). During this feedback and further discussion to capture the current situation and future and alternative scenarios changes in their land allocation were discussed to allow them to achieve food security (Figure 33). As we saw in the Ethiopia example above, this was not to make them change their farming practices but to stimulate discussion on options that they had and which one would fit best given their attitudes to risk and vulnerability and to the demands on human and livestock feed and income generation.

Photo 5: Feedback of DST scenarios to farmers in three different wealth categories n Lushoto, Tanzania.

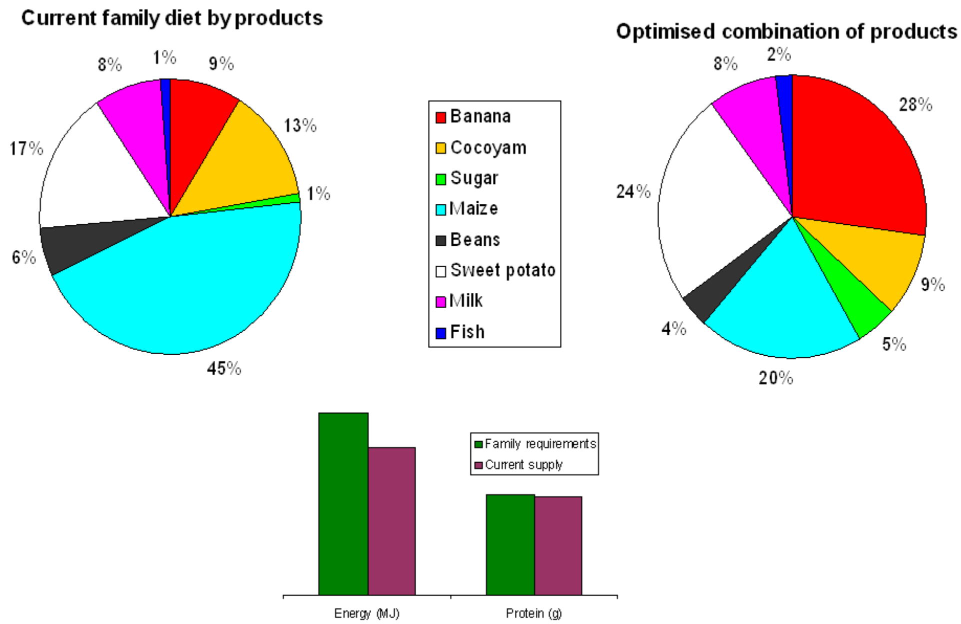
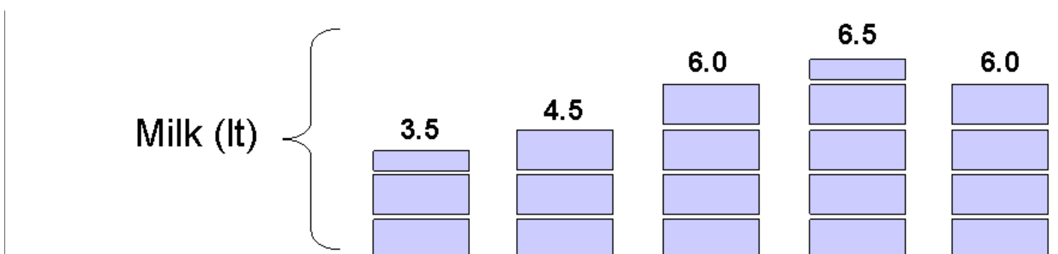


Figure 33. Comparison of current and future contribution of different crops to food security.

This first step allows farmers to see what changes are needed to be able to produce enough products to achieve food security from their farms. In many cases this is not possible and food security can not be achieved from on-farm production. In other cases the changes proposed are just not feasible, as some land needs to be maintained for livestock production or the farm has no money to invest in expanding production activities. Figure 34 shows how the RUMINANT model, as part of the DST, can be used to design ruminant diets for achieving different milk yields and how much of each feed is needed. These options, along with food security allow the group discussions to evaluate many options to find the best way forward. In another funded project run by ILRI in Kenya, farmers are using this approach to change on-farm livestock feed production and diets composition for increasing milk production.



Milk (lt)	3.5	4.5	6.0	6.5	6.0
Maize stover	2 kg	1.5 kg	2.5 kg	2.5 kg	2 kg
Napier grass	3.5 kg	2 kg			
Desmodium sp.			2 kg	2 kg	
Maize bran					
Banana leaves/pseud	2 kg	2 kg	2 kg	3 kg	2 kg
Roadside grass					1.5 kg

Figure 34. Use of RUMINANT model for designing ruminant livestock diets in Tanzania.

A critical area that was newly approached in this project was the inclusion of labor in the trade-off analysis that was conducted for achieving food security or in increasing income. Labor was detailed by production activity and by sub-activity (e.g. land reparation, planting, harvesting) in these activities to include the impact of changes on labor demands and cost.

Murewa, Zimbabwe example

In the project activities in Zimbabwe profit and labor costs were explored in relation to potential options for use or changes in targeting of inputs to the farming system. The example given here shows income and labor requirements calculated for two farmers, poor (Table 43) and wealth (Table 44). In these two examples for Zimbabwe they contain scenarios where fertilizer is free which is a reflection of access some farmers have to free inputs through NGO programs in the project area. These scenarios and analysis helps our understanding of where different types of farmers are now, where they can go and more importantly, what constraints do they have to achieve this. We must realize that not all farmers have the resources to purchase inputs or hire labor. Some don't want to hire labor but would rather invest in other farming activities or purchase other household priority items or invest in their children's education.

Table 43. Potential scenarios and implications for income generation and labor requirements for a poor farmer in Murewa, Zimbabwe.

Scenario description	Profit US$	Labor deficit (man-days)
Baseline		
1. Baseline scenario - diet at 70% WHO req.	-7	3
2. Baseline scenario - diet at 100% WHO req. (free fertilizer)	-19	3
3. Baseline scenario - diet at 70% WHO req. (fertilizer cost incl.)	-13	3
Optimized Scenario		
4. Optimized scenario - grain crop plots open (free fertilizer)	87	211
5. Optimized scenario - grain crop plots open (fertilizer cost incl.)	81	211
Explorative optional scenarios - distribution of fertilizers (fertilizer cost incl.)		
6. All fertilizer in plot 1 (Data from APSIM)	21	3
7. Fertilizer distributed equally in plots 1&2 (Data from APSIM)	40	29
8. Scenario 7 with 50% weeding in plot2	26	13
9. Fertilizer inputs distributed equally across plots 1,2&4 (Data from APSIM)	23	56
10. Scenario 9 with 50% weeding in plots 2&3	10	26
Explorative optional scenarios - legume intensification		
9. Expand area under groundnut to plot 4 (fertilizer distributed in plots 1&2)	72	46

Using this DST helps us work with partners and farmer groups to evaluate their options and to allow them to be able to decide which option suits them best, given their production objectives and perceptions of risk.

These partner and farmer group meetings proved critical in leading to improvements to simplify the data entry formats, addition of new data collection needs and a better understanding of what researchers and farmers wanted from the DST. The evolution and changes made in the subsequent two years are too many to mention but led to a total redesigning and remodeling of the DST. The resulting product has now been Beta tested in all sites. The IMPACT systems characterization database which includes the sub-models for calculating food security, farm economics and nutrient balances, with a user manual, has now been released on CD and through the internet.

Table 44: Potential scenarios and implications for income generation and labor requirements for a wealthy farmer in Murewa, Zimbabwe.

Scenario description	Profit US$	Labor deficit (man-days)
Baseline		
1. Baseline scenario - diet at 70% WHO req.	172	43
2. Baseline scenario - diet at 100% WHO req.	147	43
Optimized Scenario		
3. Optimized scenario - grain crop plots open for best option	448	153
Explorative optional scenarios - distribution of fertilizers (fertilizer cost incl.)		
4. All fertilizer in field closets to homestead (Data from APSIM)	95	18
5. Fertilizer distributed equally in plots 1&2&6 (Data from APSIM)	119	99
6. CpD+AN field 1; manure+AN field 3 (Data from APSIM)	169	90
7. manure+AN field 1; CpD+AN field 3 (Data from APSIM)	163	56
Explorative optional scenarios - legume intensification		
8. Resized plots: Expand groundnuts to plot1 (close to homestead)	165	198
9. Resized plots: Expand groundnuts to (outfield)	147	200

One problem encountered was the use and release of the DST with the optimization model installed. This problem is due to that fact that the multiple goal linear programming software is a commercial version and needs licensing, at a cost of several thousand dollars a copy. Discussions have concluded with the owning company and they have agreed to provide a run-time version for the DST at no charge. For this to be useful a final version of the linear programming software in the DST needs to be completed and this is taking more tie than envisaged. The challenge is not the programming but that every time we hold training course on the DST more ideas arise that partners want incorporated. Due to the endless nature of these requests, we have decided that by the end of 2004 to produce a run-time version and release the fully functioning DST on CD, with a users manual.

Participatory models in fostering farmer innovation to minimize trade-offs and induce win-win benefits: The case of Organic Resource Management

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This work is a continuation of earlier investigations which revealed that there is very strong trade-off for the limited organic biomass (i.e. crop residue, manure, stubble, weeds, grasses and underground biomass) at farm and landscape scales among various uses namely, as a cooking fuel, as livestock feed, as cash generation enterprise and as soil fertility restorer. And yet, the amount of organic biomass in the system is very much limited to satisfy these different needs, which are all probably important but the household decision is made based on priority needs. The objective of this work were to understand farmer experimentation processes to overcome biomass constraint in the system, to document farmer innovations towards solving the problem and to develop farmer-friendly tools & guides to improve farmer-community understanding of their farm & landscape systems for identification of niches. The major steps considered to date were: a) Participatory mapping of the current sources of biomass at plot, farm and mini-watershed-level including crops, forages, trees, valley bottoms, homestead crops and other niches b) participatory estimation of biomass yield per time and space in selected farms c) Monitoring resource flows and production fluctuations at household level in selected farms d) Participatory identification of possible niches for growing more biomass in the system, e.g. integration of high biomass producing, promiscus type legumes, (e.g. Climbing beans, Soy beans) and fast growing and browsing resistant forages (e.g. napier grass).

4.6 Quantify benefits of ecosystem services from farm to community level

4.7 Determine livelihood impacts of resilient production systems

TSBFI-Africa

Published Work

Advancing human nutrition without degrading land resources through modelling cropping systems in the Ethiopian Highlands

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Food and Nutrition Bulletin, Boston. In Press (December, 2004).
Food shortage in sub-Saharan Africa is generally considered a function of limited access to food, with little thought to nutritional quality. Analyzing household production of nutrients across farming systems could be valuable in guiding the improvement of those systems. An optimization model was employed to analyze the scenario of human nutrition and cropland allocation in enset (Enset ventricosum)/root crop–based and cereal-based systems of the Ethiopian Highlands. The type and amount of nutrients produced in each system were analyzed, and an optimization model was used to analyze which cropping strategies might improve the nutritional quality of the household using existing resources. Both production systems were in food deficit, in terms of quantity and quality of nutrients, except for iron. The energy supply of resource-poor households in the enset/root crop-based system was only 75% of the recommended daily allowance (RDA), whereas resource-rich farmers were able to meet their energy, protein, zinc, and thiamine demands. Extremely high deficiency was found in zinc, calcium, vitamin A, and vitamin C, which provided only 26.5%, 34%, 1.78%, and 12%, of the RDA, respectively. The RDA could be satisfied if the land area occupied by enset, kale, and beans were expanded by about 20%, 10%, and 40%, respectively, at the expense of maize and sweet potato. The cereal-based system also had critical nutrient deficits in calcium, vitamin A, and vitamin C, which provided 30%, 2.5%, and 2% of the RDA, respectively. In the cereal system, the RDA could be fully satisfied by reducing cropland allocated to barley by about 50% and expanding the land area occupied by faba beans, kale, and enset. A shift from the cereal/root crop-dominated system to a perennial-enset dominated system would decrease soil erosion by improving the crop factor by about 45%. This shift would also have a very strong positive impact on soil fertility management. However, any policy suggestions for change in cropland allocation should be done through negotiations with households, communities, and district stakeholders.

On-going work

Contemporary patterns of land use and land use change in contrasting areas of western Kenya S.E. Carter[1], J.J. Ramisch[2], E.L. Crowley[3], C. Mulogoli[2]
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Paper in preparation for Land Use Policy
This paper examines the changes that have taken place in land use this century in two areas of Western Kenya in order to address a number of issues related to agrarian change in African farming systems. Our practical concern is to contribute to understanding the context and dynamics of some of farmers' current land management practices in the region. Our work, conducted in the context of a programme of research on soil fertility, focuses on changes in the dominant, cultivated elements of the landscape of Western Kenya. To this end we attempt to identify the more dynamic crop components of two of the main farming systems, in order to suggest the implications that contemporary change may have for resource managers and for an applied research agenda in support of their efforts. This is particularly

important in W. Kenya since there is at present considerable debate over the relationship of agrarian change to change in soil fertility in the region.

In addition we wish to make a modest contribution to the theoretical debates on African agrarian change. Thinking in the 1990s has centred around two stances. Firstly refinements of Boserup's argument that demographically -driven agrarian change is leading to an intensification of farming systems as farmers respond positively to increased market opportunities. The second is more critical, providing a radical interpretation of change centred on power relations between institutions or between social groups or men and women. Berry (1993) attempts a synthesis of much of this work, and contributes a portait of dynamic complexity, of similar processes of social change unfolding upon very different historical and geographical backgrounds and with largely unpredictable results.

We address three questions that have some bearing on these practical and theoretical debates:

1. What are the causes of different paths of land use change in W. Kenya, be they social, economic, ecological or historical processes? To answer this we contrast Kabras and Maragoli, two areas of Kenya's Western Province that are often perceived as ethnoculturally, economically and environmentally similar but where very different paths of land use change have been taken. We think it is useful and of benefit to scientists concerned with social and environmental change in Western Kenya to try to unravel the reasons for these differences.

2. In recent years, how have farmers (men, women, "households", or wider "communities") reacted, in their choices between specific crops and between on-farm and off-farm livelihood strategies, to forces external and internal to their agro-social systems? The two study areas provide a useful comparison and contrast of farmers' strategies to cope with change, that have led to different patterns of land use. They also provide a useful comparison with some of the findings on agricultural intensification of Tiffen et al (1994) in another part of Kenya, particularly the latters' claims regarding the generality of the processes of intensification.

3. What is the relationship between changing patterns of land use and labour allocation and the maintenance of land quality? A good deal is known about the general changes that have taken place in the allocation of labour to different crops and activities within Kenya, in response to political-economic and social change during the colonial and post-colonial periods. However, Berry (1993) argues that more recent structural changes have brought about a further decline in rural people's access to labour in many parts of Sub-Saharan Africa. For example, Mackenzie (1993, 1995), writing of Kenya, suggests that structural change and increased demands on women' labour have reduced their ability to maintain soil fertility in the face of increasingly pressing short term goals. Therefore we attempt to shed some light on the relationship between land use change (as reflected in choice of crops), male and female labour allocation and soil fertility management in Western Kenya.

In order to answer these questions we examine archival, oral historical and other documentary evidence for the period from the late Nineteenth Century until after Independence. This historical analysis of past changes in resource management is important to an understanding of contemporary conditions because of the long continuity of many processes that affect farmers' management decisions. For the post Independence period we draw on additional sources of remotely sensed land use data and survey data collected by us in a random sample of 700 households (*muunzu)* in 1995. We emphasise the period from the mid 1980s to mid 1990s in our analysis, both to identify issues of relevance for contemporary applied research in agriculture and natural resource management in the region and to contribute new material to the current debates on agrarian change.