Output 4
Improved rural livelihoods through sustainable, profitable, diverse and intensive agricultural production systems

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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.

Key research questions

1. Which ISFM options are appropriate, where (farm//landscape), and for which farmers (typologies/social capital) to create profitable and resilient agricultural production systems?
2. What are the component and system thresholds for improving resilience of target farming systems?
3. Where and under what conditions does market orientation lead to increased investment in integrated natural resource management (INRM) and improved livelihoods?
4. What information, resources and knowledge do farmers need for improved decision making?

Milestones 2005

- **Decision support tools made available to identify more productive, and profitable and resilient smallholder farm production strategies**

Smallholder farmers face complex decisions on the allocation of scarce resources between different components of their farms due to conflicting demands for their use. Key questions arise at the farm level on resource use such as: How should the limited fertilizer resources available be targeted to different crops and to plots differing in initial fertility? Should all crop residues be used for animal feed, or allocated also for maintenance of soil fertility? Decisions taken by farmers on the use of nutrient resources and their allocation to crops and different fields are influenced by underlying socio-economic factors. These factors vary with the wealth status of the farms. Labour availability and ability to hire labour are major determinants in technologies and production choice by farmers. Choice of crops, their allocation and management is also driven by the need to achieve food security, which is threatened by poor soil fertility, poor access to fertilizers and recurrent droughts. Therefore, technologies attractive to farmers must be within their capacity to provide labour and nutrients, to achieve food security and should also be economically viable. For improved understanding of the multiple constraints that farmers face and the factors driving their decision making processes, there is a need for tools that holistically assess current and optional resource management strategies and that provide comparative analysis of food sufficiency, economic viability and maintenance of soil fertility at the farm level.

One approach CIAT has invested in is a Farm-level analysis of trade-offs between soil fertility management alternatives to improve understanding of complex biophysical and socio-economic factors influencing decision making in smallholder farming systems and to identify opportunities for improving resource use efficiency. A farm characterization (IMPACT) tool, developed by ILRI, linked to a generic (Household) optimisation model was used to evaluate resource use on farms in contrasting wealth categories. The Household model optimised farm productivity based on productivity of crops and livestock, off-farm activities and food sufficiency. Alternatives for management of nutrient resource were simulated using APSIM for the crop production and RUMINANT for the livestock component. The output from the simulation models was fed into the Household model and evaluated within the biophysical and socio-economic boundaries of the farms and used to assess these impacts of change on farm productivity in east and southern Africa.

Highlights

- The use of a herbicide-resistant maize variety and fertilizer reduced significantly the emergence of Striga.
- Four Lablab accessions were identified as the most likely to be accepted by farmers based on their productivity, pest and disease resistance and palatability for human consumption.
- Farmers from Uganda provided with a wider spectrum of dual purpose cowpea lines from which they can choose depending on whether they need grain, fodder or soil improvement.
- Farmer evaluation of improved soybean varieties screened in five locations in Kenya indicated that the variety SB19 can be recommended across locations and that is clearly better than the existing farmers' own variety, Nyala.
- Soil fertility is a good entry point for participatory research on ISFM.
- Households of Western Kenya producing kale for markets had a higher level of food security compared to those growing traditional vegetable crops.
- The creation of awareness of the various attributes of soybeans is currently leading to widespread adoption of soybean among the communities in TSBF-CIAT action sites in Kenya.
- The strategy of integrating research activities with extension oriented to farmers that are committed to use conservation farming practices has facilitated scaling out of minimum tillage technology and green manures cropping in the Ecuadorian and Peruvian pilot watersheds.
- Crop-pasture systems and legume-based pastures increased productivity and profitability of production systems in large and small-scale farms in sandy soils of the cerrados of Brazil.
- The combination of increased soil fertility, adapted crops and market-oriented options has the potential to improve significantly agricultural production and economic profitability of agriculture in hillsides of Central America.

Output target 2006

- ***Crop components and soil management technologies of improved systems promoted by partners in African hillsides***

Work in progress

Participatory evaluation of best-bet options for control of *Striga hermonthica* and declining soil fertility

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In the context of the project 'Striga control in western Kenya: Raising awareness, containing and reducing the infestation and developing strategies for eradication', supported by the African Appropriate Technology Foundation (AATF), the mandate of TSBF-CIAT is to investigate the containment and eradication of striga infestation through the fusion of different technical approaches. Impact on the soil fertility status and striga seed bank will be quantified. Feedback from active farmer research groups will be obtained through group learning activities on farmer-led testing and evaluation activities with a selected set of technologies.

Fourteen farmer groups were selected in Bondo, Busia, Teso, Siaya, and Vihiga districts, using level of activity, interest in farming, and presence of striga as main criteria. In each of the target sites, the farmer research group selected fields with very high striga occurrence, the latter being validated by field visits during the previous growing season. A set of best-bet interventions, consisting of the components Desmodium intercopping, fertilizer application, IR maize, striga tolerant maize, and herbaceous/grain legume rotation, was exposed to the farmer groups and agreements were made on how to manage the trials and their produce. No financial support was provided for implementation and management of the demonstration trials. A set of group learning activities was developed and is being implemented during the current growing season. During the season, interest at the Teso sites was minimal so these groups were dropped from the project, leaving 11 active demonstration sites.

Maize grain yield data from the 2005 long rainy season (treatments 1, 2, 3, 4, 11, and 12) show that yields in the treatments without fertilizer application were similar and varied between 600 and 1000 kg ha^{-1} (Figure 34). Response to fertilizer was observed for the IR-maize and the push-pull treatments (ranging between 1500 and 1700 kg ha^{-1}) (Figure 34). Striga seedling emergence was substantially reduced in both treatments with IR maize while in the mono-crop and push-pull treatments without fertilizer, Striga emergence was 4-5 times as high as for the treatments with IR-maize. Application of fertilizer to the former treatments increase Striga emergence 7 to 10-fold related to the treatments with IR-maize (Figure 35).

While IR-maize has been observed to seriously reduce Striga emergence resulting in significant response to fertilizer application, maize did not respond to application of fertilizer in the maize mono-crop systems with WH403. In the push-pull systems, application of fertilizer also led to higher Striga emergence but this did not affect the responsiveness of the maize to applied fertilizer. It is not clear at this stage, however, how a young Desmodium crop would have contributed to improved crop yields.

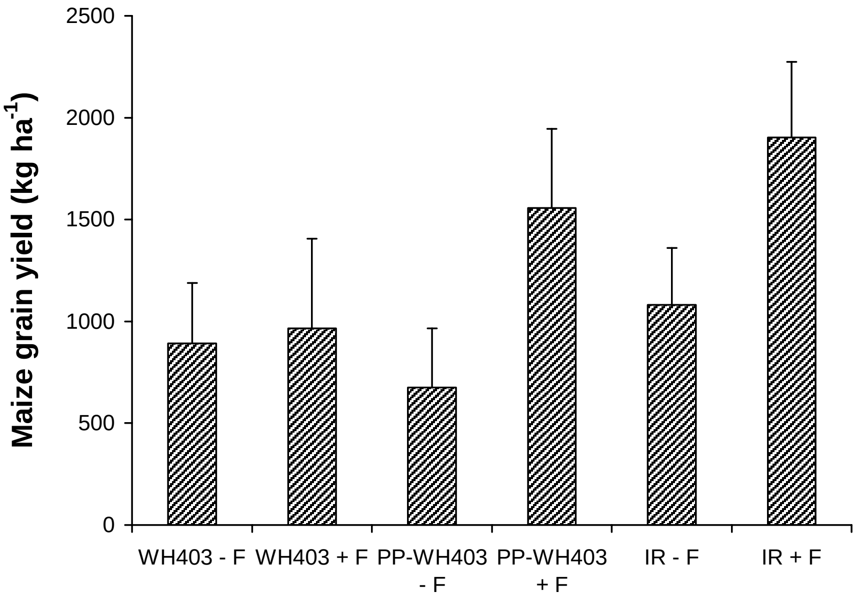

Figure 34. Maize grain yield during the long rainy season of 2005. 'F' refers to 'fertilizers', 'PP' to 'push-pull', 'IR' to herbicide-resistant maize, and 'WH403' to the non-herbicide-resistant maize variety used. Error bars are Standard Errors of the Mean (*n*=11).

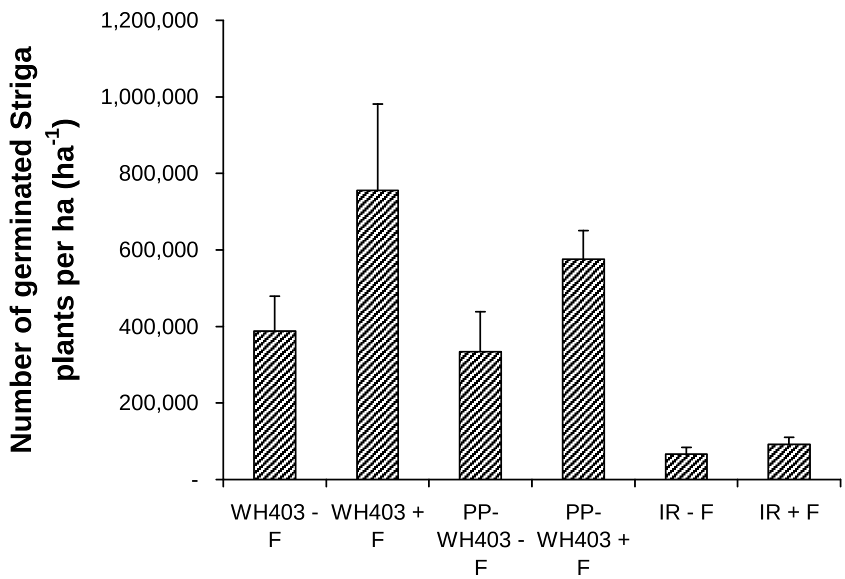

Figure 35. Striga seedling emergence during the long rainy season of 2005. Note that Striga emergence was counted at 6, 8, and 10 weeks after planting and that after each counting event, all Striga seedlings were uprooted. 'F' refers to 'fertilizers', 'PP' to 'push-pull', 'IR' to herbicide-resistant maize, and 'WH403' to the non-herbicide-resistant maize variety used. Error bars are Standard Errors of the Mean.

Building bridges, sharing insights: Making partnerships work for enabling rural innovation in Africa

P. Sanginga and the team

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With the emergence of a broader agenda for agricultural research, coupled with reducing resources, building multi-institutional partnerships has become a core strategy for promoting innovation and achieving greater impact of agricultural research at the household level. However, research efforts to improve our understanding of partnerships and to learn from their successes and failures, are still limited. This study discusses empirical experiences and lessons learned with a multi-institutional partnership, Enabling Rural Innovation' (ERI), in east and southern Africa. The ERI project aims to make agricultural research more client-oriented, demand-driven, and market-responsive. The ERI partnership has grown rapidly from only a few partners in 2000, to more than 13 boundary partners in 2004, while still expanding into new countries in 2005. This study describes the process of building the ERI partnership, and describes a participatory methodology for monitoring and evaluating critical elements of the partnerships. Results show that such elements include: the relationship should be based on a common problem definition and complimentarity of interests in achieving a common goal; strong and consistent support from senior leadership; joint resources mobilization; capacity building, as well as, a range of institutional and individual benefits. Nurturing interpersonal relationships and building social capital, lowers the transaction costs of partnerships, facilitates trust, mutual respect, and regular communication. Evidence of farm-level impacts and individual benefits are key to sustain institutional commitments, and for scaling-up with existing and new partners. Current reforms in agricultural research and development emphasizing participation, farmers' empowerment, and market orientation, also provide a conducive environment for quality partnership. However, sustaining quality partnerships is challenging. This requires creative strategies for coping with staff turnover, over-commitment of field staff, changing organizational expectations, resource limitation, imbalances between institutions and personalities. These challenges also apply to maintaining quality during scaling-up processes, as well as, overcoming the challenges of effective partnerships with private business services sector. Although there are encouraging signs of institutionalization and scaling-up of ERI with existing partners and scaling-out with new partners in new countries, there is still much to learn along the partnership journey.

Output target 2006

- ***Management practice options that increase or maintain BGBD in benchmark agroecosystems demonstrated by partners and farmers in seven tropical countries participating in the BGBD project***

Work in progress

Soil productivity, pest presence including the presence of harmful BGBD will be evaluated against the occurring BGBD and remedial measures to restore soil health using BGBD management strategies will be undertaken. The emphasis will be to use BGBD knowledge gained from the inventory and from experimentation to recommend how BGBD should be best managed to provide selected ecosystem services and to address problems of low soil fertility and inceidences of pests and diseases. This work is expected to increase the resilience of the soils through increased BGBD diversity and abundanced. The work will commence once the project starts implemnting its activities of Phase II during the second half of 2006. All seven participating countries will conduct experiments in joint experiments with farmers and NGOs in elevenbenchmark sites.

Output target 2007

- ***Crop components and soil management technologies of improved systems promoted by partners in acid soil savannas***

Completed work

Development and promotion of soil and crop management technologies in acid soil savannas of Colombia

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The neotropical savannas (243 million hectares) in South America are one of the most rapidly expanding agricultural frontiers in the world. Oxisols predominate in the Colombian savannas and cover an area of 17 million hectares. Out of this total area, 3.5 million hectares are the well-drained savannas known as "Altillanura". Intensification of agricultural production in this agroecosystem requires acid soil (aluminum) tolerant crop and forage germplasm, soil chemical and biological improvement in addition to management of highly vulnerable physical properties. Monocropping systems with high levels of inputs and excessive cultivation (disc harrowing) are not sustainable since they cause deterioration of soil physical, chemical and biological properties as well as escalation of pest and disease problems. Alternative systems incorporating components that attenuate or reverse the deleterious effects of monocultures are required, and biophysical measures of sustainability need to be developed as 'predictors' of system 'health' to sustain agricultural production at high levels while minimizing soil degradation.

Grain legumes, green manures, intercrops and leys are possible system components that could increase the stability of systems involving annual crops. To test the effects of these components on system sustainability and to identify indicators of soil quality, a long-term field study was implemented in 1993 on a Colombian Oxisol in Carimagua under native savanna grassland using a selection of alternatives based on these components. The study was extended through almost two cycles of the principal rotation, i.e., the agropastoral system, recognizing that the degrading or beneficial effects of various agricultural practices are often subtle and only manifest themselves over long periods.

The experimental design was a split-plot with four randomized blocks as replications, with main plots assigned to upland rice-based (fertilizer lime) systems and maize-based (remedial lime) systems. The rice-based system treatments included rice monoculture, rice rotated with cowpeas (for grain), cowpea green manure (GM) and rice-agropastoral rotation. The maize-based system treatments included maize monoculture, maize-soybean rotation, maize-soybean green manure rotation, and maize-agropastoral rotation. A native savanna control was used to measure changes in soil quality. Crop production and soil quality characteristics were measured in two phases. After Phase I (a period of five years with conventional tillage), the plots were split and no-tillage (direct sowing) or minimum tillage (chisel + direct sowing) treatments were introduced in Phase II with an objective to evaluate which agropastoral treatments were suitable for improving soil conditions that are needed for implementing no-till systems. Increasing intensity of production system (with concomitant use of inputs) resulted in changes in soil quality. Soil organic matter declined with increasing intensity of cultivation, as did populations of macrofauna in different systems. Some agropastoral treatments such as cereal-green manure rotation and cereal-improved pasture rotation resulted in improved soil conditions to implement no-till systems.

The above long-term studies were complemented with satellite experiments (at Matazul Farm in the Altillanura) for developing soil management technologies to build-up an arable layer as a precondition to implement no-till systems. The main purpose of building an arable layer is to improve and maintain physical and chemical conditions of the soil in order to favor root growth and soil biological activity.

These experiments were monitored over a four-year period and changes in some physical and chemical properties at different soil depths, plant growth and nutrient uptake as influenced by tillage intensity (1, 2 or 3 passes of chisel) and land use (crop-rotation, agropastoral systems) were measured. Results indicated that agropastoral systems based on acid soil adapted and deep-rooted tropical forage grasses are markedly superior to crop rotation for building an arable layer for infertile savanna Oxisols. Using this integrated soil management technology it was possible to improve profitability and sustainability of agropastoral systems in the Altillanura of Colombia. Adoption studies indicated that the most immediate impact area for the arable layer building technology is the Puerto López – Puerto Gaitán region, which is approximately 180 thousand hectares. It is considered that for its rapid adoption, investment by the Colombian government in improving road infrastructure is critical. In addition, in the more remote areas of the Llanos there are a number of other critical factors (i.e. lack of machinery, inputs, technical assistance, qualified hand labor and roads and communications) that prevent the introduction of crops to establish rotations with pastures in sustainable agropastoral systems.

Output target 2007

- ***Crop-livestock systems with triple benefits tested and adapted to farmer circumstances in hillsides***

Completed work

Improving food security for western Kenyan farm households with integrated soil fertility management for local vegetable crops

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This study analyses the food security in vegetable yields of subsistence households, which were producing kale for market and those, which were cultivating traditional African vegetables (TAVs) for home consumption. By comparing kale-producing households with TAV producing households in terms of the allocation of labour and capital and the coping mechanism enacted to cope with transitory food insecurity, we found that households producing kale have a higher level of food security. This increased food security stems from three key factors: the malleability of kale to be a vegetable and a high-value cash crop; the dedication of all households members to the daily maintenance of kale; and the location of farms adjacent to a water source. These three key factors allow for women to be able to access kale for home consumption, increase the purchasing power of households, and also, boost the total yield of vegetables cultivated on the farm. TAV producing households were found to be vulnerable to an insufficient vegetable supply largely because of geographic location and the overburdening labour demands on the women to singularly produce all household vegetables.

Findings from the study of Luhya and Teso households indicate that crops and the gender division of labour are socially malleable. Kale is able to increase food security because although it is a vegetable it can become a cash crop. This elicits the labour of men in its production and also changes the application of the gender division of labour so that it is no longer taboo for a man to perform tasks within a vegetable/cash crop that are typically done by a woman. The malleability of kale, above being able to employ men's labour, also allowed the enlarged vegetable area to be accessible by women for home consumption because it was also still a vegetable.

Published research results from a nation-wide study analyzing the monetary value of many varieties of exotic vegetable yields produced by small land-holders in Kenya that quantified the food security afforded by the production of kale, showed that only 29 percent of the kale grown by the average small landholder (5 ha) is actually sold. With the remaining 71 percent providing for the entire household, it is not surprising then that we also found kale increases food security through a labour perspective. Though the published study included other ethnic groups in Western Kenya besides Luyha or Teso households, we believe that the data is still applicable because of the similarities in production systems between the ethnic groups.

Work in progress

Farmers' participatory evaluation of a community-based learning process: "Strengthening Folk Ecology" for integrated soil fertility management in Western Kenya

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Farmers and researchers in western Kenya have used community based learning approaches to jointly developed a "dynamic expertise" of integrated soil fertility management (ISFM). This approach builds on farmers' "folk ecology" and outsiders' knowledge, taking action research on natural resource management beyond methods that are descriptive (ethnopedology) or curriculum-driven (farmer field schools). The paper presents and analyses experiences from the on-going participatory monitoring and evaluation of the Strengthening "Folk Ecology" project to document and critique the community-based learning process and its sustainability. Issues include the trade-offs and tensions between science and action-oriented research as well as the true potential of participatory methods for "leveling" power relations between different actors.

Three categories of learning outputs are addressed: a) farmers and researchers learning from experimental results themselves, b) farmers' learning from the experimentation process, and c) researchers' learning from the experimentation process.

a) Evaluating research results. Activities have been conducted every season (long and short rains) from 2002-2005. Topics addressed in collective experiments included organic resources, inorganic inputs, cereal – legume rotations, indigenous vegetables. The diversity of follow-up activities at collective and individual levels

Observations on farmers' experiments: In many cases, the over-simplified experimental design initially preferred by the project undermined the scientific rigor of findings without actually improving clarity for farmers. This allowed for many conflicting interpretations of results, which (for example) confounded local characteristics and land-use history with treatment effects. Farmers and researchers both felt that there was a need to include more farms as replicates in collective experiments to improve the chances that findings could be compared across sites. In all the study sites, farmers' data collection abilities were quite strong; when these quantitative skills were combined with participatory evaluations it proved to be a powerful learning tool.

Individual experiments were carried out in three different modes: Verifying / validating the findings of collective experiments, modifying technologies to fit new uses, and adapting the technologies to become more convenient or easier to operationalise in the local context. Farmers reported increased confidence in the dynamic expertise that emerged from their collective and individual experiments (which included the use of organic and inorganic inputs, cereal-legume rotation, the role of different soil nutrients and deficiencies, and ISFM for indigenous vegetables). Many technologies outside of ISFM were considered by farmers as part of the "Folk Ecology" project, including Striga control, soil and water conservation, and aspects of crop husbandry or agronomy such as row planting beans (formerly only broadcast). Finally, some farmers had developed erroneous assumptions from their participation, treating experimentation as a "demonstration" of good options (e.g. Stover as a beneficial soil input when it had been included in experiments as a low quality material against which to test high quality ones).

b) Farmers evaluating research process. At the participatory evaluation session held in June 2005, farmers' groups made comments on the following topics: Communication and feedback, Incentives to participate, Group politics, and Scaling up impacts. Most groups are also now re-baptizing "Folk Ecology" project with local names. To facilitate better learning from experimental results farmers insisted that there be a much faster feedback of data, test results (i.e. of soil and biomass), and of the photos and certificates that were promised by researchers. Other farmers were also faulted for lagging in the sharing of knowledge they gained from study tours, as well as the results of their individual experiments. Among the incentives to participate, many mentioned the idea of setting targets and goals (through organised competitions and prizes). Other problems included the failure of participants to honour their commitments (e.g. times and dates of activities), the need to "cost share" on onerous tasks (with payment or at least provision of lunches or sodas). Participants were also angered that researcher-designed trials employed outsiders as the day labourers when local labour could have been used. Some commentators also wanted the farmers' evaluations of the researchers to be included in the commendation (or sanctioning!) of researchers by CIAT (e.g. included in our Annual Assessments).

Other comments expressed strong desires for test crops to be broadened beyond maize to include other local staples (millet, sorghum, cassava) as well as local vegetables. Insistence on the importance of local soil types also means extending test sites (and replication) to include this variable. Seed bulking remains a priority activity for farmer groups (and individual experimenters).

c) Researchers evaluating research process. All the project activities are now linked explicitly to a phasing out of activity (end date = 30 June, 2008). This guides everything from building capacity for experimentation to establishing seed supply, group financing strategies, and links with support personnel. Self-organization and funding is being promoted with proposals to local NGOs, marketing and credit activities. It was observed that despite its complexity, soil fertility management is actually a good "entry point" for participatory research and has promoted a wide range of learning and empowerment. The group-based approach does seem to use (and reinforce?) selective pathways of communication and learning, and may not adequately address the most vulnerable community members. The top-down extension model is deeply entrenched both in farmers' and researchers' attitudes (and follows the flow of resources in this and most other TSBF projects); "scientized" language remains a marker of status in many of the interactions. More attention needs to be paid to learning from the group members who have "opted out" of formal involvement.

Impact of agricultural intensification and diversification on crop productivity and soil quality in maize-based hillsides of Central America

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Poverty remains as serious problem in hillside areas of Central America. Large surface of soils have been degraded through erosion or nutrient depletion and through un-adapted management leading to increased poverty. Farmers in Nicaragua expressed in participatory workshops that loss of soil fertility, the lack of crop options and affordable sources of nutrients were major obstacles to increase agricultural productivity. A long-term experiment was established in 2001 at the SOL (Supermarket of options for Hillsides) site at San Dionisio, Nicaragua to develop altenative cropping systems and, to assess their impact on crop productivity and soil fertility (Figure 36).

Figure 36. Overview of the long-term systems experiment at the SOL site in San Dionisio, Nicaragua.

Selected cropping systems were based in the combination of resilient crop germplasm, market oriented options and improved soil fertility management. Table 33 shows the components of these systems. The main purpose of the project is to develop technologies that support sustainable intensification and diversification of cropping systems in hillside agroecosystems. Soils in the site have on average a pH of

6.0, organic carbon 4.9 % and clay content is 40%. Available P is very variable and can range from 5 to 50 mg/kg (Olsen method).

Table 33. Cropping systems and soil fertility management strategies included in the experiment established in 2001 in San Dionisio, Nicaragua.

No	Cropping system	N (kg ha^{-1} $year^{-1}$)	P (kg ha^{-1} $year^{-1}$)
1	Control plot (continuous fallow)	0	0
2	Maize-beans – inputs –cover crop	0	0
3	Maize-beans – inputs + cover crop	0	0
4	Maize-beans + low Inputs – cover crop	30	21
5	Maize-beans + high inputs +cover crop	71	21
6	Maize-beans + high inputs –cover crop	71	21
7	Intensification (maize/beans + sorghum/beans)	71	21
8	Diversification (maize+ green pepper)	71	21

Cover crop: Cowpea (*Vigna unguiculata*).

Treatments were planted in 9 x 9 m plots using a complete randomised design with three reps. A continuous fallow treatment was included in the experiment in order to evaluate the impact of cropping systems on soil fertility parameters over time. The effect of the legume *Vigna unguiculata* as a cover crop was assessed at two N rates (0 and 71 kg N ha^{-1} yr^{-1}). Fertilizer rates applied to the traditional system (30 N and 21 P) are the same as used by producers in the region. Improved crop germplasm was selected from adaptation trials performed in 2000-2001. Green pepper was included as the market oriented crop because of its good prices in the market.

Table 34 shows the grain production and net income obtained in 2004 from the different treatments. Overall results show a significant increase in grain production in the maize-bean systems with the application of 30 kg N and 20 kg P ha^{-1} in comparison to the no input treatments (treatments 3 vs. treatment 1 and 2). Further application of N did not increase crop production probably due to P limitations. Previous experiments performed in the region have demonstrated that there is strong N x P interaction. Increasing the number of crops from two (maize-bean) to four (maize/bean and sorghum/bean) per year increased significantly grain production and economic profitability.

Table 34. Economic impact of alternative production system on grain production and economic profitability per mz[1]

No	Cropping system	Grain yield (kg ha^{-1})	Costs (US$)	Revenues (US$)	Net income (US$)
1	Maize-beans – inputs –cover crop	2411 a	104	175	71
2	Maize-beans – inputs + cover crop	2584 a	124	206	82
3	Maize-beans + low Inputs	6337 b	188	381	193
4	Maize-beans + high inputs +cover crop	7129 b	254	462	208
5	Maize-beans + high inputs –cover crop	7155 b	243	468	225
6	Intensification (maize/beans + sorghum/beans)	8695 c	292	737	445
7	Diversification (maize+ market option)	-	400	1135	735

Mz[1]= 0.75 ha.

Note: values followed by the same letter within the column are not statistically significant the 5% level.

The little effect of the legume cover crop on maize yields in this experiment can be attributed to the limited growth period for biomass production and N accumulation prior to their cutting and planting corn (40 days). Previous experiments have shown a contribution of this legume equivalent to the application of 67 kg N ha^{-1}.

Although farmers participating in the evaluation of the experiment were impressed by the results of including a high value crop in the rotation system, they are reluctant to validate this system because of the high risks involved in the production of green pepper (pest and disease problems) and the higher production costs (twice as much as their maize-bean system with low use of inputs). They are more interested in the intensification treatment. Future plans include the analysis of changes in soil fertility and the establishment of validation plots in farmer fields.

Output target 2007

- ***Strategies of BGBD management for crop yield enhancement, disease control, and other environmental services demonstrated in seven tropical countries participating in the BGBD project***

Work in progress

Green manure impacts on nematodes, arbuscular mycorrhizal and pathogenic fungi in tropical soils planted to common beans

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The management of soil organic matter is crucial to the activities of soil biota. Use of green manures can have multi-faceted beneficial effects on crop productivity arising from increased biological activity and diversity of soil organisms, which in turn can lead to minimized damage and losses from soil borne pathogens, and increased activity of beneficial organisms. However, different sources of green manure can have different effects on the balance between populations of harmful and beneficial organisms; as they have different rates of decomposition, nutrient release and impact on soil moisture and temperature that invariably affects relative population sizes. We evaluated the effect of different types of green manure on three key functional groups of soil biota: 1) pathogens (root rots of beans), 2) microsymbionts (arbuscular mycorrhizal fungi-AMF) and 3) microregulators (nematodes). An experiment was established in 2003 at CIAT's Santander de Quilichao Research Station, using a plot that had a history of high incidence of bean root rot pathogens. The plots were planted with a susceptible bean variety A 70. Immediately after planting, plots were covered with three types of green manure: (1) rapidly decomposing *Tithonia diversifolia* (TTH), (2) intermediate rate of decomposition by *Cratylia argentea*; and (3) slow decomposing *Calliandra calothyrsus* (CAL) at a rate of 6 ton ha^{-1}; and (4) the control (no green manure added). The experiment was replicated five times and samples were collected within and between rows, to measure the effect of the bean plant rhizosphere on soil biota studied. Following 6 cropping seasons, results reveal that application of *Calliandra* increased bean yield, reduced the incidence of root rots, increased AMF hyphal lengths and reduced nematode abundance. For treatments receiving *Cratylia*, minor differences were observed for root rot incidence, yield and nematode abundance, but AMF hyphal lengths were increased when compared to control. Although showing greater AMF hyphal lengths and lower disease incidence, bean yields in plots receiving *Tithonia* were lower than that obtained in control plots. These results highlight the complexity of interactions among soil biota and impacts on crop yields. The potential exists that green manures promote unknown beneficial organisms that can potentially be used to manage root rot pathogens and/or promote plant growth. The full extent of the impact of this study will be realized upon completion of studies to characterize the abundance and functional diversity of microorganisms from this long-term experiment.

Output target 2008

- ***Improved production systems having multiple benefits of food security, income, human health and environmental services identified***

Work in progress

Improved decision making for achieving triple benefits of food security, income and environmental services through modeling cropping systems in Ethiopian Highlands

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Food security in the Enset-based Ethiopian highlands is constrained mainly by land degradation, land fragmentation and limited access to technologies and skills. Enset (*Enset ventricosum*) is a perennial herb with edible corm, supporting about 13 million people in Ethiopia. A household survey, supported by field measurements, was conducted over three years (2000–2002) with 24 representative farmers to identify their production objectives and to quantify their available land resources, cropping system, crop yields and market price, for developing models to facilitate their decision making. Farmers identified three major production objectives depending on their household priorities, socio-economic status and resource base. In Scenario I, farmers were primarily interested in producing enough food from their farm. In Scenario II, they wanted food security and to fulfil their financial needs. In Scenario III, farmers were interested solely in generating cash income, regardless of its effect on food production. On average, the current cropping system is deficit in most nutritional components, and fulfils only 72%, 40%, 35%, 33%, & 25 % of the energy, protein, calcium, zinc and VitA of the recommended daily allowances (RDA), respectively. More over, the net cash income of the current production system was 624 Ethiopian birr cu^{-1} yr^{-1}. Using an optimization model it was possible to fulfil Scenario I by reducing the land area allocated to sweet potato, coffee, wheat and legumes by 11%, 45%, 22% and 63%, respectively and increasing the land area of enset (from 9 to 17%) and kale (from 2.4 to 7.6%). To satisfy Scenario II, there was a need to increase the proportion of coffee, potato, beans and enset by 30, 15, 8 and 3%, respectively, over the current land allocation. This shift would double the cash income, to 1200 birr cu^{-1} yr^{-1}. Scenario III was fulfilled by full replacement of the cereals and root crops by coffee (80.2%) and teff (19.8%), which would generate 2012 birr cu^{-1} yr^{-1}. This option drastically reduced household food production. The change from current production systems to Scenario I offers high quality livestock feed, while Scenario III offers low quality livestock feed whereby about 84% of the feed is coming from coffee husk. Moreover, a shift from the current system to Scenario I would not have any effect on the level of soil erosion, while a shift to Scenario II and III will reduce soil erosion by about 39 and 52%, respectively, mainly as a result of expansion of the area of perennial crops.

Evaluation of 33 *lablab purpureus* (L.) Sweet accessions for agronomic performance and palatability on two contrasting soil types in Uganda, East Africa

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Although preference ranking and logit regression analysis of probabilities of acceptance of 6 different legume cover crops (mucuna, canavalia, lablab, crotalaria, tithonia, tephrosia) graded lablab species with low probability of being accepted or adopted due to its inability to produce sufficient seed and slow initial field establishment, its multipurpose nature has enabled it to come out as one of the legume cover crops that could be highly preferred and probably adopted by farmers because of it ability to provide several farmers' needs (human food, animal feed, mulch, soil nutrients/manure and soil depletion control), at once. Between 2002 and 2005, germplasm for 33 *lablab purpureus* accessions were evaluated through field trials, to identify those that were potentially able to produce sufficient quantities of seeds, hence suitable for adoption. Further evaluation was done through palatability test to identify those accessions that were suitable for human consumption. This palatability evaluation also influenced the acceptance of the lablab by farmers after seeing the other uses to which it can be put. A preference analysis was done to identify those accessions that had a probability of being accepted by farmers. It was determined that four (Lablab Uganda, Njahi, 29400 and Q69887) out of the 33 accessions introduced with the purpose of characterising the new germplasm for conditions in east Africa, especially for high seed yield, were identified as the most likely to be accepted for adoption by farmers based on their consistence better agronomic performance in the field (Kawanda and Tororo) during the two seasons. These accessions had the most preferred palatability characteristics. The second best accessions selected from the palatability evaluations were 29399, 36019, Q5427, Q6988, 31364, 29400 and 30701.

Farmer participatory evaluation of cowpea for soil productivity and food uses

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Dual purpose legumes which offer both reasonable grain yield and biomass for use as fodder or soil improvement, are a new product of research that can offer best bet compromise for farmers needing to improve soil fertility and maintain their cash flow, while ensuring food security. New dual purpose cowpea lines developed by the International Institute for Tropical Agriculture (IITA) were evaluated for provision of grain and fodder in addition to improving soil fertility improvement through N fixation. A set of 14 cowpea lines were evaluated against a local check in an on-station trial in Tororo, eastern Uganda with the objectives of i) establishing the agronomic performance of new cowpea lines in the agro-climatic and farming system environment of eastern Uganda; ii) assessing farmers' preference for the different lines for food, fodder and soil fertility improvement and iii) providing the national grain improvement programme with the opportunity to select lines for further testing and use, either directly as varieties or as sources of breeding materials. Results indicated that the local variety, *Ngori*, had the highest level/probability of acceptance compared to the new lines (the local variety is already acceptable!!!!). The acceptability and logistic analyses showed that out of the 14 new lines evaluated, IT98K-205-8 and IT95K-238-3 were the best genotypes. The agronomic results confirmed the above conclusion. Although, IT98K-205-8 did not have the highest yields, its yields were not significantly different from those from IT95K-238-3, which had the highest grain yields. It was also observed that the line (IT97K-1068-7) which had the highest fodder yield produced the lowest grain yield. Although IT98K-205-8 was the most preferred according to the given criteria, the palatability test indicated that of all the new cowpea lines the most palatable one was IT95K-238-3. Cowpea line, IT95K-238-3 came out as the best lines in terms of palatability, acceptability and yielding potential. At the end of the research farmers who participated in the evaluations selected the best five lines for further evaluation and seed multiplication. This trial therefore, has provided farmers in this region with a wider spectrum of dual purpose grain legume lines from which they can choose from depending on whether they need grain, fodder or soil improvement.

Farmer evaluation of improved soybean varieties being screened in five locations in Kenya: Implications for research and development

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In order to determine the improved soybean varieties that if recommended to the farmers would have a high probability of adoption, a farmer participatory approach was used to evaluate 12 soybean varieties in five locations (Oyani in Migori district, Riana in Kisii district, Kasewe in Rachuonyo district, Akiites in Teso district, and Mabole in Butere-Mumias district) in western Kenya. These comprise of 11 improved varieties (TGX1871-12E or SB4 for short, TGX1895-4F or SB6, TGX1895-33F or SB8, TGX1895-49F or SB9, TGX1878-7E or SB14, TGX1889-12F or SB15, TGX1893-10F or SB17, TGX1740-2F or SB19, TGX1448-2E or SB20, NAMSOY 4m, and MAKSOY 1n) and one local variety (Nyala). Farmers generate all the 17 criteria with which they evaluated the varieties. One hundred and sixteen farmers (52% females) participated in the evaluation. A scoring matrix was used to articulate the results. Data analysis was done using Microsoft Excel. This study shows that of the seven varieties (all are dual purpose promiscuous) tested in all the five locations, only SB19 was acceptable in all (see Table 35). Some of the remaining varieties were acceptable in specific niches (locations), SB9 in Oyani area, Nyala in Kasewe area, SB20 in Teso area, and SB15 in Mabole area. The overall best choices by location are contained in Table 36. This result shows that to avoid the risk of low adoption, a blanked recommendation of varieties that are accepted only in selected niches must be avoided. SB19 is the only variety that can be recommended across locations and that is clearly better than the existing farmers' own variety, Nyala.

Table 35. The best soybean varieties (among the eight varieties screened in all the five sites) based on farmers' evaluation

	Oyani (Migori)	**Riana (Kisii)**	**Kasewe (Rachuonyo)**	**Akiites (Teso)**	**Mabole (Butere-Mumias)**	**All locations**
1st	SB9	SB19	NYALA	SB20	SB15	SB19
2nd	SB8	NYALA	SB19	SB19	SB19	**NYALA**
3rd	SB19	SB8	SB15	SB9	SB4	SB15
4th	SB20	SB4		SB17	NYALA	

Source: Participatory screening data, 2005

Table 36. Overall best soybean varieties by location

Rank	**Location**				
	Oyani (Migori)	**Riana (Kisii)**	**Kasewe (Rachuonyo)**	**Akiites (Teso)**	**Mabole (Butere/ Mumias)**
Overall first choice	SB17, SB19	SB19	Nyala	SB20	SB19
Overall second choice		Nyala	SB19	Maksoy	Nyala
Overall third choice	Nyala	Namsoy 4m	SB17	SB19	SB6

Source: Field evaluation data, 2005

Baseline study on soybeans (production, processing, utilization and marketing) in the farming systems of East Africa (Kenya, Uganda, and Tanzania)

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Soybean was introduced in the farming systems of Kenya, Uganda, and Tanzania many decades ago. However, the crop has remained a minor crop despite its great potentials for improving household food and nutrition security (through quality food supply), household cash income (through the sales of soybean and soybean products), household health (through the provision of high quality protein-rich food), and soil fertility improvement (through its atmospheric nitrogen-fixing ability). Literature indicates that low yield, lack of knowledge on its utilization, and lack of market are among the key factors that have contributed to lack of adoption of soybeans in the farming systems of East Africa. A recent effort based on improved dual-purpose promiscuous soybeans varieties sourced from IITA, Ibadan, Nigeria has been commenced by TSBF-CIAT.

This study aims at documenting the baseline data (on production, processing, utilization, and marketing) in order to have sufficient information to assess the impact of the improved dual-purpose promiscuous soybeans varieties on the soybean sub-sector in East Africa in future. This study is being carried out in selected districts in the three countries. Data for the attainment of the objective of this study are being collected from primary sources (household-level and community-level surveys using questionnaires), secondary sources (reports, published articles, books, etc.) and key informant interviews. Data processing is being executed using many computer applications including Microsoft Excel, SPSS, and SAS.

Data collection for the Uganda arm of the study is currently being executed. Although, data collection for the Kenya arm has been completed, the processing (validation and cleaning, and analysis) of this data is still on going. However, a complete description of the variables (constraints) and the development of the coding schemes related to the constraints have been carried out for the Kenyan data. The implementation of the baseline community-level and household-level socioeconomic data collection in Tanzania is planned towards the end of 2006 or early 2007.

Identification and development of options for sustainable soybean demand and marketing in the farming systems of Kenya

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Soybean was introduced in the farming systems of Kenya many decades ago. However, the crop has remained a minor crop despite its great potentials for improving household food and nutrition security (through quality food supply), household cash income (through the sales of soybean and soybean products), household health (through the provision of high quality protein-rich food), and soil fertility improvement (through its atmospheric nitrogen-fixing ability). Lack of market for the output is one of the key reasons given by farmers for not giving much attention to soybean production. This is compounded by the lack of knowledge on soybean utilization by many farm households. These imply that without proper market development, all efforts towards soybean development and promotion in Kenya will amount to nothing.

This study aims at identifying various ways of developing soybean market at three different levels (household-level, community-level, and industrial level by linking farmers with industries that use soybean) in the farming systems of Kenya. Data from many studies currently being carried out will contribute to this. These include (i) the baseline household-level survey of soybean in the farming systems of western Kenya, (ii) the baseline community-level survey of soybean in the farming systems of western Kenya, (iii) survey of selected food (including supermarkets) and feed industries in Kenya, and (iv) key informant interviews, among others. All these surveys are being executed using structured questionnaire. Secondary data will be derived from reports, published articles, books, etc.

Apart from the above, the processes that we are using to develop the soybean market development at household-level include (i) awareness creation on the various attributes of soybean, (ii) effective promotion through participatory training and development on the processing of easy-to-prepare soybean products and the associated recipes, etc.). At the community-level, our efforts are centered on the *VitaGoat* System (a machine used in soymilk production and the production of soybean residues that are handy in the production of high protein soy bread, soy biscuit, soy cake, livestock feed, etc.). At the industrial level, our activity is on linking farmers and producer groups to large-scale food and feed industries (to ensure the existence of market opportunities that can mop up production levels that are beyond the absorptive capacities of the household- and community-level demand and help in import substitution that can save the huge foreign exchange often spent by these industries to import soybean for their operations in Kenya

The awareness creation is currently leading to widespread adoption of soybean production among the communities in TSBF-CIAT action sites in Butere-Mumias and Migori Districts. A VitaGoat has been imported from Canada, especially for community-level soymilk processing and the generation of soybean residues for use in the production of other soybean products. Many industrial processors of soybean in Kenya, including Bidco and NUTRO EPZ have agreed to clear the market for whatever soybean that the Kenyan farmers produce and at Ksh 26 per kg.

Evaluation of key agricultural production input supply and network in the farming systems of western Kenya

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Low factor (land, labor, capital, management) productivity is a common feature of the farming systems of western Kenya. This negatively affects livelihoods by impacting negatively on household food and nutrition security. Among the other reasons, lack of access to key agricultural production inputs (inorganic fertilizers, organic inputs, seeds, etc.) by the smallholder farmers has been blamed for the low factor productivity that characterize western Kenya agriculture. The situation is further compounded by the HIV/AIDS pandemic that is most widespread in western Kenya compared to other regions of Kenya.

The objectives of this study are to (i) assess the availability farm input supply centers in selected districts in western Kenya, (ii) to evaluate the types and suitability of agricultural inputs stocked, (iii) to assess the types and qualities of other services that farm input suppliers offer to the smallholder farmers, and (iv) to make recommendations on how to improve the access of smallholder farmers to agricultural production inputs in the farming systems of western Kenya and similar environments.

This study is being carried out in eight districts from three provinces (Western, Nyanza, and Rift Valley) in western Kenya. These districts were randomly selected from the list of all the districts in the three provinces. In each selected district, a list of all the agricultural production inputs was compiled. From this list, a random sample of input suppliers was selected for interview using structured questionnaire. Secondary data sources include reports, published journal articles, proceedings of conferences, books, etc. Data processing is being carried out using Microsoft Excel, SPSS, and SAS.

Data processing is still at a primary stage.

The place of soybean among the grains (grain legumes and cereals) traded in selected marketed markets in western Kenya

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Literature, interactions with farmers and key informants have revealed that lack of market (and low prices) has been a major reason for the low presence of soybeans in the farming systems of western Kenya. This is compounded by lack of knowledge on simple methods of processing soybeans for food, making marketing the product the only option left for the producers.

The objective of this study is to (i) assess the degree of availability of soybean in the selected markets in western Kenya, (ii) to determine the types and sources of different soybean varieties found in the markets in western Kenya, (iii) to evaluate the stock and market shares of soybeans relative to the other grains traded in the markets in western Kenya, (iv) to evaluate the marketing margins associated with soybean marketing in the markets in western Kenya, and (v) to make recommendations on how to increase both the marketing margin associated with soybean marketing and the market share of soybeans compared with the other grains.

This study is being carried out in eight districts from three provinces (Western, Nyanza, and Rift Valley) in western Kenya. These districts were randomly selected from the list of all the districts in the three provinces. In each selected district, a list of all the markets where grains (including soybean) are traded is compiled. From this list, a random sample of markets was selected. At the market, the traders selling grains are listed and a random sample is taken and interviewed using structured questionnaire. Effort is made to include large and small stock traders in the sample. Secondary data sources include reports, published journal articles, proceedings of conferences, books, etc. Data processing is being carried out using Microsoft Excel, SPSS, and SAS.

Scaling out conservation farming experience in Fuquene (Colombia) to other Andean watersheds: Ambato (Ecuador) and Jequetepeque (Peru)

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The Colombian experience with conservation farming practices (minimum tillage, green manures and direct drilling) is being scaled-out by a strategy that aims to test and adapt the technology to the Peruvian and Ecuadorian production system. During 2005, training courses oriented to Jequetepeque (Peru) and Ambato (Ecuador) farmers interested in implementing the proposed technological change. In Peru, strategic alliances between the project local partner (CEDEPAS) and the farmers were created in order to establish pilot farms with green manures and minimum tillage. Complementary research activities are conducted in order to measure the impact of these practices on soil physical properties and crop diseases. For 2006, pilot implementation of these soil conservation practices was agreed between a community-based organization and the project in Ecuador. The monitoring of impacts will be measured by CONDESAN and CIAT. It is expected to extrapolate conservation farming practices in 100 ha of the Ambato watershed (Ecuador).

Output target 2008

- ***Crop-livestock systems with triple benefits tested and adapted to farmer circumstances in savannas***

Completed work

Sustainable intensification of crop-livestock systems on sandy soils of Latin America: trade-offs between production and conservation

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Large areas in Latin America are covered by coarse-textured (sandy) soils that are under extensive livestock systems, annual cropping systems and forest plantations. Low levels of soil organic matter and limited availability of water and plant nutrients, in particular phosphorus and nitrogen, are the major soil constraints to agricultural productivity. These sandy soils are also highly susceptible to massive topsoil losses through wind and water erosion. Because of this, large and small-scale farmers face the challenge of developing sustainable agricultural systems in this type of soils. The present study discusses the technical potential and socio-economic viability of two resource management technologies that were developed in the Brazilian Cerrados to enhance livelihoods of small and large farmers and productivity of sandy soils: crop-pasture systems with high use of inputs and legume-based pastures for dairy systems with low use of inputs. These technologies were developed, tested and monitored with the active participation of individual farmers, local organizations and researchers from EMBRAPA and CIAT. The two technologies described in this paper increased productivity and profitability of large and small-scale production systems in the short-term and improved resource conditions in the long run. In spite of their economic and environmental soundness, their massive adoption is constrained by socio-cultural factors, the lack of economic incentives and continuous technical backup and policies to support sustainable intensification of these soils.

Progress towards achieving output level outcome

- *Partners promoting resilient production systems with multiple benefits (food security, income, human health and environmental services)*

Farmers in Africa and Latin America are evaluating actively crop components and management technologies having benefits on food security, income generation and soil fertility. Improved lines of Cowpea and L*ablab purpureus* have been selected by farmer groups in Kenya and Uganda for their contribution to human consumption, increased fodder availability and improved soil fertility. Small farmers in the Cerrados of Brazil are increasing milk production by introducing drought-tolerant forage legumes in their pastures. Market-led crop options such as soybean and vegetables will play a major role in generating income for small farmers in Africa, provided that sustainable markets are developed and alternative uses explored. Preliminary results are promising. The combination of resistant maize varieties and improved soil fertility is showing potential to reduce Striga emergence in maize fields in western Kenya.

Progress towards achieving output level impact

- *Improved resilience of production systems contribute to food security, income generation and health of farmers*

The new production systems under development by the TSBF team and their collaborators in Africa and Latin America will have a positive impact on crop productivity and profitability in the short term. This will be translated into improved food availability at the household level and greater chances to link agricultural production of smallholder production systems with market demands. Soybean crop will become an important component of production systems if production, processing and marketing bottlenecks are solved.