4.2 OUTPUT 2. Economically viable and environmentally sound soil, water, and nutrient management practices developed and tested by applying and integrating knowledge of biophysical and socioeconomic processes

Rationale

Process level information needs to be translated into sustainable soil fertility and land management practices, adapted to the environment in which these practices will be implemented. These environments are characterized by biophysical and socioeconomic traits and those can vary at different scales, from the household (e.g., different access to resources) to the watershed (e.g., different inherent soil quality across landscapes) to the region (e.g., different policy frameworks related to natural resource management). Integration of these factors in the development of sustainable soil fertility and land management practices and understanding on how these factors influence the final outlook and components (e.g., varieties, use of inputs) of these practices is a crucial strategic research issue addressed in this output.

Practices addressed in this output are touching upon various aspects of soil fertility and land management and address the management of these natural resources in the broadest sense, far beyond agricultural production per se. Such aspects include the management of nutrient cycles, belowground biodiversity, ecosystem services, and erosion control. Certain practices are targeting one of these aspects while others are rather integrating more aspects. In terms of improved nutrient cycling, efforts are made to integrate the supply and the demand side for nutrients, and to enhance the use efficiency of organic and mineral inputs. Traditionally, soil fertility management has addressed the supply side of nutrients through concepts such as synchrony, but it is equally important to include the appropriate germplasm that will drive the demand for those nutrients, in soil fertility management strategies.

Efficient use of inputs can be achieved through integration of mineral and organic inputs and targeting soil fertility niches at the farm and landscape scale. Translating strategic information on belowground biodiversity in management practices is expected to happen through management of specific biological pools through cropping system diversification or inoculation or through management of the physical conditions of the soil by integrating conservation agricultural principles. Soil-based ecosystem services are very much related to the quality/quantity of the soil organic matter pool and the regulation of greenhouse gas production and sequestration. Consequently, management of organic resources is paramount to implementing soil fertility and land management practices enhancing ecosystem services. Finally, diversification of contour structures and building up of a soil arable layer is expected to drive the generation of practices restricting erosion and soil physical degradation.

While the above activities are focusing on the technical dimensions of the technology development and evaluation phase, specific activities addressing the socio-economic and policy constraints to the adoption of these options are simultaneously covered. Finally, Output 2 is expected to deliver enhanced farmer capacity to translate best principles for soil and land management into practices that are appropriate to their environment and decision aids, condensing that knowledge, for dissemination beyond the sites where this knowledge has been generated.

Milestones

- By 2006, decision support framework for ISFM developed, tested with and made available to stakeholders in at least 2 benchmark countries.
- By 2008, communities in at least 3 countries demonstrate and test direct or indirect management options that enhance locally important ecosystem services using BGBD.

- By 2010, local baselines and interviews show that farmers' understanding of soil processes is demonstrably enhanced within community-based experimentation in at least 5 benchmark sites.

Highlights

TSBFI-Africa

- Afnet trials have continued in over 20 coutnries in sub-Saharan Africa, on the following themes: the role of micro-organisms in African farming systems, interaction between water management and nutrient management in African Dry Lands, on-farm evaluation of soil fertility restoration technologies, long term evaluation of soil fertility status as affected by tillage and organic and mineral inputs, and others.

TSBFI-Latin America

- In the process of constructing an arable layer, the use of agropastoral systems including legume species, compared to grass species alone, had a greater contribution to labile organic N that resulted in greater soil N availability.
- Predictions generated by the NuMaSS expert system on presence or absence of N deficiency in maize matched the field data on 29 of 31 site-years of on-farm replicated experiments in Honduras and Nicaragua.
- Found that intensive dairy operations based on confined feeding of cut and carry forages result in lower net emissions of greenhouse gases per unit of produced milk, compared to grazing under a silvopastoral system.

Activity 2.1 Strategies for improved nutrient cycling by exploiting variability and intensifying and expanding legume use developed and tested.

TSBFI-Africa

Published Work

Performance evaluation of various agroforestry species as short duration improved fallows for enhancement of soil fertility and sorghum crop yields in Mali

Bocary Kaya[1], Amadou Niang[2], Ramadjita Tabo[3], André Bationo[4]
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The human population growth rate in the Sahel (nearly 3% per annum) is among the highest in the world creating a high land use pressure with the disappearance of the traditional fallow system. This has accelerated the degradation of the natural resources base by a poverty-stricken population forced to overexploit soils, rangelands and forests in order to subsist. The consumption of mineral fertilizers in SSA increased slowly by 0.6% during the last 10 years, compared to 4.4% in the rest of the other developing regions. The total annual nutrient depletion in SSA is equivalent to 7.9 Mg yr-1 of N, P, and K, six times the amount of annual fertilizer consumption in the region. In the particular case of the southern Mali region, N-K-Mg budgets in 1992 were estimated to be -25, -20, and -5 kg per hectare per year indicating that as much as 40% to 60% of the income generated by farming in this region were based on "soil mining". It is in the light of these constraints that the Malian agricultural research institute (Institut d 'Economie Rurale, IER), the Sahel Program of the World Agroforestry Centre (ICRAF) and the International Crops Research Institute for the Semi Arid Tropics (ICRISAT) joined efforts to undertake research activities aimed at sustainably improving soil fertility and agricultural crop yields in the Mali. Thus, from the year 2000 14 different trees and shrubs are being tested in improved fallow systems to find which ones perform best to replenish soils and improve crop yields. The results have i) identified most suited species for 1 or 2 yr improved fallows, ii) determined their impact on sorghum grain yields and iii) documented the remnant effects of their impact on soil fertility and crop yields. Some species could not survive more than 1 year the Samanko conditions. In 2002, the first year of cultivation, it was the Kenyan provenances of Sesbania sesban which performed best with sorghum yields over 2 t ha^{-1}. A year later, 2003, there has been a general decrease in crop yield. Again, the Kenyan provenances of S. seban, with yields 40% lower than the first year of cultivation, were the worst affected by this decrease. No significant changes were observed in the traditionally tested chemical soil parameters.

On-going Work

Farmer participatory evaluation of cowpea for soil productivity and food uses

Delve R.J. and Nyende, P.

Draft paper

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 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.

Data/information coherence and integration: Challenges and Implications for augmenting decision-support systems for soil fertility management
Bagenze, P., Delve, R.J. and Huising, J.
Draft paper from on-going M.Sc. thesis
Various datasets on agronomic practices exist to facilitate decision-making and implementation on agronomic issues. The varying quality, scale, and thematic detail of these is not presently integrated and the databases *per se* do not provide suitable decision support recommendation criteria, especially in identifying and selection of area-specific domains for agro-technology transfer. Targeting such technologies to the most promising niches entails having not only information on the technology and the niches to be targeted but also having this information/data in a format compatible with multi-decision support systems to be used for dissemination. Most of the existing technology transfer recommendations are based on very general guidelines. Trials have normally been carried out on a few research stations and little effort is made to make the observations on these research stations meaningful beyond the research station boundaries and applicable to a typically heterogeneous tropical environment targeted. This kind of information does not *per se* provide sufficient grounds upon which to base reliable technology recommendations beyond trial sites, as there is not adequate consideration of the respective spatial and temporal conditions. The on-station research findings albeit meaningful, only form part of the comprehensive package of variables both biophysical and socio-economic, which are rarely considered when choice of decision support systems for disseminating technologies is undertaken and yet have a great bearing on identifying appropriate areas to target. This paper reviews steps for identification and choice of appropriate data/information and decision support systems that can augment successful land management recommendations. It discusses the use of an array of integrated research and extension tools ranging from basic process research, to widespread on-farm targeting, verification and the use of Geographical Information Systems. The paper proposes flexible approaches to recommendation, for example, the development of decision support systems that embrace socio-economic, as well as, biophysical characterization, and field-testing of technology options as inputs into the model are critical for improved decision making.

TSBFI-Latin America

Published Work

Plant growth, biomass production and nutrient accumulation by slash/mulch agroforestry systems in tropical hillsides of Colombia

E. Barrios and J.G. Cobo
Tropical Soil Biology and Fertility (TSBF) Institute of CIAT
Agroforestry Systems 60: 255-265 (2004)

Planted fallow systems under 'slash and mulch' management were compared with natural fallow systems at two farms (BM1 and BM2) in the Colombian Andes. The BM1 site was relatively more fertile than the BM2 site. Planted fallow systems evaluated included *Calliandra calothyrsus CIAT 20400* (CAL), *Indigofera constricta* (IND) or *Tithonia diversifola* (TTH). During each pruning event slashed biomass was weighed, surface-applied to the soil on the same plot and sub-samples taken for chemical analyses. While *Indigofera* trees consistently showed significantly greater ($p < 0.05$) plant height and collar diameter than *Calliandra* trees at both study sites, only collar diameter in *Indigofera* was significantly affected at all sampling times by differences between BM1 and BM2. After 27 months, TTH presented the greatest cumulative dry weight biomass (37 t ha^{-1}) and nutrient accumulation in biomass (417.5 kg N ha^{-1}, 85.3 kg P ha^{-1}, 928 kg K ha^{-1}, 299 kg Ca ha^{-1} and 127.6 kg Mg ha^{-1}) among planted fallow systems studied at BM1. Leaf biomass was significantly greater ($P < 0.05$) for CAL than IND irrespective of site. However, CAL and IND biomass from other plant parts studied and nutrient accumulation were generally similar at BM1 and BM2. At both sites, the natural fallow (NAT) consistently presented the lowest biomass production and nutrient accumulation among fallow systems. Planted fallows using *Calliandra* and *Indigofera* trees had the additional benefit of producing considerable quantities of firewood for household use.

2.2 Development of practices for managing BGBD indirectly through cropping system design and directly through inoculation strategies

TSBFI-Africa

On-going Work

Arbuscular Mycorrhizae dependency of different banana tissue culture cultivars
J. Jefwa and B. Vanlauwe
Arbuscular mycorrhizal fungi have potential to improve the performance of tissue cultured bananas in poor soils. The magnitude of response may vary between species and within species. Therefore, prior to establishment of tissue culture cultivars in poor soils, the response of different cultivars to different AMF isolates will be determined. A greenhouse experiment will be set up to determine dependency of different tissue culture cultivars on different AMF isolates. The objective of the current activity is to establish the effects of inoculation with different AMF isolates on the performance of different tissue culture banana cultivars. The treatment structure consists of 3 factors: (i) banana cultivar (10 cultivars – availability to be established –NARO and JKUAT), (ii) AMF isolates (2 isolates of *Glomus etunicatum, Glomus globiferum, Scutellospora cerradensis, Gigaspora margarita* and *Acualospora rehmii*/*A. scobiculata* and a control), and (iii) Inoculum (inoculum bulked in sand and inoculum bulked in nursery media). The parameters to be measured are: (i) measurements of aerial parts(height, length and diameter of pseudostem girth, leaf numbers and area measured weekly and the shoot fresh and dry weight measured at harvest), (ii) measurements of root morphological properties (root fresh and dry weight, root hair density and length, root length, AMF colonization measured at harvest), and (iii) measurements of plant nutrient levels (N, P, K, Ca, Mg, Zn to be measured at harvest). The experiment has started in October 2004 and is expected to last for about 5 months (2 months of bulking up the inoculum and 3 months of greenhouse experiment).

Develop strategies for demonstrating improved BGBD management and for establishing farmer experimentation

J.J. Ramisch, J. Huising (TSBF-CIAT)

The development or design of management practices for the conservation of BGBD is aimed to be done in collaboration with the farmer community, and requires farmer participation. Aspects of farmer participation and application of farmer participatory research (FPR) approaches are therefore considered to be part of developing strategies for demonstrating improved BGBD management. At the second annual meeting of the CSM-BGBD project, held in Embu Kenya, the working group (WG3) on sustainable management was established and introduced with a plan of action. WG3 deals with all the on-farm and community-based aspects of the project. As such it supports the activities of the other working groups by ensuring that the knowledge generated by the project can be translated into practical methods for land-users to conserve and manage BGBD through direct and indirect means to enhance sustainable production. The specific responsibilities of the WG3 in each country team include the following:

1. Identifying and managing stakeholder interactions. It is expected that the relevant stakeholders include not only the many institutions that come together as "country teams" but also national extension services, NGO's, and other community-based organisations such as farmer groups. Where community organisation is low or farmer groups absent, contact will need to be made with relevant local bodies to initiate and formalise grounds for project interaction with local communities.

In addition, it may be decided that country teams will need training and capacity building in participatory research methods as a means to improve the quality of interactions between stakeholders and the utility of the data collected.

2. Characterisation of existing land management practices and socio-economic characteristics that impact on BGBD. This characterisation includes:

- Collection and assessment of the contextual, secondary data (socio-economic, demographic, land-use, etc.) necessary for the site selection (in concert with WG2).
- The implementation and analysis of a baseline survey of existing management practices as they relate both to community and household characteristics.
- Using the baseline data, development of an appropriate household typology of farms / land-users, consistent with the land-use intensity index and other project-wide variables. This typology will assist in the inter-site comparison of practices and impacts, and also in the selection and involvement of land-users in the experimentation and demonstration phases.

3. Documenting and analysing local knowledge of below-ground biodiversity. Likely topics:

- Study and analysis of local indicators of soil quality or ecosystem change. Such indicators can help identify local priority areas for intervention and may also identify the existence of knowledge gaps that the project can fill.
- The role of local social networks or institutions (i.e.: tenure arrangements) in maintaining land-use management and sharing new knowledge.

4. The design and implementation of local experiments and / or demonstrations of improved management practices. In many ways this is the most important role for WG3. It integrates outputs from WG1 and WG2 (i.e.: to identify which technologies or approaches have greatest potential utility to smallholders and communities) as well as the knowledge generated by WG3 in the preceding three tasks.

- A major component of the on-farm experimentation and demonstration will certainly reflect each country team's attention to specific ecosystem services. Since such priorities are still being defined – from the ranking of community priorities and the research interests and abilities of the country teams, it is difficult to define in advance the scope and nature of the on-farm technology development. For example, experiments and demonstrations of rhizobial inoculation for better N fixation will demand different criteria for site and farmer selection than would those for improving decomposition processes, managing pests or disease, or improving water quality.
- There is also considerable opportunity under this activity to include networked experiments that are replicated across all seven countries. Such experiments are more likely to be researcher-led

since they will reflect priorities and topics that might be of only marginal interest to local communities.

5. Monitoring and evaluation (M&E) of project activities and progress. The discussion in Lampung showed that while the project proposal was not originally explicit in addressing M&E there is a need for the following types of monitoring / evaluation:

- Internal to the project, findings of the inventory WG1 in particular need to be regularly synthesised and their implications for management evaluated.
- Using the baseline surveys and the site selection criteria, changes in land-use and management within the study areas should be tracked and implications for BGBD and stakeholder involvement evaluated (will be in conjunction with WG4's Impact assessment group).
- Periodic stakeholder evaluation of project activities, including evaluation of changes in awareness and attitudes towards BGBD, implications of potential technologies, and recommendations emerging from the project.
- Participatory monitoring and evaluation by farmers and other land-users of the technologies being tested. This data collection is a fundamental part of the experimentation and demonstration, guiding the decisions to adapt or reject technologies.
- Synthesis of these M&E activities to feed into the project's reporting requirements (6-monthly reports on the objective and activity level of the log frame).

Capacity for socio-economic and participatory research varies between the project teams, which means that wherever feasible topics of local interest can (and should) be included. Thus a final task for WG3 is:

6. Identifying opportunities for useful synergy with local partners or projects (i.e.: existing on-farm experiments or demonstrations, NGO's with strong contacts to community organisations or sustainable agriculture activities). Topics of local importance, or which can capitalise on existing relationships are therefore much encouraged. This should also include collaborative use of existing socio-economic data sets and nationally relevant methodologies.

TSBFI-Latin America

Completed Work

Biological evaluation of the arable layer build-up in soils from the Colombian savannas

D.L. Correa[1,2], E. Barrios[1], E. Amézquita[1] and M. Sánchez[2]
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Collaborative research jointly conducted by CIAT and Corpoica has shown that the physical, chemical and biological conditions of soils in the natural Colombian savannas are not suitable for agriculture. It is thus necessary to generate improved conditions for agriculture in these savanna soils by building an arable soil layer that can be cultivated. The purpose of this study was to assess the impact of two approaches to construct an arable layer on labile SOM fractions and soil N mineralization.

The Cultural Profile experiment was conducted in Matazul farm located in Puerto López (4° 9'49''N and 72° 38'23''W) in Meta department, Colombia. The experiment included three treatments with different chisel plow intensities (RAS1 = 1 pass, RAS2 = 2 passes, RAS3 = 3 passes), 3 agropastoral treatments namely: A+G = rice + *Andropogon gayanus*, A+L = Rice + Leguminosae (*Pueraria phaseoloides*+*Desmodium ovalifolium*), A+G+L = rice + *A. gayanus* + *P. phaseoloides* + *D.ovalifolium* and the control NS = native savanna almost exclusively composed of *Trachypogon vestitas*. The experiment had a randomized complete block design with 7 treatments and 3 reps. Experimental plots were 30 x 50 m and 20 soil samples (0-10 cm) were collected per plot to generate a composite sample. Size-density fractionation of SOM and aerobic and anaerobic N mineralization were conducted. Data for different parameters was analyzed using ANOVA and mean separation using the LSD test, and also treatment contrasts. Statistical significance refers to $P<0.05$.

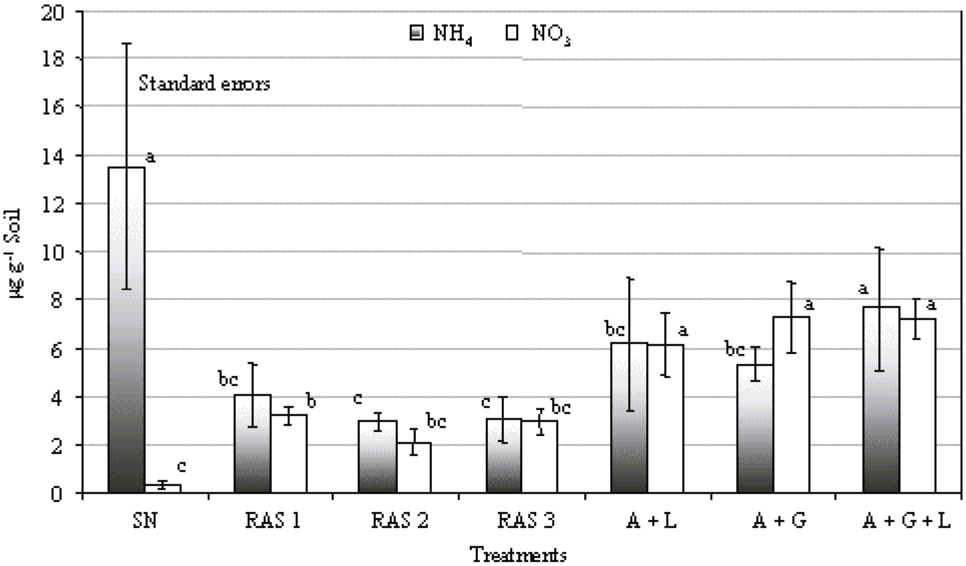

Figure 28. Soil inorganic N under different management systems used during arable layer build up in the Colombian Altillanura.* Means of treatments with the same letter does not differ statistically (*P< 0.05*).

Significant differences among treatments were only found in soil ammonium, nitrate and mineral N (Figure 28) but not in aerobic or anaerobic mineralization using lab incubations. Higher weight and lower N content in the LL (light) fraction of the native savanna and the opposite trend in other treatments was likely responsible for the lack of significant differences found in this usually sensitive parameter. These results are consistent with the literature showing that nitrification in tropical savannas is usually low so that accumulation of soil ammonium is a common phenomena.

Table 30. Contrasts test among soil management practices used for arable layer build up in the Colombian savannas.

Parameter	**Contrast**						
	Mean	**SN vs Others**		**Agp vs Lab**		**Gr vs Leg**	
Soil total Nitrogen (mg Kg^{-1} soil)	1334	135.4	ns	268.4	**	113.8	ns
Anaerobic N mineralization (μg g^{-1} soil d)	0.5	0.8	ns	0.6	*	0.3	ns
Aerobic N mineralization (μg g^{-1} soil d)	0.6	0.1	ns	0.2	ns	0.4	ns
Ammonium (μg g^{-1} soil)	6.1	8.6	**	3.1	*	-0.8	ns
Nitrate (μg g^{-1} soil)	4.2	-4.4	***	4.1	***	1.1	ns
Inorganic N (μg g^{-1} soil)	10.3	4.2	ns	7.2	***	0.3	ns
C amount in LL(mg g^{-1} fr)	376	40	***	12.3	*	-12.2	ns
N amount in LL (mg g^{-1} fr)	15.4	-3.4	**	-0.3	ns	-1.1	ns
C:N ratio in LL	24.7	9.5	***	1.3	ns	0.9	ns
N amount in LM (mg g^{-1} fr)	15.3	-1.8	**	0.8	ns	-2.4	**
Contributed N by LM(mg Kg^{-1} suelo)	5.3	-1.2	*	0.8	ns	-1.9	*
C:N ratio in LM	22.7	4.8	**	-0.9	ns	3.3	ns

Values correspond to the difference of means between contrasted treatment. *** p< 0.001, ** p< 0.01, * p< 0.05, ns = non significant. SN = Natural savanna, Gr = Grasses, Lab. = Tillage, Leg = Legumes, Agp. = Agro-pastoral

Treatment contrasts show that differences in native savanna were significantly higher for soil ammonium, LL-C concentration, and C/N ration in LL and LM, but significantly lower for soil nitrate, LL-C and N concentration, LM-N content in soil than other soil management systems studied. Treatment contrasts showed that agropastoral systems (A+G, A+L, A+G+L) had significantly higher soil total N, ammonium, nitrate and inorganic N, aerobic N mineralization and LL-C concentration when compared with tillage systems (RAS1, RAS2, RAS3). These results suggest that N input by the legume component was important in contributing to higher N stocks and availability in agropastoral systems. Agropastoral systems containing only grasses had significantly lower LM-N concentration and LL-N content in soil than those systems including legumes (Table 30). This further confirms the important role of legumes in improving SOM quality with higher N inputs that promote soil N mineralization and availability. When grass systems alone were compared with those containing legumes they had significantly higher soil ammonium but lower soil nitrate. The use of legumes during arable layer build up was shown to be important to increase soil N status and presumably also the biological activity although not directly shown in this study.

2.3 Management options to enhance soil-based ecosystem services, with an initial focus on the long-term impacts of organic and inorganic resource management, developed and tested

TSBFI-Africa

Published Work

***Senna siamea* trees recycle Ca from a Ca-rich subsoil and increase the topsoil pH in agroforestry systems in the West African derived savanna zone**

B Vanlauwe, K Aihou, B K Tossah, J Diels, N Sanginga and R Merckx

Plant and Soil, 2004, In Press

The functioning of trees as a safety-net for capturing nutrients leached beyond the reach of crop roots was evaluated by investigating changes in exchangeable cations (Ca, Mg, and K) and pH in a wide range of medium to long term alley cropping trials in the derived savanna of West Africa, compared to no-tree control plots. Topsoil Ca content, effective cation exchange capacity, and pH were substantially higher under *Senna siamea* than under *Leucaena leucocephala*, *Gliricidia sepium*, or the no-tree control plots in sites with a Bt horizon rich in exchangeable Ca. This was shown to be largely related to the recovery of Ca from the subsoil under *Senna* trees. The increase of the Ca content of the topsoil under *Senna* relative to the no-tree control treatment was related to the total amount of dry matter applied since trial establishment. The lack of increase in Ca accumulation under the other species was related to potential recovery of Ca from the topsoil itself and/or substantial Ca leaching. The accumulation of Ca in the topsoil under *Senna* had a marked effect on the topsoil pH, the latter increasing significantly compared with the *Leucaena*, *Gliridia*, and no-tree control treatments. In conclusion, the current work shows that the functioning of the often hypothesized 'safety-net' of trees in a cropping system depends on (i) the tree species and on (ii) the presence of a subsoil of suitable quality, i.e., clay enriched and with high Ca saturation.

Long-term integrated soil fertility management in South-western Nigeria: crop performance and impact on the soil fertility status

B. Vanlauwe, J Diels, N Sanginga and R. Merckx

Plant and Soil, 2004, In Press

Crop response, tree biomass production and changes in soil fertility characteristics were monitored in a long-term (1986-2002) alley-cropping trial in Ibadan, Nigeria. The systems included two alley cropping systems with *Leucaena leucocephala* and *Senna siamea* on the one hand and a control (no-trees) system on the other hand, all cropped annually with a maize- cowpea rotation. All systems had a plus and minus fertilizer treatment. Over the years, the annual biomass return through tree prunings declined steadily, most of it ascribed to tree die-off, but more drastically for *Leucaena* than for *Senna*. In 2002, the nitrogen contribution from *Leucaena* residues stabilized at about 200 kg N/ha, while the corresponding value for *Senna* was about 160kg N/ha. Over the four pruning events per year, the relative contributions of each pruning were different for the two tree species. The four *Leucaena* prunings were more equal in biomass as well as in amounts of N, P and cations, while the first *Senna* pruning was always contributing up to 60% of the annual biomass or nutrient return. Maize crop yields declined steadily over the 16 years studied, but the least so in the *Senna* + fertilizer treatment where in 2002 still 2.2 tonnes/ha of maize were obtained. The fertilizer only treatment led to a yield of only 0.4 tonnes in 2002, the absolute control without any inputs yielded a mere 40kg/ha in the same year. Cowpea yields were rarely significantly affected by the treatments and more affected by disease and/or drought than by the imposed soil fertility treatments. Nitrogen fertilizer use efficiency was usually higher in the *Senna* treatment compared to the control or the *Leucaena* treatment. Interactions between fertilizer and organic matter additions were negative for the *Leucaena* treatments in the first three years, and were positive for the *Senna* treatment in the last 6 years. At all other times, there was no interaction. Most chemical soil fertility parameters decreased in all the treatments, but this was less so in the tree-based alley cropping systems. The presence of trees had a positive effect on carbon stocks, while they were reduced compared to the 1986 data. Trees had a positive effect on the maintenance of exchangeable cations in the top soil. Exchangeable Ca, Mg and K - and hence ECEC - were only slightly reduced after 16 years of cropping in the tree-based systems, and even increased in the *Senna* treatments. In the control treatments, values for all these parameters reduced to 50% or less of the original values after 16 years. Soil pH_{KCl} values decreased with at least 0.5 units in the control and *Leucaena* treatments, but only slightly in the *Senna* treatments. In general, the soils that received fertilizer during the trial were more acid (0.2 to 0.3 units) than the ones not receiving fertilizer. All the above points to the *Senna*-based alley system with fertilizers as the more resilient one. This is reflected in all soil fertility parameters, in a positive interaction between fertilizer nitrogen and organic residue treatment and in a more stable maize yield over the years, averaging 2.8 tonnes/ha with maximal deviations from the average not exceeding 21%.

Long-term effect of tillage and manure application on soil carbon dynamics, soil biological activity and crop performance under Sudano-Sahelian conditions
Mando, A., B. Ouattara, M. Sédogo, L. Stroosnijder , K. Ouattara, L. Brussaard and B. Vanlauwe
Soil Use and Management, 2004, In Press
Human-induced degradation of natural resources in general and of soil in particular, is a major problem in Sudano-Sahelian zones. In order to find efficient soil management practices that maintain or improve soil fertility, research was conducted at Saria research station in the centre of Burkina Faso (12º 16’ N, 2º 9’ W). The combined effect of tillage and manure application on Lixisol properties and on crop performance were studied. A randomised block design with four treatments (hand hoeing only, hand hoeing + manure, ploughing only, oxen ploughing + manure) in three replications was started in 1990. Ten years later, total carbon, different fractions of soil organic matter (SOM), microbial biomass and CO_2 production were measured. Over the 10-year period, carbon content had dropped from 400 to 205 mg/100g soil in ploughed plots without manure and from 400 to 250 mg/100g soil in hoed plots without manure. Manure addition mitigated the decrease of SOM in ploughed plots and even built up SOM in hoed plots, where it increased from 400 to 580 mg/100g soil. Manure had a large effect on the fractions in which SOM is stored. In ploughed plots, a large amount of SOM is stored in physical particles > 0.250 mm, while in unploughed plots the maximum SOM is stored in finer fractions. In the topsoil, hoeing and manure resulted in a higher SOM than ploughing with no manure. However, in the 15–25 cm layer, particularly in September, there was more particulate organic matter (POM) in ploughed plots with manure than in hoed plots with manure. The SOM decomposition rate was 17 % less on the ploughed plots without manure than on hand-hoed plots without manure. CO_2 production was higher and quicker for hoed plots with manure than for ploughed plots with manure. Crop yields were highest on ploughed + manure plots and lowest on ploughed plots with no manure. We conclude that applying manure annually mitigates the

negative effect of ploughing and hand hoeing on soil carbon and related properties and therefore can contribute to the sustainability of the agricultural system in the Sudano-Sahelian zone. Furthermore, ploughing with manure has the most significant impact on yields and has little effect on soil carbon except for a slight loss in the topsoil and a slight accumulation in deeper layers and therefore should be promoted in the region.

Long-term effects of inorganic and organic fertilization on soil organic matter fractions, sorghum yield and fertilizer-N recovery under sudano-Sahelian conditions

Mando, A., Bonzi, M., Wopereis, M.C.S., Lompo, F., Fofana, B., Vanlauwe, B., Stroosnijder L., Breman, H

Soil and Tillage Research, 2004, In Press

Knowledge of changes in soil organic matter fractions resulting from agricultural practices is important to assess their sustainability. A long-term trial sited in Burkina Faso under semi-arid, sudano-sahelian conditions and initiated in 1980 was used to assess the effect of organic and inorganic fertilization on soil organic matter fractions, sorghum yield and inorganic fertilizer-N recovery. During 22 years, 11 treatments were tested with 6 replications. Organic fertilizers (i.e. sorghum straw, kraal manure and aerobic and anaerobic compost) were applied yearly at 10 t ha^{-1}, with and without 60 kg of urea N ha^{-1}. The remaining three treatments included a control (no fertilization), only inorganic fertilization (60 kg N ha^{-1}) and fallowing. Fallow plots had significantly higher SOM and N levels over all other treatments. SOM and N concentrations increased in the following order: only urea application < straw < control < straw + urea < anaerobic and aerobic compost with or without urea < manure with or without urea < fallow. Taking land out of fallow had an adverse effect on SOM and soil organic nitrogen status, however this mostly affected the fraction of SOM > 0.053mm (particulate organic matter, POM). The POM concentrations in the control, straw and urea-only plots were about half of the POM concentrations in the fallow plots. POM concentrations increased in the following order: urea < control < straw with or without urea < aerobic or anaerobic compost with or without urea < manure with or without urea < fallow. The fraction of SOM < 0.053mm (fine organic matter, FOM) was greater than POM in all plots except in fallow and (manure + urea) plots. Total nitrogen concentration followed the same trend as soil organic matter, but cultivation led to a decline in both N-POM and N-FOM. Crop yield and nutrient uptake were greatest in the manure plots and lowest in the straw, control and urea only plots. Urea-N recovery was 53% in manure plots, 40% in straw plots and 10% in control plots. Results indicate that under the semi-arid conditions of the experiment, SOM status, POM and FOM fractions, crop yields, nutrient uptake and fertilizer recovery were better sustained using organic resources with a low C/N ratio (manure) than through organic resources with a relatively high C/N ratio (straw). Urea improved the effect of the organic resources with high C/N ratio, particularly in case of straw application. Skilled use of available organic resources combined with judicious use of mineral fertilizers is key to sustainable agriculture in the Sudano-Sahelian zone.

On-going work of AfNet

On-farm evaluation of soil fertility restoration technologies

Site 1: Karabedji and Gaya

Past research results indicated a very attractive technology consisting of hill placement of small quantities of P fertilizers. With DAP containing 46% P2O5 and a compound NPK fertilizer (15-15-15) containing only 15% P2O5, fields trials were carried out by farmers on 56 plot per treatment to compare the economic advantage of the two sources of P for millet production. As hill placement can result in soil P mining another treatment was added consisting of application of phosphate rock at 13 kg P/ha plus hill placement of 4 kg P/ha as NPK compound fertilizers.

The data in Table 31 clearly shows that there was no difference between hill placement of DAP and 15-15-15 indicating that with the low cost per unit of P associated with DAP, this source of fertilizer should be recommended to farmers. The basal application of Tahoua Phosphate rock gave about additional 300 kg/ha of pearl millet grain.

Table 31. Farmers managed trials at Karabedji and Gaya, 2003 rainy season.

	Millet grain yield (kg/ha)		Millet TDM yield (kg/ha)	
Treatments	**Karabedji**	**Gaya**	**Karabedji**	**Gaya**
1=farmers' practices	252	319	1709	1826
2=NPK HP	714	559	2766	2563
3=DAP HP	699	752	2771	3125
4=PRT+NPK HP	921	997	3274	3838
SE	8	23	13	64
CV	10%	26%	4%	16%

NPK: 15-15-15 compound fertilizers
DAP: Diammonium phosphate
HP: hill placement at 4 kg P/ha
PRT: Tahoua Phosphate rock broadcast at 13 kg P/ha

The combination of hill placement of water-soluble P fertilizer with phosphate rock seems a very attractive option for the resource poor farmers in this region. The data in Figures 29&30 is showing the variation of yield of each plot in farmers fields as compared to the farmer's practices and clearly shows that the application of Tahoua PR with hill placement of water soluble P outperformed the other treatments in most instances.

At Gaya, the same effect can be observed and DAP seem better than NPK and confirm the choice on this source (Table 31).

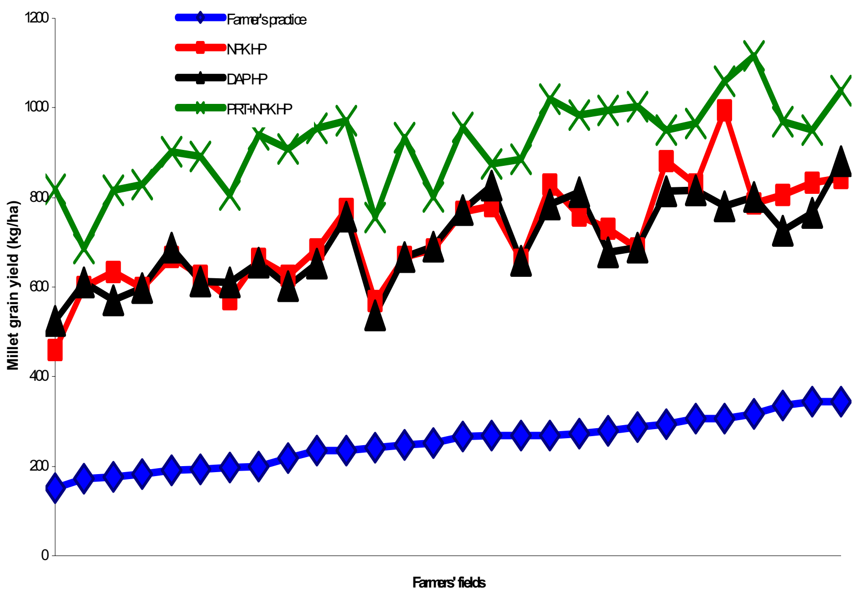

Figure 29. Millet grain yield response to different management practices, Karabedji, Niger, 2003 rainy season

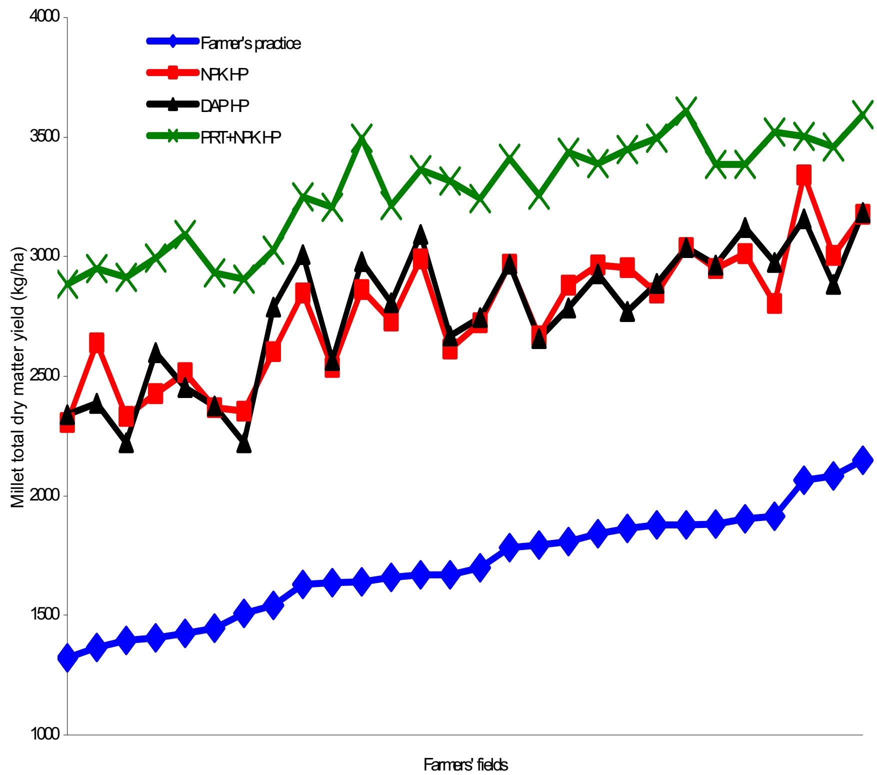

Figure 30. Millet total dry matter yield response to different management practices, Karabedji, Niger, 2003 rainy season

Site 2: Kenya

On-farm evaluation and scaling-up of soil fertility management technologies in western Kenya

On-farm trials were conducted during 2002-2004 cropping seasons in two village clusters in Tiriki West and Kabras Divisions in Vihiga and Kakamega Districts, respectively. Farmers were involved in selection of treatments, monitoring and evaluation of the trials. Prior to setting up the trials, relevant technologies were exposed to farmers by researchers and extension agents. The farmers selected maize as the test crop and the following treatments by consensus: 5 tha^{-1} FYM (Farm Yard Manure); 60 P2O5 kg ha^{-1} & 60 N kg ha^{-1} (inorganic fertilisers); 2.5 t ha^{-1} FYM & 30 P2O5 kg ha^{-1} (inorganic fertilisers); and farmers' practice, which varied from farm to farm. Field days were organised to expose many farmers to the technologies and obtain their perceptions. Data were analysed by conventional economics techniques and through farmer evaluations. Results show that farmers did not necessarily choose technologies with highest agronomic and/or economic performance (60 P2O5 & 60 N kg ha^{-1}). About 75% of the farmers preferred 30 kg ha^{-1} P2O5 + 2.5 tha^{-1} FYM, despite not generating the highest yield and economic returns, but because they perceived that they could afford or access the requisite inputs.

Completed Work

Emissions of greenhouse gases in an intensive dairy farm in Rozo Colombia

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Cattle are responsible for important direct emissions of methane to the atmosphere. There are also appreciable fluxes of greenhouse gases (GHG) involved in the process of producing the forage consumed by the animals as well as on the disposal of the animal manure. It has been proposed that intensive operations based on controlled balanced diets could result in a net decrease in net emissions of methane per unit of final product (meat or milk), compared to traditional extensive or even intensive grazing systems. However there are very few studies comparing intensive versus extensive systems regarding net emissions of greenhouse gases associated with cattle.

A study was conducted at the Pasoancho dairy farm located near the village of Rozo in Colombia. to assess net emissions of GHG associated with the production of feed for confined dairy cows and the fluxes resulting from the disposal of animal manures in an intensive dairy farm operating a cut and carry system. The study was conducted Annual rainfall is 800 mm and average temperature is 26.8°C. The farm maintains a herd of around 920 confined cows and produces 10,500 liters of milk per day from 570 lactating cows. Forages used in the system are produced in 230 hectares of intensively cultivated land. Cut and carry forages include alfalfa (*Medigaco sativa*), Sorghum (*Sorghum bicolor*) and Guinea grass (*Panicum maximum*). The farm also has 26 ha of a silvopastoral system integrating guinea grass and tress of *Psamanea saman,* where 4 heads.ha^{-1} of grazing cows are maintained. The farm has operated with this system for about ten years and forage production has been managed as monocropping. The farm produces a large amount of animal manure (12.8 Mg. $head^{-1}.y^{-1}$) that is spread using a special tool on top of the pastureland. The soil is a typic vertisol of loamy texture with neutral pH and high levels of available nutrients. Alfalfa has a cycle of 28 days from seeding to harvest while the sorghum cycle is 56 days. The guinea grass is cut at around one month intervals.

To assess net fluxes of GHG in the cut and carry system, various components were measured: fluxes from the land used to produce the forages; fluxes from the animal excreta during the time that they stay in the stable and fluxes resulting from the application of untreated animal manures to the forage land. Methane emissions from the enteric fermentation were estimated using factors from tropical regions (IPCC, 2001). Fluxes from a silvopastoral system on the same farm were also measured. The vented chamber methodology was used in all cases. Fluxes from the soil were monitored over a six month period. Fluxes from animal untreated excreta were monitored intensively over a 20-day period. One of the grass plots that is regularly spread with the manure was selected. A section of the plot (20 m x 20 m) was used as a control with no application of the manure. Fluxes on the manure in the stable were intensively monitored over a three-day period. Gas samples were collected in pre-evacuated glass vials and were analyzed within a week by ECD-FID gas Chromatography.

Net release of methane and nitrous oxide from the animal excreta at the stable is very high at 1200 mg $m^{-2}d^{-1}$ and 70 mg $m^{-2}d^{-1}$ respectively, likely as a result of prevalence of anaerobic condition which favor methanogenesis and denitrification processes. Residence time of the excreta is around 1 day in the stable and due to this short residence time the contribution of emission in the stable to total emissions is not very significant. The application of untreated animal excreta to the fields result in net equivalent emissions of 472.8 mg CH_4 m^{-2} and 64.3 mg N_2O m^{-2} per application event (excreta is applied at a total rate of 50 Mg $ha^{-1}y^{-1}$, split in 6 applications). As can be seen in figure 31, essentially all the methane is released within the two initial days after application, while the nitrous oxide is released in the initial week. Methane dominates total emissions of GHG from the manure, however given the high warming potential of N_2O as compared to CH_4 (around 12 times higher), nitrous oxide emission from the manure can not be neglected.

In Table 32, values are shown for the area under different livestock production systems in the farm as well as net fluxes for of methane and nitrous oxide measured between the soil and the atmosphere. Guinea grass receiving fresh applications of manure showed the highest emissions of methane at 306.5 kg CH_4 $year^{-1}$, followed by emissions from the silvopastoral grazing plots. Both plots received applications of fresh animal manure and this input is responsible for most of net emissions of both gases. The plots on alfalfa and sorghum are net sinks of atmospheric methane, but cannot counterbalance net emissions from the manured plots, and at the farm level emissions from applied manure account for most of the methane balance. Rates of N_2O emissions were higher in the plots receiving manure application. These plots also received additional applications of 80 kg N.ha^{-1} while alfalfa received 40 kg N.ha^{-1} and sorghum 60 kg N.ha^{-1}. Due to their large area cover, plots with sorghum account for the majority of the emissions of nitrous oxide (689.3 kg N_2O $year^{-1}$) at the farm level.

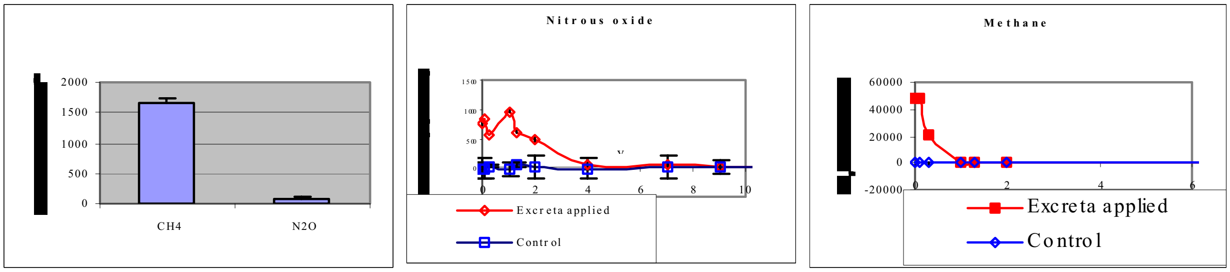

Figure 31. Emissions of methane and nitrous oxide resulting from one event application of animal untreated manure to pasture plots. Rate was equivalent to 8 Mg fresh manure ha^{-1}. Fluxes were monitored over a 20 day period.

Estimation of fluxes of methane from enteric fermentation were based on factors proposed by the IPCC. The same factor was used for both production systems. Total annual methane emission from confined feeding cattle was estimated at 52.4 Mg CH_4 y^{-1}. Corresponding flux for the grazing cows was calculated as 2.96 Mg CH_4 y^{-1}. At the farm level, total fluxes of methane are dominated by emissions by cattle totaling 99% of methane emissions.

In Table 33, the net global warming potential (GWP) resulting from the emissions of methane and nitrous oxide for the silvopastoral and confined feeding systems including methane emissions by enteric fermentation, are presented in units of kg of CO_2 equivalents. Data for milk production in the two systems is also reported. The silvopastoral system supports a stocking rate of 4 heads per ha with a rotation period of 20 days and 20 of resting, which results in an effective stocking rate of 2 head ha^{-1} over the year.

Table 32. Annual fluxes of methane and nitrous oxide from soils under two production systems.

Forage	Total area	Emission rate: $kg.ha^{-1}.y^{-1}$		Farm emissions: $kg.y^{-1}$	
		Methane	Nitrous oxide	Methane	Nitrous oxide
Silvopastoral*	26	11.5	7.1	299.3 (45)	195 (38)
Confined feeding					
Alfalfa	10	-0.662	1.91	-6.62 (1.5)	19.1 (4.4)
Sorghum	180	-0.311	3.83	-55.9 (6.9)	689.2 (134)
Guinea Grass *	16	22.5	5.6	360.1 (54)	96 (29)
Total Confined feeding	206			297.4 (52)	804.3 (152)

Animal excreta applied at an annual rate of 50 Mg. ha^{-1} .Number in parenthesis represent standard deviation.

Data on Table 33 supports the hypothesis that intensive confined feeding livestock systems could result in lower emission rates of greenhouse gases per unit of product as compared to grazing systems. Given that total emissions are controlled by the cattle contribution, it is necessary to generate measurements to assess the effect of the two types of diets in the farm on measured emissions from the enteric fermentation. An attempt will be made to obtain this information using a Rusitec in vitro rumen simulation methodology. Results from a parallel study (data not reported here) measuring net fluxes of methane and nitrous oxide from animal manure being stabilized before application to the grass plots, indicated that total emissions of the two gases could be reduced to less than half by the aerobic stabilization procedure, therefore recommendations have been provided to farm managers to adopt processing of the animal excreta before spreading it to the fields.

Table 33. Global warming potential from the production systems: grazing vs. confined feeding at the Pasoancho dairy farm. Colombia.

System	GWP in Mg CO_2 equivalents. y^{-1}			Milk production $ML.y^{-1}$	GWP per unit product. kg $CO_{2\ equivalents}.L\ milk^{-1}$
	CH_4	N_2O	Total		
Confined feeding	1213	267	1479	3.83	0.386
Silvopastoral	75	55	130	0.20	0.655

2.4 Innovations for managing erosion and soil biophysical conditions/constraints developed and tested (e.g. conservation tillage, arable layer, water harvesting, organic matter build-up, etc.)

TSBFI-Africa

On-going Work

This work is being conducted by a Masters student registered at Makerere University, Uganda to investigate the on-farm comparison of the economic profitability of selected dual purpose live barrier in hilly ecosystem. The objectives of the study are:

1. To assess the effectiveness of selected dual-purpose live barrier system in soil conservation;
2. To the profitability the selected dual purpose, live barrier used soil conservation; and
3. Determine nutrient loss through the established live barrier.

Accelerated soil erosion poses a serious threat to agriculture in highland farming systems through increasing soil fertility loss. Live barriers are considered to be a potential option for soil and water conservation in highland ecosystems. However, adoption of such technologies is low because most farmers do not see a demonstrated, economic benefit, for adopting such technologies and because the benefits of soil and water conservation alone don't repay the investment in labor and land. Farmers selected four multi-purpose live barrier systems (Calliandra, Napier, Setaria, and sugarcane and were evaluated under the same experimental conditions to identify the most efficient and economic live barrier system in soil and nutrient loss reduction, income generation and returns to investment. Setaria grass, followed by sugarcane was the most efficient in soil erosion reduction in the three cropping seasons compared to Napier and Calliandra. This was mainly because Setaria and Sugarcane had a high number of dense tillers compared to Napier which had widely spaced tillers. Napier grass was the most economically viable and profitable option because of its high yield of fodder which was sold, followed by Sugarcane. This work will be continued to allow comparison of the slower growing Calliandra over more seasons.

TSBFI-Latin America

Published Work

Use of deep-rooted tropical pastures to build-up an arable layer through improved soil properties of an Oxisol in the Eastern Plains (Llanos Orientales) of Colombia

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Agriculture, Ecosystems and Environment 103: 269-277 (2004).

It is widely believed that tropical soils (mainly Oxisols) have excellent physical characteristics such as high infiltration rates, high permeability of water, good and stable soil structure and that consequently, they can support mechanized agriculture. However in the Eastern Plains (Llanos Orientales) of Colombia, when Oxisols are subjected to tillage using disc harrow, soil physical conditions deteriorate rapidly. We report here that change in land use with deep-rooted tropical pastures can enhance soil quality by improving the size and stability of soil aggregates when compared with soils under monocropping. In addition, rates of water infiltration improved by 5 to 10-fold while rainfall acceptance capacity improved by 3 to 5-fold. We suggest that intensive and sustainable use of these Oxisols, could only be possible if an "arable" or "productive layer" (i.e. a layer with improved soil physical, chemical and biological properties) is constructed and maintained. One option to achieve this arable layer is through the use of introduced tropical pastures with deep rooting abilities that can result in increased soil organic matter and associated improvements in soil physical, chemical and biological properties. One land use option that can achieve these soil improvements is agropastoralism whereby pastures and crops are grown in short-term rotations.

Development of an arable layer: A key concept for better management of infertile tropical savanna soils

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In: A. Bationo, J. Kimetu and J. Kihara (eds). International Symposium of the African Network for Soil Biology and Fertility (AfNet) of TSBF Institute of CIAT. Improving Human Welfare and Enfironmental Conservation by Empowering Farmers to Combat Soil Fertility Degradation. Yaoundé, Cameroon, May 17-21, 2004. pp. 112-113.
A concept that is highly relevant for the better management of infertile tropical savanna soils is that of the buildup of an arable layer". Before tropical savanna soils can be used for no-tillage systems, the soil's quality in terms of physical, chemical and biological characteristics need to be improved. The application of this concept will depend on the prevailing soil constraints and current land use, for example, soil compaction and loss of soil structure versus depletion of soil nutrients and the type of crops to be cultivated. The concept includes tillage practices to overcome physical constraints, an efficient use of amendments and fertilizers to correct chemical constraints and imbalances, and the use of improved tropical forage grasses, green manures and other organic matter inputs such as crop residues, to improve the soil "bio-structure" and biological activity. The use of deep-rooting plants in rotational systems to recover water and nutrients from subsoil is also envisaged in this scheme. This concept builds on earlier suggestions for the better management of tropical soils. To be functional, however, more attention needs to be given to the driving forces behind farmer decision making and the existing policies for intensifying agriculture on infertile savanna lands.

Physico-chemical conditions of a soil under different treatments and their effect on yields, weed populations and root development in direct planting in the Colombian Plains

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In 1993 a trial, referred as Culticore, was established in Carimagua, Meta Province, Colombia. The purpose was to develop sustainable production systems in the Oxisols of the Eastern Plains. In Phase I (1993-1998) soil management practices were implemented leading to improvement of the soil through liming, fertilization and implementation of crop rotation systems: fundamentally rice-cowpeas, maize-soybeans, and grass alone or with legumes in plots of 18 x 200 m, with 4 replications. In 1999 the trial was split in two, leaving plots of 18 x 100 m for Phase II, in which the objective was to determine whether the improvement obtained in Phase I was sufficient to support or not direct planting. Rotational systems of rice-soybeans and maize-soybeans were established along the plots, using tillage with a chisel or not, and planted directly with a seed drill. This work was done in a well-drained, clay-silty Oxisol (tropeptic haplustox, isohyperthermic) with low fertility, pH 4.5, low exchange values of Ca, Mg and K, an Al saturation of more than 90%, and an annual average rainfall and temperature of 2280 mm and 26^{o}C, respectively. Samples were taken for yield in rice and maize, for botanical composition to evaluate

undesirable plants and for roots evaluation in the crop's flowering stage. Significant differences were found among treatments and tillage. In 2000 the highest maize yields were obtained in T10 (pasture of *Panicum maximum* + legumes) with an average production of 4178 kg/ha. In 2001, 4191 kg/ha were recorded in T8 (maize-soybeans green manure). Maize yield under tillage with the chisel was better in 2001 than in 2000; whereas with zero tillage, the yields decreased with respect to the previous year. In rice it was observed that the average yield for 2001 was lower than that obtained the previous year, where the highest production was in Treatment 10 (pasture of *P. maximum* + legumes) with 3604 kg/ha; while in 2001 it was in Treatment 3 (rice-cowpeas green manure) with 2797 kg/ha. In general all treatments were affected, to a greater or lesser extent, by the presence of undesirable species; thus there were low correlations between weed coverage and yields. In the case of species such as *Digitaria horizontalis*, *Borreria capitata*, *Emilia sonchifolia*, *Mimosa pudica* and *Croton trinitatis*, there were negative correlations, which indicates that grain yields will diminish to the extent that these species increase. There was a high correlation (r^2=0.72) between root development and yields.

The effect of improving soil properties on productivity in two soils of the flat savannas in the Province of Meta, Colombia

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Oxisols represent 57% of the Colombian national territory, of which almost 17 million hectares belong to the savannas in the Eastern Plains. Within this region flat savannas account for 3.4 million hectares. These soils are characterized by low pH values (4.0-4.8), high Al saturation (> 90%), and low levels of nutrients (P, K, Ca and Mg) available for the plants—all factors that limit the production of this zone. The susceptibility of these soils to degradation and the loss of productivity when they are submitted to agriculture and/or livestock production is the principal constraint for commercial-scale and sustainable use. Low-depth tillage done with a disk harrow has caused problems of a physical nature, such as surface sealing and crusting, high bulk density, compaction, low infiltration rates, low rainfall acceptance, high susceptibility to erosion in recently prepared soils, and high runoff. To overcome these problems, the concept of constructing an arable layer was proposed, defined in this context as a surface layer of soil, planned and developed by man, with minimum physical, chemical and biological constraints in order to guarantee stable crop yields, sustainable over time. This study proposed the construction of productive arable layers in two soil textures in a three-year period, using a rigid chisel for tillage and different strategies of soil improvement, seeking to accomplish: (1) vertical loosening of the soil to achieve greater infiltration of water in the soil for a more homogeneous distribution of amendments and nutrients in the profile of improvement and (2) physical stability to the post-tillage soil through the use of materials with high root production to maintain the favorable conditions obtained with the vertical tillage. By the third year of improvement, there were two- to five-fold increases in the infiltration rates of water in the soil, 13-21% increases in total porosity, 60-80% reductions in the resistance to root penetration, 50-65% decreases in horizontal tangential resistance to root expansion, and a 10-15% decrease in compaction of the soil. As a result of the integrated improvement of the soil, the yields of crops adapted to the zone increased the second to third year of soil improvement. It was then possible to plant high-yielding maize materials, which had high levels of production in comparison to the adapted ones.

Completed Work

Strategies for constructing productive arable layers in two texture soils of the Colombian savannas

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A special project financed by PRONATTA from 2001 to 2003 was completed this year. From 1996 to 1999 a diagnosis made on the impact that time of use of the soil had have in their characteristics, entitled "*Impact of different uses and management of soil in the chemical, physical and biological conditions"* and conducted by CIAT-CORPOICA and UNILLANOS, showed that several negative changes had occurred over time. The results of this project, together with other long-term experiments, clearly indicated that the management given to these soils had led them to structural degradation and loss of productivity. Significant losses in organic matter and decrease in macroaggregates in comparison with undisturbed savannas in a wide range of textures were found. These effects, produced soil sealing, which was reflected in high levels of soil hardness, compaction and fall of water infiltration. As a consequence, of the use of harrows, more than 70% of the lime and nutrients applied, were concentrated in the top first 0-5 cm of soil depth in all land uses. As a solution to this problem, the construction of a productive "arable layer" in two textural soils, over a three-year period was proposed, using plow chisels as the basic tool for tillage at two depths: 0-30 and 0-45 cm, with the following proposes: (1) to increase water infiltration and water storage capacity and to get a more homogeneous distribution of lime and nutrients in the chiseled soil depth, and (2) to obtain a better physical stabilization of the tilled soil by promoting rooting of already adapted genetic plant materials to plantain the favorable conditions accomplished by the vertical tillage.

The following are main conclusions from this project:

Chemical improvement of the soil

1. In the two soil textures, light and heavy, the goals for calcium saturation (50 and 40%) and magnesium saturation (20 and 16%) in the first 0-15 cm of the profile were reached.
2. The goals for calcium (1.5 cmol/kg)) and magnesium content (0.6 cmol/kg) in the first 0-15 cm of the profile were reached in the heavy texture but not in the light one, which was reflected in less crop yields.
3. The goals for phosphorus content of 10 and 8 ppm for light and heavy textures, respectively, were higher in all cases.
4. The models generated to correct acidity and leave acceptable levels of calcium and magnesium in the soil for sustainable agricultural production were estimated at 5200 and 6500 kg of dolomitic lime per hectare (distributed over two years) for light and heavy textures, respectively.
5. At 15-25 cm in depth the calcium content continued to be limiting in the two soil textures, reaching levels from 0.15 to 0.24 cmol/kg with Al saturations of 65 and 79% for the light and heavy textures, respectively.
6. Soil nutrition capacity in the subsoil can be improved by applying calcium and magnesium sulfates, which help lower the bases in the profile when the physical conditions of the soil have improved.
7. A tillage depth of 0-45 cm produced a higher level of chemical improvement of the soil in all cases, with lower levels of Al saturation at all depths.
8. The crop systems including pastures and legumes, showed better chemical improvement that the annual crops system.

Organic improvement of the soil

9. The light texture showed increases in organic matter until 35 cm of the soil profile at both tillage depths; while in the heavy texture this increased to a tillage depth of 0-30 cm.
10. In general the tillage treatments conserved or increased the organic matter content of the soil. Greater increases of organic matter are expected in the future as these soils will not be subjected to further tillage activities. They will be cultivated under no-tillage system.

Physical improvement of the soil

11. In relation to native savanna, greater infiltrations of water were obtained at a tillage depth of 0-30 cm in the light-textured soil and 0-45 cm in the heavy texture, possibly associated with better root distribution.
12. Besides of improvement of infiltration rates (two to five-fold increase) at the third year there were 13-21% increases in total porosity, 60-80% reductions in penetrability, 50-65% decreases in soil strength, and a 10-15% decrease in the susceptivility to compaction.

13. A better pore size distribution was obtained in the two soil textures. The two tillage depths, maintaining or decreasing the micropores and significant increased the mesopores and, to a lesser extent, macropores, favoring processes of water storage and soil aeration.
14. Highly significant ($P<0.001$) correlations were found between the variables resistance to penetrability and soil strength ($r=0.97$), between soil strength and root density ($r=-0.72$); between root density and percent of organic matter ($r=0.83$), and between organic matter and bulk density ($r= -0.92$).
15. The available water in the light soil was exhausted after 3-4 days of drought; but by the second day, the plants were stressed. In the heavier soil water was exhausted in 7-8 days.
16. A pressure of 11.7 kg/cm^2 was considered as a critical level for penetrability. The area affected by the compaction was estimated at 6.3%.

Biological improvement of the soil

17. Decreases in the populations of *Actinomyces* and fungi occured in all the treatments, possibly as a result of changes in the quality of the organic matter of the soil in the case of *Actinomyces* and for an increases of pH in the case of the fungi. It also could be due, to an improvement of soil aeration.
18. Although the bacterial populations tended to increase, they continued to be marginal. The question that remains is whether the soils have few bacteria or the current methodologies of counting in the petri dishes are not reliable.
19. After the maize harvest in the third year, high populations of VAM were found with high percentages of infection, the populations being significantly higher in the heavy-textured soils at all the depths of the profile.
20. The biodiversity of the VAM species increased with the soil improvement, going from six species in savanna soils to 15 and 16 species in improved soils at depths of 0-30 and 0-45 cm, respectively.
21. The biodiversity of species of fungi increased with the soil improvement, going from three species in savanna soils to six species for the two depths of soil improvement.

Improvement in productivity

22. The *B. brizantha* (cv. Toledo) grass showed increases in forage biomass equivalent to 1-2 t/ha when lime+Sulcamag were used as amendments and greater tillage depth used.
23. The rice and millet showed no response, in grain yield, to Sulcamag or tillage depth, given that these materials are better adapted to the conditions of acidity of these soils.
24. Soybeans gave greater grain yields with Sulcamag and depth of tillage in both textures; however, the response was greater in aerial biomass, height and greenness, which suggest that other cultivars with greater genetic potential could be used.
25. Maize H-108 showed positive responses in grain yields to Sulcamag and tillage depth, in the second year of soil improvement. Yields increased from the second to the third year of soil improvement, from 3789 to 4560 kg/ha in the light texture and from 4306 to 4703 in the heavy-textured soil.
26. When the change was made from maize H-108 to an HYM (high yield maize) in the third year, the yields increased from 4560 to 5375 kg/ha in the light-textured soil and from 4703 to 6196 kg/ha in the heavy texture.

Improvement in profitability

27. The two technological options presented [(1) soil improvement at 0-30 cm depth and use of dolomitic lime with regional crops and (2) soil improvement at 0-45 cm depth with the use of lime+Sulcamag and HYM, showed high profitability, with return internal rates of 30 and 33% respectively.

Environmental improvement

28. Indicators of environmental improvement are presented in terms of conservation, increase of soil organic matter quality, increases in the biodiversity of fungi and VAM, decrease in hardness both vertically and horizontally, greater porosity and infiltration of water in the soil that help to prevent erosion, loss of nutrients by runoff and contamination of waters.

2.5 Socio-economic and policy constraints to the adoption of ISFM options identified and potential solutions tested.

2.6 Decision tools for improved soil, nutrient, and water management developed and disseminated.

TSBFI-Africa

Published Work

Laboratory validation of a resource quality-based conceptual framework for organic matter management

B. Vanlauwe, C Gachengo, K Shepherd, E Barrios, G Cadisch, CA Palm

Soil Science Society of America Journal, 2004, In Press

Organic resources (ORs) are essential inputs in tropical farming systems and their decomposition dynamics are related to their quality. A Decision Support System (DSS) for organic N management has been proposed earlier that subdivides ORs in 4 classes depending on their N, lignin, and soluble polyphenol contents. To validate this DSS, a 28-day aerobic incubation experiment was initiated with 32 ORs, mostly crop and tree residues, applied to a sandy loam soil. The ORs contained 1.4 to 53.2 g kg^{-1} N, 25 to 295 g kg^{-1} lignin, and 4 to 148 g kg^{-1} soluble polyphenols. In-vitro dry matter digestibility ranged from 70 to 820 g kg^{-1}. After 28 days, CO_2-C production varied between 199 and 905 mg CO_2-C kg^{-1} soil, and mineral N contents ranged from 5 to 109 mg N kg^{-1} soil. Based on N mineralization data, 3 classes of ORs were evident: class A with N release > 0, class B with N release ≈ 0, and class C with N release < 0 (N immobilization). Criteria to separate those classes were based on the OR N and polyphenol content and cut-off values between the classes agreed well with those proposed in the original DSS. For class A ORs, N mineralization was negatively related to their lignin/N ratio (except for *Gliricida* residues) and for class C ORs, N immobilization was positively related to their N content. Short-term mineralization data supported the existence of 3 classes of ORs instead of 4 originally proposed by the DSS. However, ORs also govern other functions, operating in the medium to long term, and for these functions, the original 4-class concept may be proven valid.

Decomposition and Mineralization Rates of Organic Residues Predicted Using Near Infrared Spectroscopy

Keith D Shepherd, Bernard Vanlauwe, Catherine N Gachengo, and Cheryl A Palm.

Plant and Soil, 2004, In Press

Characterization of decomposition characteristics is important for sound management of organic residues for both soils and livestock, but routine residue quality analysis is hindered by slow and costly laboratory methods. This study tested the accuracy and precision of near-infrared spectroscopy (NIR) for direct prediction of *in vitro* dry matter digestibility (IVDMD) and C and N mineralization rates for a diverse range of organic materials of varying quality (n = 32). The residue samples were aerobically incubated in a sandy soil and amounts of C and N mineralized determined after 28 days. IVDMD and quality attributes were determined using wet chemistry reference methods. IVDMD and C and N mineralization rates were predicted more accurately from NIR than using models based on wet chemical analysis of residue quality attributes: reduction in root mean square error of prediction with NIR, compared with using quality attributes, was IVDMD, 6%; C mineralization after 28 days, 8%; and N mineralization after 28 days, 8%. Cross-validated r^2 values for reference versus NIR predicted values were for IVDMD, 0.88; C mineralization, 0.82; and N mineralization, 0.87. Precision was higher with NIR than the original reference methods: on average NIR halved the measurement standard deviation. NIR should be used for routine prediction of decomposition and nutrient release characteristics of organic residues. Priority should be given to construction of spectral calibration libraries in centralized laboratory facilities using standardized methods for determining organic resource quality and decomposition dynamics.

On-going Work

Using community-based learning to promote farmer experimentation and innovation with ISFM options in western Kenya

J.J. Ramisch, M.T. Misiko, I. Ekise, J. Mukalama (TSBF-CIAT)

Since 2001, farmer research groups (FRG) in four sites of western Kenya (Emuhaya, Vihiga district; Matayos and Butula, Busia district; Chakol, Teso district) have been experimenting on an ever-increasing number of ISFM principles. The approach used, termed "strengthening Folk Ecology" relies on collective demonstration and experimentation activities testing key principles (soil nutrition, organic resource quality, effects of legume rotation) followed up by individual experimentation applying these principles within ISFM technologies adapted to local priorities and conditions. When the activities began in 2001-02, only five FRG were active in the process, and only one collective activity (a demonstration in Emuhaya) was proposed and completed. However, through the course of interactions between the FRG's and the stimulation of dialogue between FRG's and researchers, the activities have continued to grow substantially, including now 12 FRG, 8 active collective activities that include much more experimental learning than simple demonstration, and a wide range of over 100 individual experiments designed to test and adapt the ISFM technologies.

Highlights of the farmer-researcher interaction process include:

1. Using "simpler" topics as entry points permits long-run empowerment and co-learning. The original experiments in all sites explored local and scientific understanding of soil nutrition. The demonstration plots tested the effectiveness of organic resources of differing qualities (guided by the Organic Resource Database criteria of nitrogen content, lignin, and polyphenol contents) on improving crop yields. At the same time, organic resources were combined with different treatments of inorganic N and P to allow the interactions of organic and inorganic inputs to be contrasted with those inputs used on their own. Farmers agreed that this design could be understood as a relatively simple experiment, whose findings could be readily explained to other group members and then later to visitors, such as other farmer groups or outsiders. The confidence instilled by this first step fed directly into new sets of questions and research objectives for the farmer groups in subsequent seasons.

2. Similar "lessons" have inspired very different follow-up activities in the different sites. It was expected that local concerns and priorities would lead the different FRG to eventually conduct different follow-up activities, however divergent interests became apparent immediately after the conclusion of the first experiments on crop nutrition and resource quality. Coordinating research efforts, so that different sites could learn from each others' experiences has become quite a challenge, walking a fine balance between supporting FRG to test the same concepts independently in different sites and facilitating innovation in unique directions. At the close of 2004, FRG experiments now include: the use of dual-purpose or high biomass grain legumes in rotation with the standard maize-bean intercrop, identifying and applying new high quality materials from local vegetation that would perform "like tithonia", improving the quality of farmyard manure and compost through selective management of inputs and control of aeration, and applying organic resource quality concepts and inorganic fertilizers to non-cereal crops, such as market vegetables (sukuma wiki) or to home garden crops (see discussions below).

3. Experimentation and learning on ISFM topics stimulated group empowerment for other topics. Without explicitly planning the research as "action" research, virtually all of the FRG have gained substantial confidence and skill from their ISFM activities. The social capital that has formed through the course of several years of collective and individual ISFM experimentation has been applied in several ways. First, as the numbers of interested farmers grew, and as tensions over research priorities increased, several of the FRG have split off from original members to pursue their own activities. Thus the numbers of participating farmers has increased through a fissioning of the original FRG, a scaling out process that has relied on founder members looking for and recruiting new members to join them in mutually interesting activities. Second, as part of this fissioning, group activities have broadened considerably beyond ISFM to now include topics as diverse as raising poultry or rabbits for market, running "merrygo-round" investment services for members (part of Kenya's "table banking" movement), and addressing health and nutrition, including the palliative care of people living with HIV or AIDS.

Farmer evaluation of soybean processing options

J.J. Ramisch, M.T. Misiko, I. Ekise, J. Mukalama, V. Munkangwe

Farmer research groups in Western Kenya are increasingly seeing good potential for the growing, consumption, and marketing of grain legumes, particularly high-biomass soybeans, in rotation with their current maize-bean intercrop. To promote wider use and appreciation of soybean, the Emanyonyi farmer group (Emuhaya division, Vihiga district) invited TSBF-CIAT and the local Ministry of Agriculture to a cooking and nutrition demonstration held at their farmer field school site on 5 October, 2004. This event was used to demonstrate the use of soybeans in preparing typical foods of Kenya (chapatti, mandazi, tea, infant formula, fried soya nuts) as well as novel products (cakes, "milk", livestock feed mix). Farmers were interested to see so many uses for the crop, but researchers also wanted to evaluate to what extent these new foods would be acceptable or could integrate into local diets. A participatory evaluation activity after the cooking event helped to score the various products as follows:

Table 34. Participatory evaluation of soybean products, Emanyonyi FFS (26 women, 12 men).

Product	Taste (Sweet-ness)	Mouth-feel (Softness)	Work	Cost	Satisfaction	Able to stay fresh	Smell	Nutritive value	AVERAGE
Chapati	3	3	2	1	3	2	2+	3	**2.37**
Milk	2	-	1	3	3	2	3	1	**2.14**
Mandazi	3	2	1	1	3	2	2	3	**2.12**
Chai	2	-	1	3	2	-	1	3	**2.00**
Livestock feed	3	-	2	3	1	1	1	3	**2.00**
Cake	1	2	2	2	2	2	2	3	**2.00**
Karanga (fried)	3	3	1	1	1	2	1+	2	**1.75**
Infant porridge	1	-	1	1	3	2	1	3	**1.71**

Items were scored versus the "standard" non-soya product, 1=inferior, 2=just the same, 3=superior

Three of the products were considered superior to the "standard" non-soybean product, namely chapatti (a flat bread that accompanies meals), mandazi (a deep fried bread eaten as a snack or breakfast), and the soy "milk" (Table 34) Tea and livestock feed made using soya were considered no better or worse than the non-soya versions – the soybean cake was also considered comparable with the "normal" cake but only a handful of the participants felt able to judge this particular item since cakes are not a common food item. The fried soybean was considered an inferior alternative to fried groundnuts, popular in the area, because they required a great deal of oil. The infant porridge was felt to have too strong a taste in the version proposed – participants suggested several ways to use soybean in a porridge that would not be refused by children.

This activity showed that adoption and wider use of dual purpose soybean varieties will rest not just on their soil fertility improving properties but also on the usefulness of the grain produced. Ready markets do exist for soybean in western Kenya, but a strong domestic demand will help drive adoption. Activities like this one, initiated by the farmers themselves, are a promising sign that awareness and adaptation of the crop can be promoted with minimal investment by research bodies.

ISFM options developed and tested to specifically benefit resources controlled and managed by women (e.g. Home gardens)

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A year-long study was conducted in three sites of western Kenya to evaluate the extent to which women are actively managing the soil fertility of home gardens (typically located on the patches of land that farmers identify as the "richest" site on the farm) and whether ISFM interventions would be able to contribute meaningfully to the yields of garden vegetables. Farmers used collectively managed plots to test inputs on local varieties of leafy green vegetables and also to screen new (disease or drought-resistant) varieties of familiar vegetables. The collective experimentation process was accompanied by detailed participant observation of key informants and their management of gardens. In general, participants in all three sites found the experimentation with vegetables to be extremely rewarding, especially since this was the first time that ISFM was being explicitly demonstrated on vegetable crops. Many felt that it was more worthwhile than the "traditional" experiments that had been conducted on maize, since garden crops are more likely to be grown on small plots such as those used in experimental designs, and for many this was also the first time that they were actively managing the agronomy of vegetables (local practice is to let vegetable crops grow "wild", without weeding, thinning, or attention to crop nutrition). The wealth of data collected from this study is being analysed as part of an honours thesis at the University of Toronto.

Cultivating complexity: Local soil ecological knowledge and the management of home gardens in Western Kenya

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Poster presented at World Agroforestry Congress, Orlando, Florida, 29 June, 2004

The value of "local agro-ecological knowledge" is increasingly promoted by both international and national scientific "professionals" as a major contributor to natural resource management in East Africa. This increasing interest can be attributed to several factors, including the failure of technicist interventions to stimulate agricultural productivity, to reverse or even halt apparent continent-wide problems of soil fertility decline, and also the increasing use of multidisciplinary teams to address natural resource management.

This paper looks at how local soil fertility management practices in western Kenya are informed by knowledge that has been generated and refined experientially. Such knowledge is responsible for the creation and maintenance of various "hot spots" within any given farmscape, most notably the "home garden" for vegetables, medicinal plants, and other valued species. Specific examples will show how the management of these niches reflects dynamics of power and decision-making within the household, and also the broader framework of gender relations and communities' access to information and markets.

The role of local soil ecological knowledge in managing home gardens serves as a useful entry point for examining the more general question of how households allocate capital (financial, human, and natural) to the maintenance of soil fertility on small-holder farms in Western Kenya. It is important to recognise that soil fertility managers and researchers alike must understand the strengths and limits of local knowledge before they can develop a "shared" knowledge base for soil fertility management concepts.

Whose land degradation counts? Understanding soil fertility management in Western Kenya

(Paper presented at the African Studies Association, New Orleans, 10-15 November, 2004)

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Continental-level analyses of African land degradation are overwhelmingly negative and contrast markedly with much more ambiguous local-level analyses. Solutions to land degradation proposed at the macro-level are likewise dramatic and drastic, including replenishing soil nutrient capital or replacing existing farming systems with new varieties and new inputs. While micro-level studies do not suggest that all is rosy, it is clear that land degradation is embedded within wider concerns about livelihood viability. Local studies also reveal potential if not already viable production systems that can confront land degradation, but that taking these solutions to higher scales requires deeper understanding of the local agro-ecological knowledge (LAK) base.

The soil fertility management practices in western Kenya are informed by LAK that has been shaped by repeated social interactions between farmers themselves and between farmers, agricultural "technicians", and other outside "experts". There is thus no single, coherent "body" (or "system") of knowledge about soil, soil processes, or land degradation within any of the four communities studied, nor do practitioners view soil knowledge as distinct from other aspects of rural livelihood. Technically defined "land degradation" emphasises nutrient depletion and soil erosion, while LAK treats system decline more holistically, including attention to non-agricultural livelihood concerns. Scientific efforts to "validate" soil LAK in technical terms therefore can often backfire by trivialising it. Even well intentioned, "participatory" methods used to identify and evaluate LAK with a view towards integrating it with outsiders' scientific knowledge risk marginalising these local knowledges merely as "starting points".

TSBFI-Latin America

Completed Work

Testing Diagnosis of the NuMaSS expert system for N and P applications in corn-based systems

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Corn yield response to N, P and K fertilization in 31 site-years of on-farm replicated field trials was evaluated for watersheds in Tascalapa, Honduras and Calico, Nicaragua in 2003. Each trial consisted of 5 treatments: 1) control without fertilization, 2) 100 kg N ha^{-1} as urea, 3) 100 kg P ha^{-1} as triple superphosphate, 4) 100 kg ha^{-1} each of N and P, and 5) 100 kg ha^{-1} each of N, P and K (as KCl). Analysis of composite soil samples collected from each field replicate, prior to the establishment of fertilizer treatments showed that soils in the Tascalapa watershed had pH values ranging from 5.3 to 7.0, N (KCl) from 1303 to 4592 ppm, P (Olsen) from 3.1 to 13.4 ppm and a clay content 35%. Samples from sites in Nicaragua showed pH values between 5.9 to 6.2; $NH4^{+}$ between 1.37 to 2.37 ppm, $NO3^{-}$ between 0.99-9.35 ppm and a mean clay content of 43%. Yield and soil data were combined to evaluate how well NuMaSS predictions in Diagnosis module of the NuMaSS expert systems matched the field-observed yield responses with corn to N and P fertilization.

NuMaSS Diagnosis of N and P constraints for each site are compared with field-observed corn yields responses to N and P in table 35. Results for trials in the Honduras watershed showed that predictions by NuMaSS Diagnosis of the presence or absence of a N deficiency matched the field data on 7 of 8 farm sites. Predictions by NuMaSS Diagnosis of the presence or absence of a P deficiency, based on estimated Bray 1 P levels, matched the field data on 5 of 8 farm sites. Predictions by NuMaSS Diagnosis with the actual Olsen-extractable P data using a fixed critical value of 15 mg kg^{-1} P, matched field-observed yield responses in 7 of 8 farm sites.

NuMaSS Diagnosis of soil N in experiments from Nicaragua matched corn yield-based results on 22 of 23 farm sites. Diagnosis of the presence or absence of a P deficiency, based on estimated Bray 1 P levels, matched the field data on 16 of 23 farm sites. Phosphorus Diagnosis based on a fixed critical value of 15 mg kg^{-1} P, matched field-observed yield responses in 12 of 23 farm sites.

The number of "mis-matches" in the Nicaragua watershed between NuMaSS Diagnosis of a P constraint and field-observed corn yield responses to fertilizer P, raise questions about the software's estimates of critical soil P levels in these soils. Soils at most of these sites are believed to be Inceptisols with 2.1-dominated clay mineralogy, whereas most of the existing data and algorithms for estimating soil critical P values in NuMaSS comes from soils with clay mineralogy dominated by kaolinite and oxides.

Since very little field data on soil critical P levels was found in the existing literature for the region, new P fertilization trials were designed and are being installed during the current year.

Table 35. Comparisons of NuMaSS Diagnosis of soil N and P constraints with corn yield-based responses to N and P fertilizers in farm trials for the watershed in Tascalapa, Honduras and trials for the watershed in Calico, Nicaragua (2001 y 2001).

Farms	**N**		**P**		**Pred. Bray 1 P**[†]	**Pred. Bray 1 Crit. Level**[†]
	Predicted[§]	**Observed**[¶]	**Predicted**[†]	**Observed**		
Watershed in Tascalapa, Honduras (2001):						
Sol	Yes	Yes*	No	Yes*	24.9	8.1
Peña	Yes	Yes*	Yes	Yes*	7.4	12.6
Bonilla	Yes	No	No	No	9.8	8.1
R.Corea	Yes	Yes*	Yes	Yes*	8.4	10
J.Corea	Yes	Yes*	Yes	Yes*	5.8	8.1
Jes. Corea	Yes	Yes*	Yes	Yes*	7.7	8.1
D. Romero	Yes	Yes*	No	Yes*	23.4	11.3
P.Pérez	Yes	Yes*	No	Yes*	25.3	8.1
Watersehd in Calico, Nicaragua (2001):						
Torres	Yes	Yes	No	No	9.1	8.1
Castro	Yes	Yes	No	No	13	8.1
Arauz	Yes	Yes	No	No	24.5	8.1
Blandon	Yes	Yes	No	No	99	8.1
Diaz	Yes	Yes*	No	Yes*	10.9	9.4
Soza	Yes	Yes	No	No	11.1	10
Rojas	Yes	Yes	No	No	16	8.1
SOL	Yes	Yes*	No	Yes*	81.7	8.1
Watersehd in Calico, Nicaragua (2002):						
1	Yes	Yes	Yes	No	9	15
2	Yes	Yes	No	No	47	11
3	Yes	No	No	No	40	16
4	Yes	Yes	Yes	No	10	20
5	Yes	Yes*	No	Yes*	58	13
6	Yes	Yes	No	No	69	12
7	Yes	Yes	No	No	18	11
8	Yes	Yes*	Yes	Yes*	11	15
9	Yes	Yes	No	No	79	10
10	Yes	Yes	No	No	36	11
11	Yes	Yes	No	No	30	13
12	Yes	No	No	No	22	11
13	Yes	Yes	No	Yes	16	8
14	Yes	Yes	No	No	18	9
15	Yes	Yes*	No	Yes*	13	8

¶ Nutrient deficiency based on obtaining a 1 t ha^{-1} yield increase between the control and N alone or P alone treatments; in the case that such a yield response is only obtained between the control and the N+P treatments, both N and P are considered deficient and are denoted with an *.

§ NuMaSS predictions based on Honduras - humid tropical location, target yield = N+P treatment, grain/stover ratio = 0.75, previous land cultivation with unfertilized corn of unknown yield, Inceptisol and no data for soil organic matter.

† NuMaSS predictions based on clay content and Olsen P for each site. Since NuMaSS predictions with Olsen P do not adjust the critical P level for soil clay content (a fixed value 15 mg kg^{-1} regardless of the soil clay content), soil P values were converted to Bray 1 P (which does adjust critical P level with soil clay content) using the function *Bray 1 P = (Olsen P)/0.53*. This function was derived from a literature review and is similar to the conversion function of *Bray 1 P = -6.0 +1.8(Olsen P)* found for a clayey Oxisol in the Amazon of Brazil.

Evaluation of the CERES-Maize growth simulation model applied to the maize in Oxisols of the Eastern Plains of Colombia

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Acta Agronómica 52: 39-44 (2004)

Intensification of agricultural production on the acid-soil savannas of South America (mainly Oxisols) is constrained by the lack of diversity in acid (aluminum) tolerant crop germplasm, poor soil fertility and high vulnerability to soil physical, chemical and biological degradation. In 1993, a long-term field experiment (CULTICORE) was established in Carimagua, Colombia. The average annual rainfall and temperature are 2200 mm and 26°C, respectively, with a dry season from December to March. Soils are well drained and are defined as fine, kaolinitic, Isohyperthermic Haplustox (clay loam soil). The main objective of the field experiment was to determine the influence of various systems on soil quality and system productivity. As part of this work, the simulation model of CERES-Maize (DSSAT v3.5) was evaluated for its suitability to the tropical conditions. Initially we focused on six genetic coefficients of the maize variety (Sikuani V110), which were calibrated based on field experiments conducted at 3 locations, Carimagua, Palmira and Santander de Quilichao. The evaluation of the model presented close relation between the observed and the simulated data for the principal variables of response including grain yield, biomass and phonological characteristics. The validation of the model using data from CULTICORE resulted in a close relation (r^2=0.95) between the observed and the simulated data. Results indicated that the model could simulate very well the performance of maize variety in terms of production of grain and total biomass as well as other parameters such as days to flowering and days to harvest.

Land use planning in the Llanos of Colombia at landscape units: The case of Puerto López

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GeoTrópico, volumen 2 (1), online: http://www.geotropico.org/2_1_Santana

In this article criteria and recommendations are advanced in support of the process of land use planning in the savanna land-ecosystem. The municipality of Puerto Lopez, Colombia is used as a case study to illustrate the problem. An analysis of landscape and soil characteristics was conducted, taking into consideration biophysical and management aspects, in terms of limitations and potentialities for crop and agroforestry production, and in terms of conservation of different geomorphic settings. The methodology included the overview and conceptual discussion of terms related to land use planning. Satellite LANDSAT TM and RADARSAT imagery was used to define landscape units. Soil data were used to characterize each landscape unit. Fieldwork allowed us to refine the study of soil and landscape relationships, by gathering georeferenced data of the terrain, current land use, and management. The most important findings were summarized in maps and tables.

On-going Work

Determination of the P buffer coefficients for the NuMaSS expert system

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Sites were selected in Yorito and Candelaria, in Honduras to initiate long-term P and N fertilization trials during the current year. The experiments contain 5 rates (including a zero) of broadcast fertilizer P. These P treatments will be monitored for soil test P and enable the determination of the soils' P buffer coefficients for the NuMass expert system. Yield responses for several cropping seasons, probably of corn and common bean, will be related to soil test P values to estimate critical soil P values. A subset of 3 of these broadcast P treatments will be in factorial combination with 5 fertilizer N rates (0 - 240 kg N ha^{-1}). The intent of the NxP factorial is to further investigate potential interactions between these nutrients. In the NPK trials for the Tascalapa watershed in Honduras corn yield responses to either N or P only occurred when both nutrients were applied in combination. Contrastingly, yield response to N in 16 of the 21 sites at the Calico watershed in Nicaragua did not require a supplementary P application. A factorial combination of several N and P rates will allow further elucidation of this interaction between nutrients.

2.7 Identify socioeconomic and policy constraints to the adoption of ISFM options and test potential solutions
(see also 4.4 and 4.7)

TSBFI-Africa

Completed Work

Assessment of adoption potential of soil fertility improvement technologies in Chuka Division, Meru South, Kenya (M.Sc. defended)

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In experimental trials at Kirege primary school Chuka division, a number of soil fertility improvement technologies were demonstrated from which farmers were encouraged to voluntarily select and practice on their farms. This study evaluated the extent to which farmers adopted and adapted the demonstrated technologies and also identified the factors that influenced their adoption or non-adoption of these technologies. To do this a farmer follow-up study was carried out in Chuka division over a period of two cropping seasons. Data was collected using farm surveys, on-farm trials and visual records. The data was then subjected to logic regression and cost benefit analysis to determine important variables affecting adoption and the most profitable treatments of the new technology respectively.

Although inorganic fertilizers were considered farmers' most preferred option, the rates of use were low because of high local costs and restricted availability. Most farmers practiced soil fertility improvement technologies involving the use of cattle manure, which was readily available, although again in inadequate quantities to supply the required nutrients. Further, lack of access to credit and inadequate extension services were identified as some of the critical issues limiting effective adoption of soil fertility improvement technologies. Eighty (80) farmers adopted the soil fertility improvement technologies during the short rains season 2001. During the subsequent two seasons, 163 and 206 farmers representing an increase of 99% and 150% above the initial adopters started practicing the proposed soil fertility improvement technologies. Technologies involving the use of *Tithonia diversifolia* and

Calliandra calothrysus alone or in combination with inorganic fertilizer were readily adopted due to the high yields obtained. During the first season of farmer follow-up, tithonia + half rate of inorganic fertilizer gave the highest net benefit of Kshs. 50133 per hectare followed by the full rate inorganic fertilizer treatment with a net benefit of Kshs. 48568. Fertilizer treatment had the highest benefit cost ratio (BCR) of 7.5. Sole manure treatment recorded the lowest net benefit Kshs. 4601 and hence the lowest BCR of 0.9. However during the second season manure plus half-inorganic fertilizer recorded the highest net benefit of Kshs. 41567 with a BCR of 3.7. Farmer practice involving no input had the lowest BCR of 0.2 with a net benefit of Kshs. 9853.

Constraints to the adoption of the proposed soil fertility improvement strategies were identified as inadequate labour, poor yields observed from some of the technologies at the demonstration trial, inadequate organic and inorganic resources and laxity due to fear of failure. Logistic analyses of the factors affecting adoption of soil fertility improvement technologies identified gender, farmer's occupation, land size and land under food production as major factors significantly affecting adoption of soil fertility improvement technologies in Kirege location, Chuka division. In conclusion there is need for the researchers to put in mind the factors that might affect adoption of a technology in order to have high adoption rates in any given area.