3. RESEARCH HIGHLIGHTS

TSBFI-AFRICA

Strenghtening soil fertility management research capacity in sub-Saharan Africa: Various efforts were made to further strengthen the research for development capacity of the African Network for Soil Biology and Fertility (AfNet). First of all, a successful 9th AfNet symposium was organized in Yaounde, Cameroon, with over 150 participants from all over sub-Saharan Africa and beyond attending. Several guidelines were adopted that will guide the future research agenda of AfNet and its restructuring. Secondly, two training courses aiming at broadening the research capacity of AfNet members were organized. A frist training course on 'Participatory research and scaling up' aimed at fostering social science capacity in AfNet while a second training course on 'DSSAT Version 4: Assessing Crop Production, Nutrient Management, Climatic Risk and Environmental Sustainability with Simulation Models' aimed at strengthening the modeling capacity of AfNet members. Thirdly, funds were secured to broadend the range of network trials implemented in each of the sub-regions in sub-Saharan Africa. Such network trials cover several aspects of the ISFM research agenda and contribute significantly to the strategic understanding of how specific soil fertility management options perform, as influenced by agro-ecological conditions. Research activities in AfNet have also gradually moved towards adaptive research in the areas of management of mineral and organic inputs, the integration of legumes in cropping systems, and soil and water conservation. Interdisciplinary country-level proposals are being developed to further strengthen this adaptive research component.

Implementing integrated soil fertility management: Major efforts were made to further implement the new strategy of TSBF-CIAT, facilitated by the approval of new projects, the implementation of new initiatives, and the strengthening of existing activities. At the strategic level, activities aiming at quantifying long-term impacts of organic resources of varying quality have continued for the third subsequent year in Kenya, Zimbabwe and Ghana. Extra funds were identified that will allow to look at specific soil organic matter fractions and their quality and see how organic resource quality affects C turnover and stabilization. Activities exploring integration of variability at the farm, i.e., within-farm soil fertility gradients, and the community level, i.e., farmer typologies based on resource endowment, have made a lot of progress at the characterization level in Kenya and Uganda, while initial steps have been taken to study the impact of this variability on site-specific soil fertility management options. At the systems level, activities have been initiated that aim at developing integrated soil fertility management strategies for banana systems in Kenya and Uganda and at integrating dual purpose soybean in cropping systems in Kenya, Uganda, and Tanzania. In the context of the latter work, nation-wide soybean marketing studies have been finalized in above countries, indicating a high potential demand for soybean products. Finally, activities have started that back up development efforts in the Democratic Republic of Congo and Rwanda, mostly focused around integration of various classes of legumes with multiple functions in existing cropping systems.

Integrating "formal" and "folk" knowledge of soil ecological processes. The recognition that local communities possess and use a functioning local ecological knowledge system has driven work in western Kenya since 2001 that uses a community-based learning strategy to promote dialogue between this "folk" ecology and the "formal" or systematized science of ecology. This year has seen the philosophy of this work bear fruits in several domains. Firstly, the quality of research and number of topics being embraced by the farmer research groups (FRGs) has grown substantially. At the close of 2004, FRG experiments now include: adding dual-purpose or high biomass grain legumes to traditional rotations, applying new high quality local materials to perform "like tithonia", improving the quality of farmyard manure and compost by managing inputs and aeration, and applying organic resource quality

concepts and inorganic fertilizers to non-cereal crops, such as home garden vegetables. These activities are also increasingly being linked to exploring market potentials, such as for soybean or for vegetable crops like kales. Secondly, the number of FRG involved in these co-learning activities continues to grow. When the activities began in 2001-02, only 4 FRG were active in the process with only one collective activity. Now 12 FRG manage 8 active collective activities that include much more experimental learning than simple demonstration, and a wide range of over 200 individual experiments designed to test and adapt the ISFM technologies. Thirdly, the participatory research methods and tools developed and refined through the course of the "Folk" Ecology project are now being applied in diverse new settings. These include the adoption of diagnostic and focus group discussion tools for identifying local indicators of soil quality within the work on managing soil fertility gradients in Kenya and Uganda, as well as tools for integrating local and outsider knowledge being applied within the CSM-BGBD project in Cote d'Ivoire, Indonesia, Mexico, and Kenya.

Use of legumes in southern African cropping systems: A regional synthesis for southern Africa on previous evaluations of boundary (soil) conditions affecting legume performance, input use strategies in legume cereal rotations and screening legumes for use in cropping systems was carried out. Attempts that were made to map soil type effects on biomass productivity were not particularly successful as differences between soils were not large enough. It was also clear from the data from the different sites that green manuring technology is a technically sound system under most biophysical conditions (except very sandy and degraded soils), and the successful integration of the technology in farming systems has to be through identifying niches based on socio-economic considerations rather than biophysical ones. The range of legume options available for use on depleted sandy soils is narrow. Mucuna is remarkably adapted to the harsh soil conditions and fixed the bulk of the N it accumulated without added P, but requires substantial labor and does not yield a directly usable product. Legume green manures and grain legume/cereal rotations are not enough in themselves to overcome major nutrient deficiencies in soils that are already very degraded in both N and P and this limits N use efficiency that is added through the legumes. N uptake and recovery after green manures was in most cases poor as the N input through the large legume biomass was seldom translated into grain N. Where both soil organic matter and P contents are very poor, legumes do not accumulate significant amounts of biomass and when they do so, N use efficiency will invariably be poor due to other nutrients becoming more limiting. Thus, for the subsequent maize crop to effectively utilize the legume N, other deficient nutrients will have to be added through mineral fertilizers. Opportunities exist to intensify legume use by intercropping cotton and cowpeas however farmers favor cotton over cowpeas because of absence of secure markets for cowpeas. Future strategies should link farmers to markets in order to enhance their income from legumes and increase indirect benefits to soil fertility.

Improving whole farm resource use efficiency in southern Africa: Soil fertility gradients are important. Higher nutrient efficiencies are obtained in home-fields compared with the outfields. There are a lot of trade-offs to be considered in optimally managing these different niches. Simulation modeling using APSIM and IMPACT has shown that concentrating resources on the best field and growing maize without fertilizers on the other fields was less profitable than when fertilizers are distributed evenly across the farm. However profitability was often associated with increases in labor demand, which is a critical factor in determining adoption. The benefits of basal and organic fertilizers can be enhanced by targeting them on legumes and allow maize to grow on residual fertility and N fixed by the legumes.

Advances in CSM-BGBD methodology and inventory: This year, significant progress was made in the GEF funded Conservation and Sustainable Management of Below-ground Biodiversity (CSM-BGBD) project in all the participating countries in terms of methodology development and inventory of below-ground organisms. Functional groups of soil organisms, for which the inventory by prescribed standard methods was mandatory, were clearly defined and assigned to all the participating countries. A list of

optional functional groups, with all the attendant methods for their inventory, was developed in consultation with the partners. The project also produced its first global brochure and newsletter that were circulated extensively to the project participants, donors and other partners of CIAT and TSBF Institute. Progress was also made in project communication. A total of thirteen mailing lists were prepared in addition to a discussion forum and a database of members for communication amongst the project partners. The mailing lists have made it easy for the project partners to communicate and exchange ideas freely and extensively on any topical issue. A website has also been designed and developed for the project and will be launched before the end of the year. The prototype project database is also ready and will be installed in four countries before the end of 2004. In addition, all the project partners have organized national workshops where they have exposed and disseminated the project objectives and outputs to their beneficiaries and policy makers. Much has also been achieved in capacity building. Most of the participating countries have MSc and PhD students attached to the project. Some countries like Brazil have already realized MSc and PhD graduates from the project activities. Other in-country training has also been conducted. Examples include GIS training (Kenya) and training in earthworm taxonomy (Brazil and Mexico).

TSBFI-LATIN AMERICA

Strengthening regional partnerships to facilitate integrated soil fertility management: TSBFI-LA team has been particularly active during this year in supporting partner institutions of the Integrated Management of Soils (MIS) consortium in the development of research and validation proposals. Recent funding from the Water and Food CP will allow NARS from Honduras and Nicaragua to conduct collaborative research with TSBFI-LA on management principles of the Quesungual Agroforestry system and validate the system in hillsides of Nicaragua and Colombia. Masters and PhD students from the region will be trained in new methodologies to quantify nutrient and water dynamics under the system. Additionally, members of the consortium are validating the potential of the NuMaSS expert system to generate recommendation of N and P fertilization in maize-based systems in hillsides of Honduras and Nicaragua. This activity is being carried out with the financial and technical support of the USAID-CRSP consortium. The International Union of Soil Sciences has nominated one of the members of the MIS consortium as the convener for a mega-symposium on methods to assess soil degradation during the next World Congress of Soil Science in 2006. The TSBFI-LA team played a central role in the success of the Latin American Congress of Soil Science, where one keynote address, five invited talks, thirteen oral presentations and four posters were presented by the team and were well received. As one of the highlights of the Congress, the Latin American Soil science Council, approved at its biannual meeting, the creation of the Latin American network of soil science (LatNet). The network aims at promoting the use of common methodologies across countries and institutions, facilitating information sharing and promoting the development of joint research activities. Members of TSBFI-LA were selected to coordinate the launching of the network and TSBFI will host the website of the network. Another main achievement was the successful completion of a national workshop in Colombia dedicated to the topic of indicators of soil quality and land degradation, where the tools developed by the team were exposed to and adopted by a wide audience. The workshop was sponsored by the Ministry of Agriculture and Rural Development from Colombia and was attended by 80 researchers, academicians, farmers and students from twenty institutions from all over the country. Because of the demand from the region, the team intends to plan a second event more likely to take place in Central American hillsides and a third one in a different country for the savannas in South America.

Developed a method to screen tropical legumes for soil fertility improvement*:* Multipurpose legumes (MPLs) used as planted fallows, green manures and mulches are a source of N in many parts of the tropics where N fertilizer is not economically feasible. Interdisciplinary research and the combination of methodological know-how from animal nutrition and soil science become increasingly necessary to fully

explore the high potential of MPLs. Parallels of plant degradation in the ruminant digestive system with litter decomposition in the soil have been described. The aerobic decomposition of plant materials is a slow process and thus methods used to estimate degradation rates on the soil are time and resource consuming. We found that plant measurements used to assess forage quality in animal nutrition studies are more rapid and resource saving predictors for decomposition of tropical legumes than initial plant quality ratios commonly used by many researchers. Furthermore, we confirmed the potential usefulness of In Vitro Dry Matter Digestibility (IVDMD) for screening tropical legumes and guide their optimal use for soil fertility management.

Developing an arable layer to rehabilitate degraded lands in the tropics: Many soils from the tropics, even under natural conditions lack appropriate conditions to support sustainable agricultural production. Constraints could be of chemical, biological or physical nature. These conditions get exacerbated when the soils become degraded. A concept that is highly relevant for the better management of infertile tropical soils is that of the "buildup of an arable layer". Improved soil quality is a prerequisite for implementing no-tillage systems on infertile tropical soils. 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. The practice of building an arable layer requires a detailed initial identification of major soil constraints and then the implementation of appropriate management practices to correct such limitations. Research conducted in close collaboration with CORPOICA and other partners in the Llanos of Colombia indicate that building an arable layer in tropical savannas is not only technically feasible but also economically attractive to farmers who are increasingly adopting the strategy. The arable layer concept and practice is an important component of ISFM approach to restore degraded lands. It contributes to an effective use of the belowground biodiversity and enhances the provision of several environmental services from the soil such as improved water quality and carbon sequestration. This concept builds on earlier strategies 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.

Developing an integrated approach for soil fertility, pest and disease management: Integrated approaches are needed to overcome major problems such as soil degradation and soil pest and diseases to achieve agricultural sustainability and environmental protection in the tropics. The combination of soil fertility and pest & disease management approaches would provide a unique opportunity to exploit synergies allowing a better control of soil fertility/pest & disease limitations to crop productivity than either approach alone. Use of green manures can have a multi-faceted beneficial effect on crop productivity and are showing the potential to reduce crop losses from soil borne pathogens (root rots) and to improve the activity of native beneficial microorganisms (non-pathogenic nematodes, mycorrhizae and rhizobia). First results indicate that despite the relatively limited time of green manure treatments application of 6 t ha^{-1} of *Calliandra houstoniana* (CIAT-20400) biomass to root-rot infested soil significantly reduced incidence (about 15%) and simultaneously increased yield (about 10%) in root-rot susceptible bean variety (A70) compared to control plots. However, while application of *Tithonia diversifolia* reduced the root–rot incidence by close to 30%, it also resulted in considerable yield reduction. Further studies are in progress to understand the interactions among soil fertility, soil biota (pathogenic and beneficial), and crop yield.

Carbon sequestration potential of the savannas of Colombia and Venezuela: Tropical savannas (Llanos) of Colombia and Venezuela account for nearly 50 million hectares (Mha) and represent the last

frontier where agriculture can be expanded in the region. In recent decades around 8 Mha have been converted into crops, forestry plantations and introduced pastures. Pastures now cover nearly 6 Mha. Data from a long-term agropastoral experiment (CULTICORE) at Carimagua in the Llanos of Colombia indicated that these deep-rooted pasture grasses are able to increase soil carbon stocks at around 2.5 Mg $C.ha^{-1}y^{-1}$ over an 8 year period. To estimate carbon storage in soils from the Llanos, the region was divided into different landscape positions with similar soils. Land use cover was calculated from recent satellite images and combined with a comprehensive review of available C content and soil bulk density data. Under current conditions, the Llanos store, an estimated 3.1 Pg of C in the top 30 cm of the soil. It is projected that in the coming two decades, 7 Mha of native vegetation will be converted into pastures, crops and forest plantations. This would result in an additional net C sink of about 160 Tg C in the soils from this ecoregion.