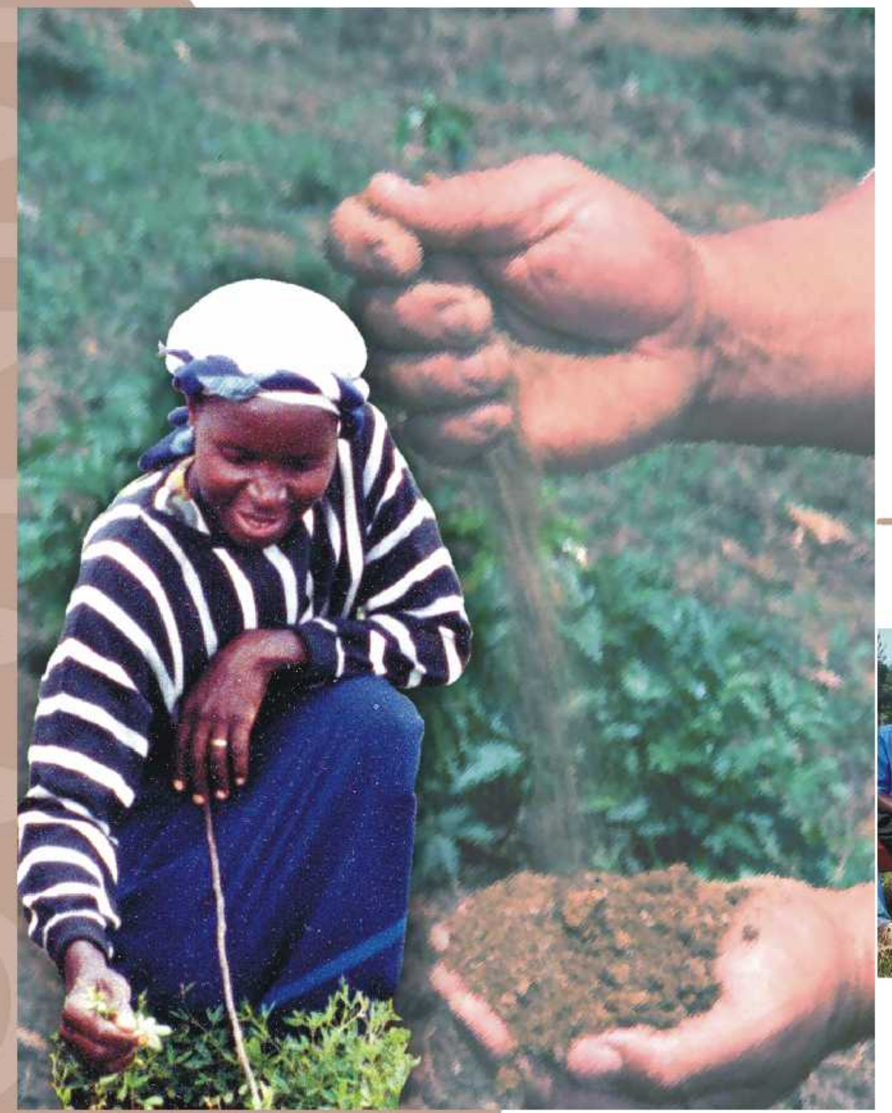
Rising to the Challenge of Global Soil Degradation

The Soil, Water and Nutrient Management Program

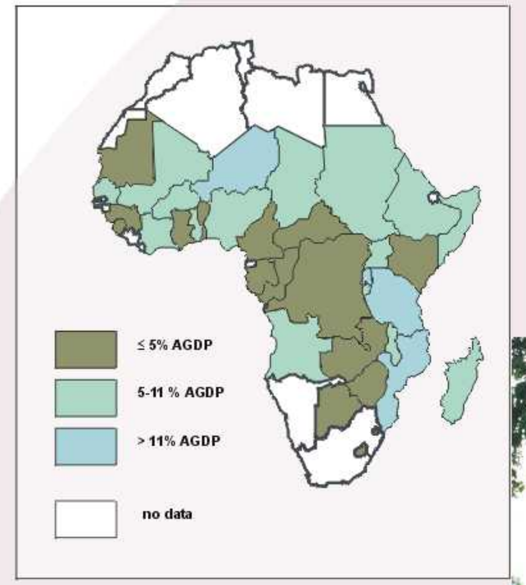
SWNM



A system wide program of the Consultative Group on International Agricultural Research (CGIAR)

5. Assessing the costs of soil nutrient depletion and erosion (MSEC)

Catchment level research, as conducted by MSEC, targets on-site as well as off-site impacts. The advantages and shortcomings of different methods for the economic assessment of soil erosion and nutrient depletion were reviewed. The output was a corresponding framework and tool that address different scales and stakeholders, including society at large. Applying this tool to sub-Saharan Africa, IBSRAM showed that the depletion of available nutrients accounts for about 7% of the agricultural share in the average GDP, with national values as high as 25% of the AGDP. This indicates that soil nutrient mining is a significant factor in current economic performance.



This tool serves scientists in selecting an appropriate methodology and economic approach, while a version for farmers focusing on "plant nutrientsfarmers' capital" illustrates the costs of nutrient mining to the land user. For field application of the tool, a MSEC-MIS cross-consortia workshop has been organized.

6. Systems modeling linked to farmer participatory research in sub-Saharan Africa (SSA)

A collaborative activity of the SWNM Program, Participatory Research and Gender Analysis (PRGA) Program, ICRISAT, and CIMMYT has been initiated to explore the linkages between farmer participatory research and computer-based simulation modeling in order to increase crop productivity for smallholders. The aim is to better enable scientists to interact with farmers by incorporating farmer participation in the conceptualization of researchable questions, the definition of variables, and in the provision of data. Such interactions facilitate the construction of realistic scenarios for simulation and formulation of recommendations and options for improved soil fertility management.

This activity builds on OSWU's activities in SSA and on an across-consortia SWNM project on the use of the APSIM model (Agricultural Production Systems Simulator) convened by IBSRAM and TSBF. ICRISAT has extended the APSIM modeling package to make it more useful in SSA. In addition, pigeonpea and pearl millet growth and development modules, a manure module (simulates decomposition and nutrient mineralization of manure in relation to manure quantity and quality), a phosphorus module, and a weed module are in use at ICRISAT for SSA.

APSIM has now been evaluated extensively in many parts of the world. However, there is still a need to evaluate it in new environments and particularly to do this for new modules. For applications involving farmers, a test of "reasonableness" is required, which is done by running the model against last year's weather data and asking researchers, extension agents, and farmers whether the result is reasonable on the basis of knowledge of last year's growing season.

On-farm research across a transect of four sites in Malawi (Mangochi) and Zimbabwe (Mahuto, Tsholotsho, and Manama) has been brought together through modeling using the APSIM package. This is currently done by annual modeling workshops conducted in collaboration with CIMMYT and NARES/NGO partners (DR&SS and Agritex in Zimbabwe and Concern Universal in Malawi). In the workshops the group examines questions to address through on-farm experimentation. This has the potential to speed up the research process by designing better options for testing and discarding options that are shown to be more likely to fail. Researchers and extension specialists have tested questions such as the comparison of investment in fertilizer with investment in weeding, which field(s) on a farm to fertilize, whether to spread the available fertilizer over one field or two fields, and whether to sell an animal in order to buy fertilizer with the hope of buying a replacement animal with the profits.

OSWU and CNDC now plan to expand this transect approach for the benefit of small-scale farmers in other parts of SSA. A concept entitled "Evaluation of Agroecological and Socioeconomic Constraints to Crop Production across Transects in East and West Africa: Contributing towards Utilization of Resources Effectively in sub-Saharan Africa" has been developed, which proposes a partnership between ICRISAT, IFDC, TSBF, and NARS in up to nine countries.

Similarly, CNDC in West Africa is developing an On-Farm Fertility Evaluation and Recommendation (OFFER) decision support tool that is based on (1) a participatory diagnosis to identify with farmers concrete problems of soil fertility management, (2) natural resource databases (soils, long-term historical weather, crop, and genotype information), (3) soil-crop simulation models, and (4) strategy analyzers to predict potential yield, rainfed potential yield, nutrient dynamics, and nutrient-limited crop yields and to make fertilizer recommendations.

The DSS utilizes simulated results, on-farm yield and fertility data, and national and regional crop yields and fertilizer usage information to give site- and crop- specific fertilizer recommendations. With improved understanding of integrated nutrient and soil amendment technologies and methodologies, and modeling capabilities, the OFFER package will be able to address the integrated soil fertility management technologies for smallholder farmers. This project is a collaborative activity involving SWNM partners, the Ecoregional Fund Project, IFAD, and IITA.

Strengthening research capacity

Across-consortia training events have been organized on the following topics:

- Economic assessment of nutrient depletion and soil erosion in Central America (MSEC-MIS)
- Local soil quality indicators in Uganda and Tanzania (MIS-CNDC)
- Modeling workshop (OSWU-CNDC-Systemwide Program on Participatory Research and Gender Analysis, NRM soils group in Zimbabwe)
- More than 90 NARES partners have been trained in various countries by MSEC in the use of a methodology for economic assessment of soil erosion and nutrient depletion and in other areas, such as project management, participatory approaches, hydrology, GIS and modeling, socioeconomic site characterization, on-farm research, and rainfall simulation.
- OSWU has conducted a training course on the use of CropSyst simulation model to extend its capabilities across the WANA region.
- CNDC has held seven training programs on participatory diagnostic methodologies, decision support tools, interdisciplinary field research, crop modeling, and minimum data sets in the West African savannas over the last 12 months.
- CNDC partners, INRAB, together with IITA and KULeuven, Belgium organized an international symposium on recent developments on integrated soil nutrient management, entitled "Balanced Nutrient Management Systems" and held on 9-12 October 2000 at Cotonou, Benin.

Future directions

Scaling out

The Program will focus on the production of generic products for use by ecoregional and other programs. Wherever possible the SWNM Program will link with other systemwide and ecoregional programs in order to achieve greater dissemination and impacts of its products. Joint projects with the systemwide Participatory Research and Gender Analysis Program, the Systemwide Livestock Program, and African Highlands Initiative are already under way. Discussions are on-going with CONDESAN for training events in SWNM methodologies and tools.

A competitive grant scheme will be introduced in 2002 to further focus the Program on the highest priority themes and to encourage synergy among Program participants. In 2001 the Program will organize workshops to review progress and plan the next phase of collaborative projects.

Donor support:

The SWNM Program is supported by the governments of Australia, Germany, The Netherlands, Norway, Switzerland, and the United Kingdom. Financial support is also received by MSEC from the Asian Development Bank.

The SWNM program currently operates through four research consortia co-convened by the following institutions.

Combating Nutrient Depletion (CNDC):
Tropical Soil Biology & Fertility Programme (TSBF), Kenya
International Fertilizer Development Center (IFDC-Africa)
Institute of Agricultural Research (IAR), Nigeria
Kenyan Agricultural Research Institute (KARI)

Managing Soil Erosion (MSEC):
International Board of Soil Research and Management (IBSRAM) now the S-E Asia Regional Office of IWMI, Thailand
Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCAARD)

Integrated Soil Management (MIS):
International Center for Tropical Agriculture (CIAT), Colombia
Escuela Agrícola Panamericana Zamorano, Honduras
Universidad Nacional Agraria, Nicaragua

Optimizing soil water use (OSWU):
International Center for Agricultural Research in the Dry Areas (ICARDA)
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
Institute of Rural Economics (IER), Mali

Impact story:

Mr. and Mrs. Simeon Moyo, Godzo (near Tsholotsho, Zimbabwe): The Moyos provide a great example of how OSWU and CNDC technologies can be used to raise crop productivity. Two years ago, they volunteered to tackle several problems in their on-farm research. Now, their farm is like a small research station, with trials to test options for soil fertility replenishment, using manure, fertilizers, and legumes. The couple also test ways to improve water use efficiency, including modified tied ridges, infiltration pits, dead-level contours, and seed priming. Initially, things did not go well. Heavy early rains caused severe damage to the trials. After some discussion with researchers and based on ideas Mr. Moyo gleaned at a field day in another district, he applied a range of erosion control and water management measures that resulted in a recovery that astonished his scientist-partners. .

His sorghum then yielded far more than the average for the district. The second year has also proved difficult. Two months without rain after sowing has devastated crops in the Tsholotsho District. But the Moyos' water and soil fertility management has helped their crops through the crisis, and they once again expect above-average yields. After two field days, many of the Moyos' neighbors are starting to invest in soil, water, and fertility management. Experiences such as this demonstrate again that research is not just the province of those holding PhDs. Farmers like the Moyos can also apply scientific techniques to improve their lives and the lives of their neighbors. Mr. Moyo declares, "you haven't seen anything yet!"

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Rising to the Challenge of Global Soil Degradation

A subtle threat

As agricultural production in the tropics is intensified to meet the demands of growing populations and economies, the soils of both fertile and marginal lands are slowly but surely being exhausted.

Most of the damage is subtle. Farmers often do not realize that the soil is losing vital functions, such as the regulation of nutrient supplies and water flow and quality. Increasing the efficiency of soil water use is a high priority, given projections that 67% of the world's population will live in water scarce areas by 2050. Policy makers rarely include appropriate discount rates in their plans to take account of the decreasing productivity of the natural resource base. By the time they do, it is too late and too expensive to restore the soil to health and to maintain the vital environmental services it provides.

SWNM solutions

The SWNM program has been helping multiple stakeholders rise to the challenge to reverse degradation of soils through the development of sustainable practices for managing soil, water, and nutrients.

Operating through four complementary research consortia the program and currently focuses on six main outputs:

1. Decision support tools for improved SWNM developed and evaluated.
2. Improved technologies for increased production adapted and applied by land users, based on efficient use of water and nutrients.
3. Impacts of improved practices on production & environment & socioeconomic conditions assessed.
4. Improved framework for information exchange and communications established and materials produced for stakeholders.
5. Stakeholders capacity for better SWNM enhanced.
6. Efficient program management, communication, monitoring and evaluation.

The program has developed a series of decision support tools and methodologies that are being tested across the different regions covered by the Program. Described below are some examples of these SWNM products.

1 A guide to match local and technical soil quality indicators (MIS)

Farmers need early warning signals and monitoring tools to help them assess the status of their soils, since by the time degradation is visible, it is either too late or too expensive to reverse it. Furthermore, the costs of preventing degradation are often several times less than costs of remedial actions. Technical solutions to soil degradation abound but are often left on the scientists' shelves, because they are developed without the participation of the land user or do not build on local knowledge of soil management.

A common language is required to link local and technical knowledge so that acceptable, cost-effective, solutions to degradation can be developed. For this purpose a guide has been produced that brings together local and technical soil quality indicators. It helps stakeholders identify and classify local indicators of soil quality and is a first step in the development of local soil and water quality monitoring systems (Figure 1). The guide is one of nine tools developed by CIAT and collaborators to help decision making in natural resource management.

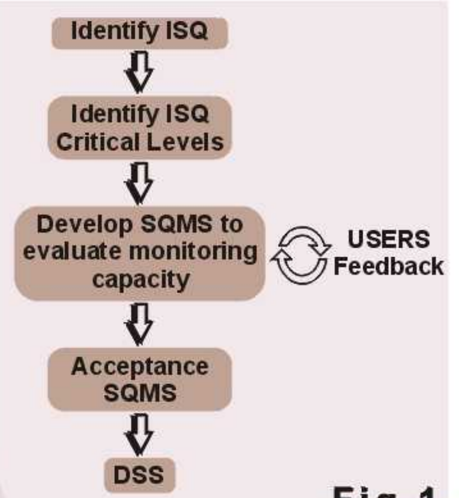
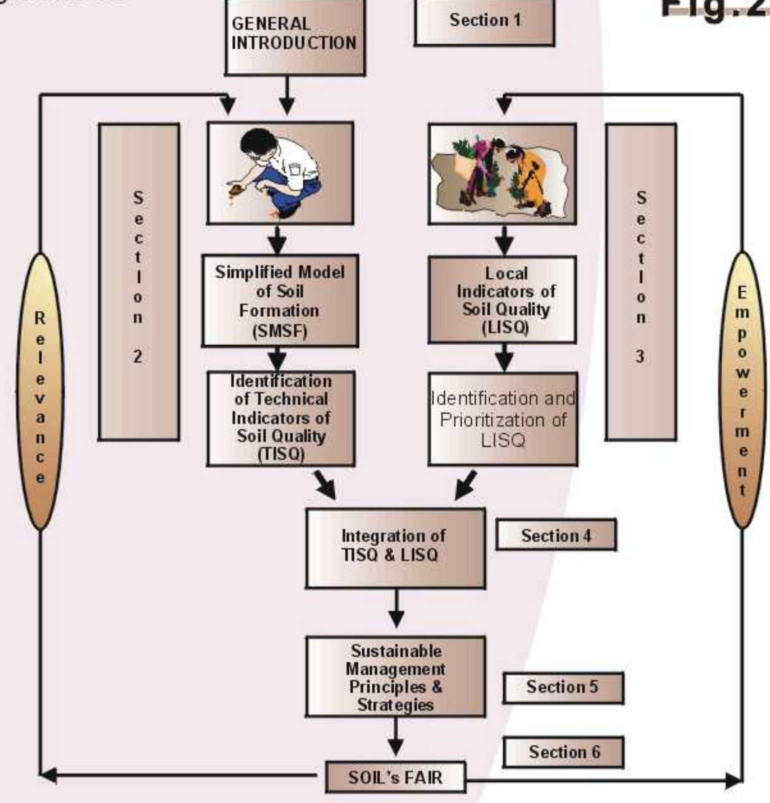


Fig.1

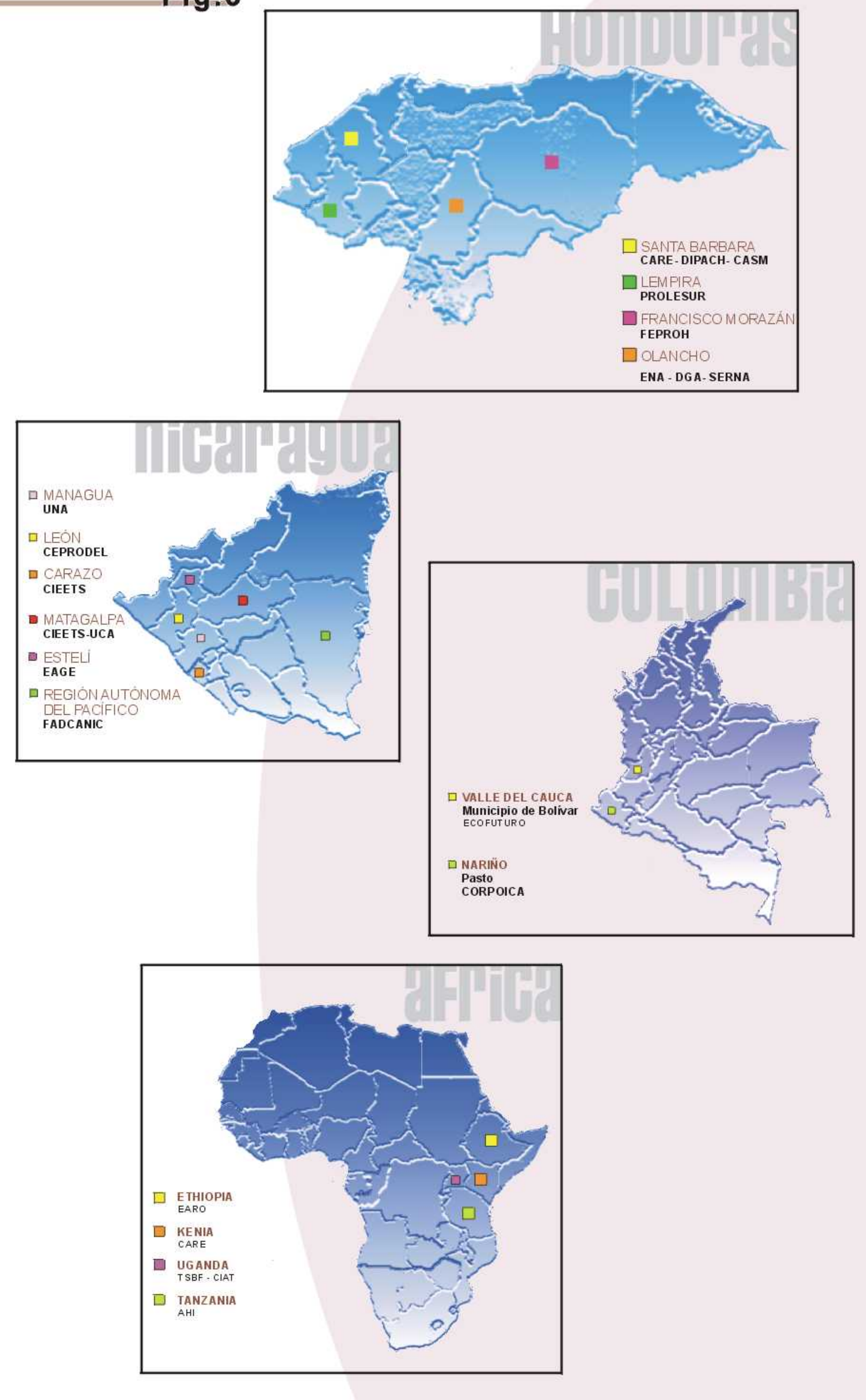
The structure of the guide is shown in Figure 2 and features the identification of technical soil quality indicators with the participation of professionals from NARES, NGOs, universities, and IARCs and the identification of local soil quality indicators with the participation of farming communities. These sets of indicators are brought together in an exercise with farmers called the "soils fair." Here farmers and scientists communicate through a commonly developed language and simple demonstrations on how to measure soil quality. This key activity helps build skills of both technicians and farmers in order to solve local problems of land degradation.

Fig.2



Participants in the training event associated with the guide are encouraged to develop "action plans." These are plans of how the participants are applying the guide in their own environments. Too date, more than 23 action plans have been put in operation in five countries of Latin America and eastern Africa (Figure 3 map).

Fig.3



2 The organic resource database and decision tree (CNDC)

Organic resources play a dominant role in soil fertility management throughout the tropics through both their short-term effects on nutrient supply and their longer term contribution to soil quality through soil organic matter (SOM) formation. Although organic resources used alone supply insufficient amounts of nutrients to sustain crop yields and build soil fertility, they will continue to be a critical nutrient source in areas where access to adequate quantities of mineral fertilizers remains beyond the reach of smallholder farmers. Even when mineral fertilizers are available, organic resources will be needed to optimize the use efficiency of these nutrients and build soil quality.

Numerous studies have reported nutrient contents, resource quality, decomposition, and nutrient release patterns of organic materials from tropical agroecosystems. Analysis of these data indicates a hierarchical set of critical values of N, lignin, and polyphenol content for predicting the "fertililizer equivalence" of organic inputs.

Working together with Imperial at Wye (formally Wye College), University of London TSBF has consolidated this information and knowledge into a computerised Organic Resource Database (ORD) To date, more than 2,000 data entries derived from research conducted by TSBF, the Kenya Agricultural Research Institute, Wye College, and CIAT, together with published data have been included.

The knowledge contained in the ORD has been used to construct a Decision Support System (DSS) for Organic Matter Management, which provides farmers with recommendations for appropriate use of organic materials for soil fertility improvement.

Data from the network trials in eastern and southern Africa confirm a critical level of N for increasing crop yield of about 2.4%, significantly modified in some cases by high levels of polyphenols The importance of the lignin content has, however, not been confirmed. On-going network experiments are now adressing the organic/inorganic interactions to allow the refinement of the recommendations of the other three categories in the DSS dealing with materials containing less than 2.5% N.

CNDC, in partnership with NARS and APSIM and DSSAT modelers, is synthesizing information generated from integrated nutrient management trials in sub-Saharan Africa and Latin America and linked with the Organic Resources Database to develop and test a model that captures N dynamics in integrated nutrient management system. One result of this collaboration is a modified DSSAT model that simulates the release of nitrogen from organic matter.

3 Decision tree for efficient rainwater use (OSWU):

Water scarcity is likely to be the main threat to agricultural production in many areas of West Asia, North Africa, and elsewhere. Appropriate technologies for reducing the production risks in drought-prone areas are urgently required. OSWU has focused its efforts on reducing runoff water losses, on runoff water collection, and on harvesting and storage of runoff water for later use. Often, these technologies are combined with soil fertility management practices.

Rigid recommendations of a single technology are often not adopted by farmers. Developing technology options with farmers can help extension workers and farmers make more informed choices that are suitable for different agroecological conditions. OSWU's researchers, extension agents, and farmers have developed a decision tree for assisting the choice of water management technologies in the dry areas of sub-Saharan Africa. The choice of management options for improving the efficiency of rainfall water use depends on the relative risk of the occurrence of climatic or edaphic drought as well as on the ability of crops to make optimal use of water stored in the soil. The prototype decision tree integrates the understanding of water management with scientific and traditional practices. These include the traditional Zaï, half-moons ("demi-lunes"), stone bunds, as well as surface management practices such as tied-ridging, plowing, and crop residue management. Such technologies build on appropriate soil management practices, including no-till options for conservation, the use of adapted crop cultivars, inorganic fertilizer, crop residue management, cropping system management, pest control, and integrated watershed management. The decision tree now has been disseminated to other researchers, extension agents, and farmers within the OSWU mandate countries for evaluation and feedback.

4 . The rock phosphate decision tree (CNDC)

A phosphate rock decision support system (PRDSS) for West Africa has been partially completed based on 57 observations of agronomic factors that affect the feasibility of using rock phosphate (PR). The decision system is based on our current understanding of PR response as influenced by PR sources, soil pH, soil P, soil texture, CEC, organic matter, type of crop, and moisture/rainfall regime.

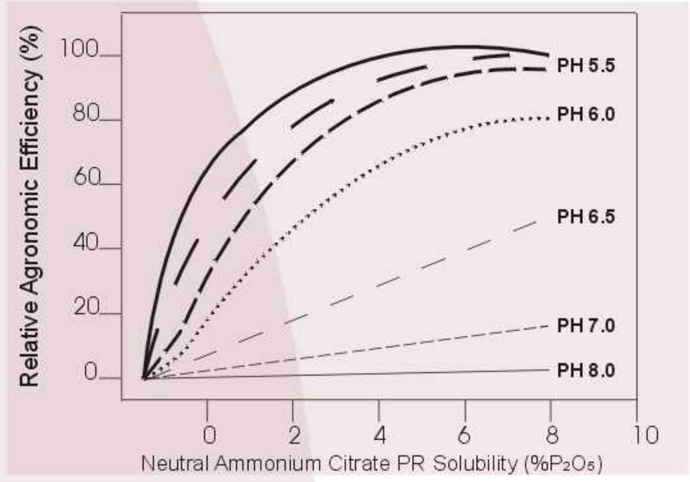
The PRDSS predicts the relative agronomic efficiency (RAE) with respect to water-soluble sources, such as of triple super phosphate (TSP), single super phosphate (SSP), or diammonium phosphate (DAP). For reliable use of PRDSS, the following requirements must be met:

- Soil/crop is responsive to P application. The model is not meant to be used for determining if P is limiting or the P requirement rate.
- Other management factors, such as water, nutrients, and pests are not limiting crop performance.
- If crop performance is affected due to above limitations, then the influence on PR will be similar to water-soluble P fertilizers.

Fig 4

Effect of PR solubility an pH on relative agronomic efficiency of cereals.(Based on data from IFDC trials in West Africa and other published sources).

Socioeconomic aspects are not considered in the current version of the model, but the relative agronomic efficiency value from the PRDSS would form the basis for socioeconomic evaluation. The effect of phosphate rock sources and pH on RAE of cereal crops (maize, wheat, upland rice, sorghum, and millet) is shown in Figure 4.



In general, as the PR solubility increases, its effectiveness with respect to water-soluble P fertilizers improves. However, soil pH has an overriding effect; for example, at pH > 7 the RAE of PR independent of its solubility will be below 15%. Togo PR with PR solubility of 4.1% P_2O_5 in neutral ammonium citrate has RAE efficiency ranging from 85% to 0%, as the soil pH changes from 4.5 to 8 for some grain cereals (Figure 4).

Thus, the choice of PR will depend on its effectiveness with respect to water-soluble P fertilizers as dictated by soil and crop factors. The PRDSS with future modifications and refinements will incorporate other site-specific parameters.