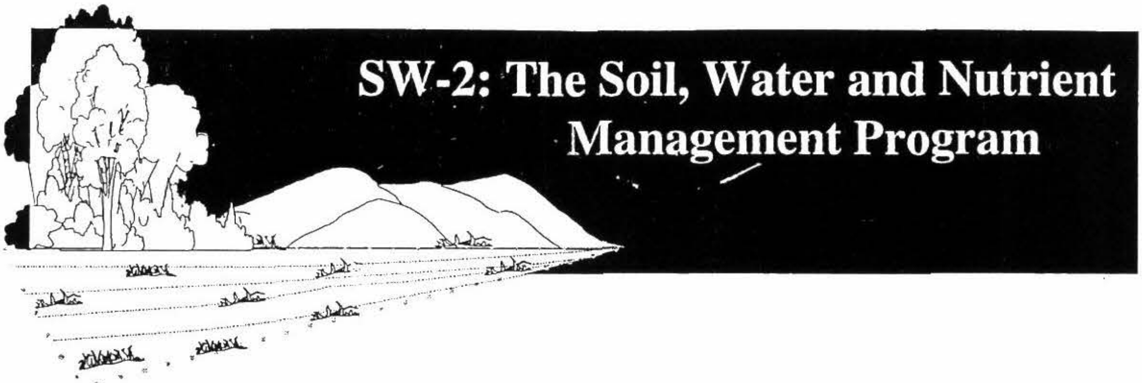
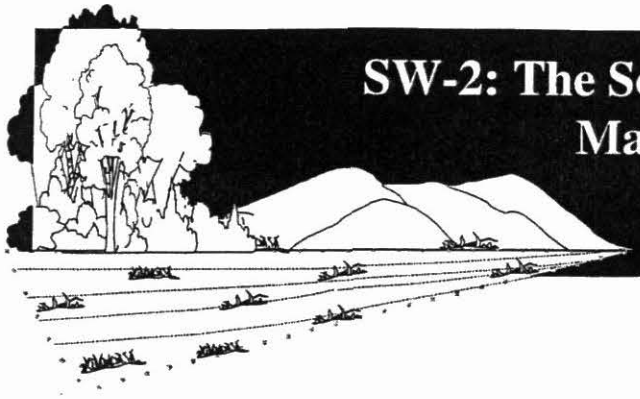


SW-2: The Soil, Water and Nutrient Management Program

Annual Report 2000

CIAT
Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture



SW-2: The Soil, Water and Nutrient Management Program

Annual Report 2000

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SW-2 The Soil, Water and Nutrient Management Program

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Executive summary

After four years of operation the SWNM program underwent a partial review as part of CIAT's 1999 CCER. An external consultant reviewed each consortium and a report was presented to CIAT during the CCER. A full report was completed in May 2000. The SWNM reacted swiftly to the review by organizing a program meeting in Wageningen February 21-23, 2000.

The main recommendations from the review and SWNM responses were;

1. Future activities should aim at producing generic products for inclusion in a SWNM toolbox for use by ecoregional programs and other stakeholders.

Response: The Wageningen meeting discussed the tool box and generic products and these have been included in the new logframe. The tools were presented to donors at ICW00.

2. All consortia must contribute to the development of a logframe, which should be integrative in nature and realistic focusing on generic outputs that can be used both in other programs and by all the stakeholders.

Response: A new logframe was partially completed at the Wageningen meeting and has subsequently received inputs from the four consortia. The logframe is reported in this document.

3. The timetable for deliverables should be developed both for individual consortia as well as cross-consortia synthetic activities.

Response: Time frames were added to the products in the logframe and individual consortia should state these clearly in their project documents and annual reports.

4. A synthesis plan for among consortia activities should be developed.

Response: Across consortia activities formed a major part of the discussions of the Wageningen meeting and details are included in the revised meeting report.

5. A program meeting of participating scientists should be convened regularly to review and develop the logframe and for discussion on inter- and intra-consortium synthesis.

Response: The first meeting was held in Wageningen in February 21-23, 2000. A second meeting was held at the Balanced Nutrient Management meeting to be held in Benin in October 2000 with IITA.

6. The relative roles of CIAT and IBSRAM as co-convenors should be clarified.

Response: Discussions are underway between CIAT and IBSRAM on this issue and proposals for changes in governance below and program management are under discussion within the program.

7. Guidelines should be prepared for preparation of the Annual Report 2000.

Response: Guidelines were already available but have been modified in 2000 to ensure consistency.

8. An e-mail/address list should be made available to all consortium participants and a simple newsletter should communicate planned and ongoing activities as well as results among consortium members and stakeholders.

Response: A list server for the SWNM has been established and a new website created at www. swnm.org. A SWNM newsletter was distributed in May 2000.

9. Exchange of personnel should be stimulated among consortium members and between consortia.

Response: There was general agreement at the Wageningen meeting that this would be desirable. See also the proposals below for evaluation of project proposals. This includes weighting for joint positions.

10. The establishment of a Scientific Steering Committee should be considered. Alternatively, the Global Steering Committee could decide to perform the functions outlined in the TAC submission.

Consortia have nominated centre staff for the Scientific Steering Committee.

11. A full-time coordinator should be appointed for the program (alternatively a 50% scientific coordinator plus administrative support) to strengthen the currently existing and excellent work at CIAT HQ.

Response: This issue is also under discussion . In the meantime additional time of R. Thomas has been allocated to the SWNM by CIAT.

A new logframe and work breakdown structure were developed and are included below in the main report. A set of 6 outputs were developed in order to promote better inter-consortia collaboration and greater synthesis of research undertaken by the individual consortia. These outputs are:

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

A paper on the contribution of the SWNM to the CGIAR's efforts on Integrated Natural Resource Management was prepared for the meeting held in Penang in August 2000. It features examples of the decision support tools that have been developed by the program. This will appear in the publication of the conference proceedings and an amended abbreviated version was submitted for journal publication.

A proposal to change the way that SWNM funds are distributed was prepared and discussed at the SWNM meetings in Penang and in Benin during the conference on Balanced Nutrient Management. The aim of the proposal is to focus SWNM efforts more sharply on activities that add value to the program consortia and to seek better complementarity with other efforts on soil management within the CGIAR.

Funding for the program continues to decline slightly with pledged amounts for 2000 in the order of $740,000. This is a worrying trend and the program will be reviewing its position with respect to the changes expected within the CGIAR system when these become clearer. In the meantime the program is

The program's presentation to donors at ICW00 focused on the tool box concept with examples being given from each consortia. The response from the donors was favorable with questions concentrating on what were the reasons for the success of the program rather than questions on programmatic content or progress.

Highlights from the consortia:

Output 1. Decision support tools for improved SWNM developed and evaluated in different agro-ecological zones

Combating Nutrient depletion

- Continued data entry and development of the Organic Resource Database (ORD)
- Continued experimentation in Africa and Latin America for refinement of the N management decision tree
- Version 3 of the ORD released
- Prototype decision tree for phosphate rock (PR) developed
- Database for PR trials using PR in SSA being compiled
- Project implementation workshop held
- Improvements to models
- Initial modelling exercises conducted

Integrated Soil Management (MIS)

- Data from the long-term experiments on phosphorus cycling in the savannas have contributed to the development of an improved crop model (CERES) and have been made available to other groups via a multi-institutional collaborative project within the SWNM program.
- Testing of NuMaSS (nutrient management decision support system) decision support system using the data from field experiments indicated that in the Llanos of Colombia upland rice production is considerably more profitable than either maize or cowpea given the yields obtained and the costs of fertilizer and the price of grain.
- Soil quality indicators have been identified for the savannas and hillsides agroecosystems have been incorporated into a guide that is being tested in Colombia, Central America and the East African Highlands.

Managing Soil Erosion

Methodologies for economic assessment of soil erosion developed and tested

- The methods for the economic assessment of the on- and off-site impacts of soil erosion has been prepared and published as ISLM No. 2
- Based on these methods, a draft guideline for socioeconomic site characterization has been prepared.
- Draft guideline discussed during the meeting with the NARES in April and July in Bangkok. It now serves as the basis for the data collection being conducted in the field
- Analysis of the results and evaluation of the guideline is ongoing

Optimizing Soil Water Use

- Modelling studies of cropping systems using CropSyst and APSIM undertaken in the WANA region
- Training course held on modelling

- Decision tree on water use developed

Output 2 Improved technologies for increased production based on efficient use of water and nutrients adapted and applied by land users

Combating Nutrient Depletion

- Continued experimentation for refinement of cropping systems models in Nigeria and Benin
- Compared performance of phosphate rock *versus* commercial P fertilizers
- Field training continued on collection of minimum data sets and interdisciplinary research
- Model validation with data from Nigeria completed
- Work plan prepared
- Ex-ante analysis conducted
- Field trials established in Togo and Benin
- Continued participatory learning and action research in East Africa
- Coordination committee established to facilitate project activities
- Workshop on site selection and on participatory methods conducted
- Synthesis paper for testing alternative nutrient sources submitted
- DSS tool tested using primary and secondary data

Integrated Soil Management MIS

- A beneficial population of soil earthworms should consist of one or more epigeic species and one or more anecic species that construct vertical galleries, produce biogenic structures on the soil surface and mix plant residues with the mineral soil substrate.

Managing Soil Erosion

- Representative of model catchments in Indonesia, Laos, Nepal, Philippines, Thailand and Vietnam have been fully characterized and instrumented for soil erosion and hydrological measurements. At least four micro-catchments of different land uses within the selected catchments have also been characterized and instrumented.
- The benchmark survey and characterization, calibration of the catchment sites and the conduct of the on-farm research are ongoing. These activities are expected to generate the needed information to identify alternative technologies and land management systems that will be acceptable to major stakeholders.
- Analysis and evaluation of indigenous technical knowledge and related land use policies are also being done.
- Interventions will be introduced later after getting some baseline information and consultation with the farmers.

Optimizing soil Water Use

- Water harvesting technologies tested in Jordan and S. Africa
- Experiments on effects of planting pattern, tillage and weed management on water use efficiency initiated in Morocco
- The "zai" land rehabilitation technique increases the amount of water in the soil profile and plant available water but did not increase water storage at the end of the cropping season in Niger
- No- and minimum-tillage technologies show promise in terms of energy efficiency compared with conventional tillage in cropping systems in Central Anatolia, Turkey.

- APSIM model is being used to bring together results from on-farm research in Southern Africa

Output 3. Impacts of improved practices on production, the environment and socioeconomic conditions assessed

Integrated soil management MIS

- A training course on the economic assessment of soil erosin and nutrioent depletion was held in Nicaragua in October 2000 with MSEC

Managing Soil Erosion

- The IBSRAM ISLM No 4 publication (IBSRAM's impact: Making the difference in sustainable land management research) is being reviewed and adapted for application in evaluating IBSRAM projects. The paper "A framework for impact assessment: Its application to evaluating IBSRAM programs" is prepared for presentation at the International Conference on Impact of Agricultural Research and Development in Southeast Asia from 24-26 October 2000 in Phonm Penh, Cambodia.
- A literature review of impact assessment of the participatory approach to sustainable land management research is also being done.
- The developed methodological guidelines for the economic assessment of soil nutrient depletion will be applied by IBSRAM-Africa to urban and peri-urban agriculture in the frame of a FAO funded economic environmental impact assessment (10/2000 – 12/2001)

Optimizing Soil Water Use

- Potential impact of OSWU research evaluated using Bayesian belief networks

Output 4. Improved information and communication exchange framework established and materials produced for stakeholders

Integrated soil management MIS

- The local soil quality indicator guide is available in Spanish and English and a version suitable for east African conditions is under preparation

Managing Soil Erosion

Analysis of successful catchment management studies conducted

- Literature review in preparation.
- IBSRAM-Africa published a framework for the economic assessment of soil nutrient depletion (ISLM 7). *Target group: Scientists*
- IBSRAM-Africa published a farmer version of IBSRAM's ISLM 7 "tool" on the economics of soil nutrient depletion. *Target group: Farmers*
- IBSRAM-Africa prepared a policy brief related to ISLM7 addressing the economics of soil nutrient depletion (*Target group: Policy makers*) and posted it on IBSRAM's web page.
- Various MSEC reports and information have been prepared for donors and readers of IBSRAM's Highlights 2000, IBSRAM's Newsletter (no 55, 56 and 57), and the *Sustainable Land Management Network* (SLMNET) electronic listserver.

Optimizing Soil Water Use

- Steering Committee meeting held in October 2000

Output 5. Stakeholders capacity for better SWNM enhanced

Combating Nutrient depletion

- NARES capacity building on field minimum data set collection
- Training, evaluation, and standardization of laboratory procedures for soil and plant nutrient analyses
- Training on use of DSS for scientists and extensionists.
- 11 farmer exchange visits held
- 5 training events on N management and species selection
- More than 250 farmers in eastern Uganda and western Kenya testing legume cover crops, Tithonia for N management, and improved farmyard manure management
- Development of a training manual on participatory methods for Indicators of Soil Quality
- Training of partners in participatory method

Integrated soil management MIS

- Twelve field days were held in Pescador (January-September/2000), Cauca, Colombia with the participation of 276 visitors mainly farmers, extensionists and students from universities and schools; and one field day for Swedish Agricultural University (SLU) researchers was held in San Dionisio, Nicaragua.
- A methodological guide entitled "Indentifying and Classifying Local Indicators of Soil Quality. East African Version. Participatory Methods for Decision Making in Natural Resource Management." was prepared.
- A training course entitled: "Local Indicators of Soil Quality", was held in Mukono, Uganda and sponsored by the CIAT, SWNM and AHI.

Managing Soil Erosion

- 1 NARES staff trained on SWNM ...
- Twelve (12) NARES MSEC partners attended the training workshop on GIS, Economic Valuation of Environmental Impacts and Statistical Techniques, in Bangkok from 24-29 April 2000. While the participants voiced the limited time that has been provided, they mentioned that they learned a lot from the workshop.
- From 5-7 July 2000, MSEC conducted a follow-up meeting on socioeconomic site characterization and on-farm research in Bangkok. This time, 13 NARES partners presented the initial outputs of their socioeconomic site characterization and further learned on how to data collection and analysis, looking at both on-site and off-site effect of erosion. They were also familiarized with the guidelines for socioeconomic site characterization and reviewed their outputs vis a vis this guideline.
- In addition to conducting regular training programs, MSEC also conducts a less formal in-country training-demonstrations during the monitoring visits to the sites. These have been done during visits to Indonesia, Laos, Nepal, Philippines, Thailand and Vietnam sites.
- MSEC-CIAT/MIS training held in October

Output 6 Efficient program management, communication, monitoring and evaluation

Combating Nutrient depletion

- Seven publications were prepared in 2000.

Integrated soil management MIS

- A five-member steering committee was appointed for the MIS consortium with members from Nicaragua and Honduras
- The MIS consortium established its own webpage at www.mis@optinet.hn
- The MIS consortium has held two meetings during 2000.
- The first across consortia activity was the training event on economic costs of soil erosion and nutrient depletion held in October 2000.
- A joint post-doctoral fellow appointment with TSBf under the CNDC has entered its third and final year under the DFID-SWNM project.
- 25 refereed publications were supported by MIS during 1999-2000.

Managing Soil Erosion

- Regular meetings of scientific groups,....
- Regular monthly meeting of the MSEC group at IBSRAM has provided better interaction and sharing of ideas within MSEC, also as basis for any correspondence with the SWNM program coordination. Regular visits to the MSEC sites are still another major activity to monitor progress and anticipate problems in implementation.

- MSEC-CIAT/MIS training October, 2000

Soil, Water, and Nutrient Management (SWNM)
A systemwide program of the CGIAR
CIAT Project SW-2

Program overview

Objective: To contribute to long-term increases in agricultural productivity, poverty reduction, and the conservation and enhancement of land and water resources.

Outputs: Economically viable SWNM technologies that are socially acceptable and ecologically sound. Improved methods and diagnostic tools for participatory research. Indicators to monitor the environmental and economic impact of land use systems. Decision support systems, such as models and geographic information systems, for generating and extrapolating options. Stronger institutional capacity to implement SWNM programs and policies. A framework for partnerships between stakeholder groups. Information available on appropriate policies to promote sustainable practices.

Gains: Linkages of research on SWNM at key sites within the CGIAR ecoregional programs. Improved research efficiency through collaboration among NARS, IARCs, and SROs (specialized research organizations rather than ARO's) through capacity building. Avoidance of duplication of efforts in SWNM and increased rate of technology development. A core group of resource management scientists. Accelerated scientific progress through sharing of experience, common methods, databases, and models across regions. Strengthened research projects already in place through an integrated approach. Complementation of ongoing research where knowledge gaps exist and provision of new knowledge required to improve natural resource management worldwide.

Milestones:

1998 Four research consortia active in Latin America (1), Africa (2), and Asia (1). Three training courses held on aspects of soil degradation in Asia, Africa, and Latin America. Methods for watershed selection and on economic assessments of soil erosion published.

1999 Database on use of organic resources for small-scale farmers. Guidelines for integrated nutrient management published. DSSAT models improved for use in tropical soils. Indicators of soil quality identified and compared with local knowledge. Research data from the MAS project in Brazil and elsewhere published in two books. Stakeholders consultation meeting on optimizing soil water use published as a book.

2000 Logframe for across consortia activity. Common outputs and activities amongst consortia. Website for the SWNM program established. Scientific steering committee established and first meeting held. Decision support tools developed, tested and validated with stakeholders.

Users: Farmers and other land users, NARS, extension workers, NGOs, and community-based groups.

Collaborators: IARCS, TSBF, IBSRAM, IFDC, ICRISAT, ICARDA, IITA, ICRAF, ORSTOM, NARS, universities and advanced research organizations of the four SWNM consortia.

CG System linkages: Saving Biodiversity (5%), Increasing Productivity (35%), Protecting the Environment (35%), Strengthening NARS (15%), Improving Policies (10%).

Purpose:

The program's primary objective is to develop effective, ecologically sound technologies and systems for land management and conservation. Related objectives are to:

- Develop, test and promote new, community-based institutional mechanisms that encourage the use of sustainable technologies
- Through research partnerships, enhance the capacity of stakeholders to plan and implement programs on sustainable land management
- Develop and promote policies that address equity issues such as gender, access to resources and, land tenure.

Rationale:
As global food production has expanded to meet growing demands, the soils of both marginal and fertile lands have suffered. The effects of degradation, which also bring problems of water quantity and quality, cannot always be compensated, even partially, by applying fertilizers. Instead, natural soil fertility must be maintained, conserved and enhanced, requiring increased research emphasis on soil, water and nutrient management. The SWNM program addresses this challenge by bringing together four complementary research consortia.

The SWNM program was approved by the TAC of the CGIAR in 1996. The four consortia of the program with their target areas and regions are presented in Table 1.

Table 1. The consortia of the SWNM program

Consortium	Target area	Conveners
Combating Nutrient Depletion (CNDC)	East and West Africa	TSBF, IFDC, KARI and ARI
Managing Acid Soils (MAS)	Latin America	CIAT and EMBRAPA
Managing Soil Erosion (MSEC)	S-East Asia	IBSRAM and CSAR
Optimizing soil water use (OSWU)	West/North and Sub-Saharan Africa	ICRISAT, ICARDA and IER

The GCIAR has no formal reporting requirements for Systemwide Programs (SWP's) other than an annual financial report. However the SWNM program does present a progress report to the CGIAR and its donors at the Mid-Term meeting held annually during May. In addition from 1998 CIAT has included the SWNM program in its set of project profiles and is reported as project SW-2 Currently 30% of a senior scientists position and 60% of an assistant is devoted to this project. Information about the SWNM program has been placed on the CIAT home page on the internet. A new webpage will be available in June 2000 at: http://www.swnm.org There are three types of funding for the program;

1- unrestricted or core funds that are distributed equally amongst the four consortia
2- restricted or special project funding that donors specify for a number of the consortia or for a given program theme
3- funds raised independently by each consortium that supports SWNM activities

The consortia have had to adopt this funding strategy as a result of insufficient pledges from CGIAR donors for the SWNM program.

The SWNM program's current logframe is presented below and was revised in 2000. An independent assessment of the program by a CIAT-commissioned external review was completed in May 2000.

Outputs/activities in the form of a work breakdown structure version September, 2000

Output 1 Decision support tools for improved SWNM developed and evaluated in different agro-ecological zones	Output 2 Improved technologies for increased production based on efficient use of water and nutrients adapted and applied by land users	Output 3 Impacts of improved practices on production, the environment and socioeconomic conditions assessed	Output 4 Improved information and communication exchange framework established and materials produced for stakeholders	Output 5 Stakeholders capacity for better SWNM *enhanced*	Output 6 Efficient program management, communication, monitoring and evaluation
Activities: 1.1 Develop and test methodologies for economic assessment of soil erosion and nutrient depletion (MSEC) 1.2 Validate and improve decision tree and database for organic matter uses (CNDC/MIS) 1.3 Develop and test decision support tool for phosphorus amendments (CNDC) 1.4 Improve, evaluate and compare crop/system models (CNDC/OSWU) 1.5 Develop and test decision tree for efficient rain-water	2.1 Develop improved practices for fragile soils at different scales e.g., crop/tree/pasture systems (MSEC/MIS/CNDC) 2.2 Comparative evaluation of water and nutrient constraints to crop production (yield gap analysis) and develop recommendations for improved production systems by matching of options to constraints (CNDC/OSWU) 2.3Test alternative nutrient sources on-farm and evaluate	3.1 Elaborate common approach to impact assessment for SWNM technologies and conduct impact studies at selected sites (OSWU/MSEC) 3.2 Apply methodologies for economic assessments of soil erosion and *nutrient* depletion (MSEC, MIS, CNDC) 3.3 Determine impact of improved SWNM practices on soil and water quality (MIS/OSWU/MSEC)	4.1 Analyses of successful catchment *management studies* and exchanges of information (MSEC/MIS) 4.2 Develop and disseminate to stakeholders user friendly information on SWNM *practices, strategies* and policies. (All consortia)	5.1 Training of NARES staff on SWNM technologies and use of DSS (All consortia). 5.2 Organize farmer field schools for SWNM technologies (MIS,CNDC) 5.3 Organize thematic workshops with stakeholders on priority SWNM issues (All consortia	6.1Scientific coordinators appointed for each consortium 6.2 Webpage, e-mail list server and newsletter for information exchange and communication with land users, policy makers and donors 6.3 Annual reports 6.4 SWNM program publications 6.5 Regular meetings of scientific groups, consortia convenors 6.6 Across consortia exchanges/visits for joint activities 6.7 Monitor adoption of

use (OSWU)- 1.6 Identify soil quality indicators, develop and test a soil quality monitoring system (MIS) 1.7 Improve targeting of recommendation domains for SWNM technologies using spatial analyses (OSWU/CNDC/MIS)	DSS tools (CNDC/MIS)				improved SWNM practices (All) -

SWNM program logframe Sept, 2000

Summary	Indicators	Means of verification	Important assumptions
Goal: To contribute to the long-term increases in agricultural productivity, poverty reduction and the conservation and enhancement of land and water resources	Agricultural production increased in benchmark sites. Farmer's income increased. Land degradation halted or decreased.	Agricultural census data Human welfare statistics	
Purpose: Effective, ecologically sound technologies and decision support systems for sustainable land management and conservation developed, disseminated and implemented by land users.	Information and decision support tools on SWNM in user friendly forms distributed and used by different stakeholders	Surveys of land management practices. Publication materials available National agricultural development plans. Training programs for extension workers	Policy environment is favourable for thre adoption of improved SWNM technologies. Farmers are reached through NARES and IARC's. NARES have means to disseminate technologies, tools and information
Output 1: Decision support tools for improved SWNM developed and evaluated in different agroecological zones. Output 2: Improved technologies for increased production based on efficient use	- - Guidelines and at least 3 decision support systems developed. - Cropping system simulation models linked to GIS. - Maps available on production of crops, water use and efficiency, soil fertility, nutrient dynamics under different practices. - Decision tree for efficient use of rain-water available - New/improved	Computer programs, CD's publications and reports. Computer programs, CD's publications and reports. Progress reports, GIS maps, publications, computer programs, CD's. - Progress reports and publications	

of water and nutrients adapted and applied by land users	technologies and strategies for soil and water conservation developed with NARES - Improved technologies in soil, water and crop management evaluated in farmers' fields with 20% adoption rate	- Progress reports, publications and agricultural statistics - - - -	
Output 3: Impacts of improved practices on production, the environment and socioeconomic conditions assessed	- - Common methodology for impact assessment developed and impact studies conducted in at least three reference sites	- Guidelines for impact assessment - Reports of impact studies - Progress reports	
Output 4: Improved information and communication exchange framework established and materials produced for stakeholders	- NARS scientists collaborating in joint research with SWNM - NARS personnel trained in SWNM technologies and DS tools. - Training manuals and guidelines produced	- Annual reports - - - - Manuals - - - - - - - - - - -	
Output 5 Stakeholders capacity for better SWNM enhanced	- Workshops, farmer field schools and symposia conducted	- Workshop programs, lists of participants	
Output 6: Efficient program management, communication, monitoring and evaluation			

	Scientific coordinators meetings Webpage List server		
Activities Output 1:			
1.1 Develop and test methodologies for economic assessment of soil erosion and nutrient depletion (MSEC)	Models tested and applied. Results extrapolated for other ecologies.		
1.2 Validate and improve decision tree and database for organic matter uses (CNDC/MIS)	Decision tree available To NARES and other organizations		
1.3 Develop and test decision support tool for phosphorus amendments (CNDC)	Tool available in different media		
1.4 Improve, evaluate and compare crop/system models (CNDC/OSWU)	Cropping system models linked to GIS Models being used by IARC's and NARES to solve problems	Reports, journal articles and website information	
1.5 Develop and test decision tree for efficient rain-water use (OSWU)	Decision tree available.	Progress reports Guide for soil quality indicators	
1.6 Identify soil quality indicators, develop and test a *soil quality* monitoring system (MIS)	Soil quality indicators available for different agroecologies, Monitoring kit developed.	Progress reports	
1.7 Improve targeting of recommendation	Maps available on production of crops,water use efficiency, soil		

domains for SWNM technologies using spatial analyses (OSWU/CNDC/ MIS)	fertility and nutrient dynamics.		
Output 2 (Activities): 2.1 Develop improved practices for fragile soils at different scales e.g., crop/tree/pasture systems (MSEC/MIS/CN DC) 2.2 Comparative evaluation of water and nutrient constraints to crop production (yield gap analysis) and develop recommendations for improved production systems by matching of options to constraints (CNDC/OSWU) 2.3Test alternative nutrient sources on-farm and evaluate DSS tools (CNDC/MIS)	Optimum management options identified, tested and evaluated by farmers. Recommendations for target domains prepared. Improved technologies in soil, water and crop management evaluated in farmers' fields. Network trials established	Annual reports, journal articles Annual reports, journal articles	
Output 3 (Activities) 3.1 Elaborate common approach to impact assessment for SWNM technologies and conduct impact studies at selected sites	Methodology for impact assessment identified and applied.	Reports	

(OSWU/MSEC) 3.2 Apply methodologies for economic assessments of soil erosion and nutrient depletion (MSEC, MIS, CNDC) 3.3 Determine impact of improved SWNM practices on soil and water quality (MIS/OSWU/MSEC) Output 4 (Activities) 4.1 Analysis of successful catchment management studies and exchanges of information (MSEC/MIS) 4.2 Develop and disseminate to stakeholders user friendly information on SWNM practices, strategies and policies (All)	Case studies chosen in different regions Impact of SWNM technologies on resource sustainability measured and monitored. Case studies chosen. Manuals and bulletins prepared and distributed to stakeholders. .	Reports	
Output 5 (Activities) 5.1 Training of NARES staff on SWNM technologies and the use of DSS 5.2 Organize farmer field schools for SWNM technologies(MIS, CNDC)	Numbers of NARES staff trained in SWNM technologies and DS tools Numbers of farmers participated in training Events		

5.3 Organize thematic workshops with stakeholders on priority SWNM issues (All) Output 6 (Activities) 6.1 Scientific coordinators appointed for each consortium 6.2 Webpage, e-mail list server and newsletter for information exchange and communication with land users, policy makers and donors 6.3 Annual reports 6.4 SWNM program publications 6.5 Regular meetings of scientific groups, consortia convenors 6.6 Across-consortia exchanges and visits for joint activities 6.7 Monitor adoption of improved SWNM practices (All)	Numbers of workshop(s) conducted. Coordinators appointed by each consortium New SWNM webpage, list server and newsletter produced Annual reports Publications Meetings held Exchanges and visits organized		

Theme 1. Combating Nutrient Depletion Consortium

1. Introduction and project overview

The Tropical Soil Biology and Fertility (TSBF) Program in the East African Highlands and the *International Fertilizer* Development Center (IFDC) in the West African Savannas coordinate the Combating Nutrient Depletion Consortium (CNDC). CNDC activities are in the following countries in sub-Saharan Africa - Benin, Ghana, Kenya, Nigeria, Tanzania, Togo, and Uganda and in Latin America - Colombia, Honduras, and Nicaragua. The interconsortia approach is evident from participation of MIS, MSEC, and OSWU.

2. Highlights of progress in outputs of the SWNM logframe.

Output 1 Decision support tools for improved SWNM developed and evaluated in different agroecological zones.

- Continued data entry and development of the Organic Resource Database (ORD)
- Continued experimentation in Africa and Latin America for refinement of the N management decision tree
- Version 3 of the ORD released
- Training event held for Southern Africa collaborators
- Prototype decision tree for phosphate rock (PR) developed
- Database for PR trials using PR in SSA being compiled
- Project implementation workshop held
- Improvements to models
- Initial training conducted
- Experiments chosen for validation of the model
- Initial modelling exercises conducted

Output 2 Improved technologies for increased production based on efficient use of water and nutrients adapted and applied by land users

- Continued experimentation for refinement of cropping systems models in Nigeria and Benin
- Compared performance of phosphate rock versus commercial P fertilizers
- Field training continued on collection of minimum data sets and interdisciplinary research
- Model validation with data from Nigeria completed
- Work plan prepared
- Ex-ante analysis conducted
- Field trials established in Togo and Benin
- Continued participatory learning and action research in East Africa
- Coordination committee established to facilitate project activities
- Workshop on site selection and on participatory methods conducted
- Synthesis paper for testing alternative nutrient sources submitted
- DSS tool tested using primary and secondary data

Output 3 Impacts of improved practices on production, the environment and socioeconomic conditions assessed.

No activity reported.

Output 4 Improved information and communication xchange framework established and materials produced for stakeholders.

No activity reported.

Output 5 Stakeholders capacity for better SWNM enhanced.

- NARES capacity building on field minimum data set collection
- Training, evaluation, and standardization of laboratory procedures for soil and plant nutrient analyses
- Training on use of DSS for scientists and extensionists.
- 11 farmer exchange visits held
- 5 training events on N management and species selection
- More than 250 farmers in eastern Uganda and western Kenya testing legume cover crops, Tithonia for N management, and improved farmyard manure management
- Development of a training manual on participatory methods for Indicators of Soil Quality
- Training of partners in participatory method

Output 6 Efficient program management, communication, monitoring and evaluation

- Seven publications were prepared in 2000.

3. Progress report on CNDC activities reported under the SWNM logframe format.

Output 1: Decision support tools for better SWNM developed

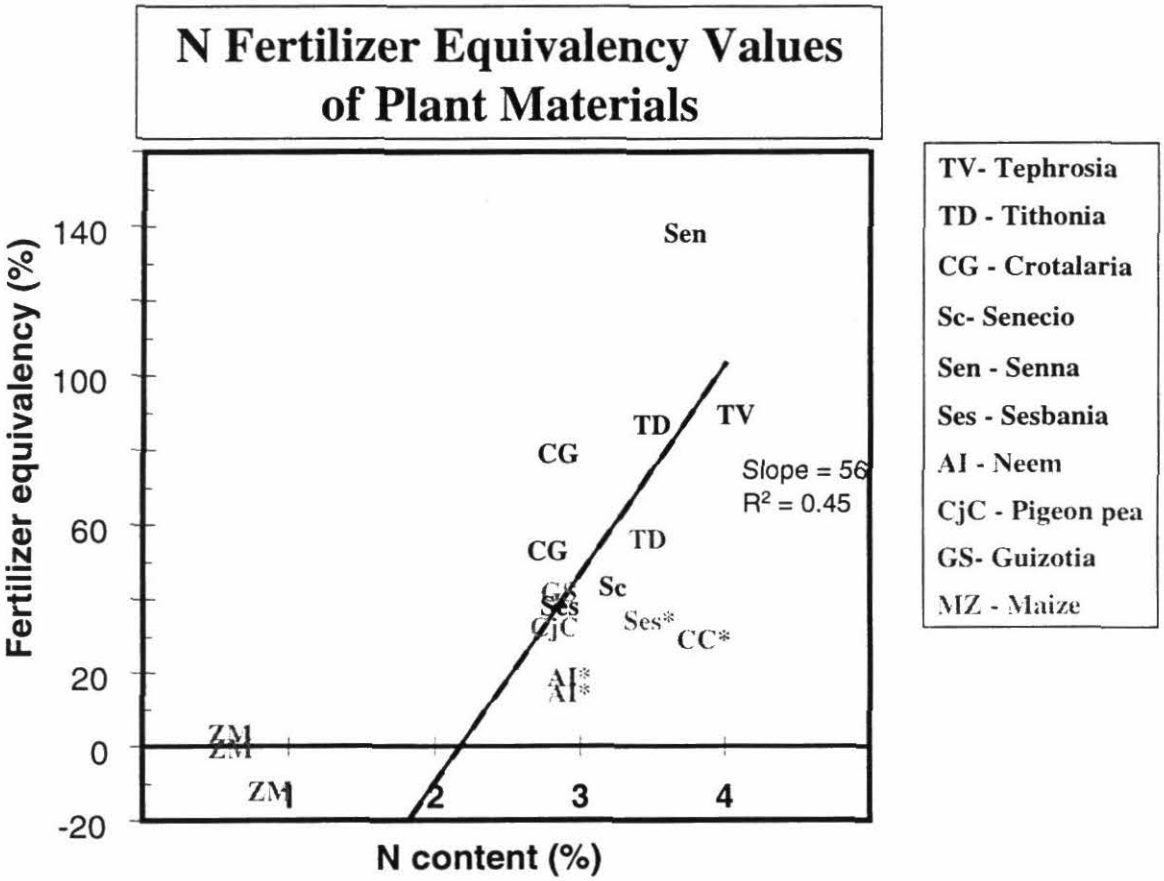
Activity 1.2 Decision tree and database for organic matter uses (CNDC/MIS) Funded by core SWNM funds, a DFID funded project to SWNM)

- Continued data entry and development of the Organic Resource Database (ORD)
- Continued experimentation in Africa and Latin America for refinement of the N management decision tree
- Version 3 of the ORD released
- Training event held for Southern Africa collaborators

Africa (CNDC consortia)

TSBF continues to co-ordinate INM network trials conducted by national collaborators in 4 AHI benchmark countries. Most of these trials are conducted on farm. These trials have been designed to test the preliminary TSBF Organic Matter Management Support System for Nitrogen (decision tree) described in Output 2. As reported in the 1999 annual report the network experiment results from several sites in East and Southern Africa show that the prototype decision tree for N management is useful. In April a synthesis meeting with the scientists involved in these experiment's was held to bring together the 1999b and 2000a seasons data. The results basically confirm those of the first season. The results support the decision tree (Figure 1) in the fact that materials with high N (>2.5%) but low lignin (<15%) and low polyphenol (<4%) increased yields while those with low N contents (<2.5%) did not increase yields above that of the control. Also material with high N but high polyphenol reduced yields compared to those with high N and low polyphenol. Contrary to the expectations from the decision tree materials with high lignin content (>15%) did not decrease yields compared to materials with high N and low lignin. It must be noted that the highest lignin values for materials used in the network trial was 21%. A linear relationship between N content and fertilizer equivalency is observed (Fig 1), for each 0.1% increase in N concentration of the organic material there was a 6% increase in fertilizer equivalency value, except for those materials with high polyphenol contents.

Two on-station trials in Uganda established to test and refine the Organic Matter Management Support System for Nitrogen have two seasons data. The experiments are 1) to investigate the fertilizer equivalencies of locally available organic resources, *Tithonia diversifolia*, *Lantana camara*, *Acanthus eminens* and mature *Canavalia ensiformis* and 2) to compare ways to use of the low quality organic resources, maize stover, coffee litter and mature *Canavalia ensiformis* such as mulching versus incorporation. Early indications are that the crop responses to the treatments in experiment 1 shows no significant differences between treatments. Analysis of experiment 2 is still on-going.



In the 2000a season further network trials were established in Eastern Uganda. The experiments are 1) to investigate the effects of below-ground versus above ground components of legume cover crops (*Mucuna puriens* and *Canavalia ensiformis*) to crop production and the optimal amount of legume cover crop biomass needed for increasing crop yields and 2) to investigate the fertilizer equivalencies of *Tithonia diversifolia* and the interaction with different sources of P. The work in Uganda is funded through a DFID grant to SWNM.

Version 3 of the Organic Resource Database has been released, it incorporated the items reported in Activity 1.1. This updated version is available through the Wye College webpage and on diskette. To date more than 50 requests have been received by TSBF through the webpage. As part of an IFAD funded workshop on 'results and planning workshop for TSBF/AFNET projects in Southern Africa' held in Harare a training course was conducted on the use of the ORD for Southern Africa collaborators.

TSBF has continued to add data from their collaborative projects within East and Southern Africa as well as other published data during 2000. In 2000 a further 300 entries were made into the database, as well as further modifications to the database structure.

Contributors:

Robert Delve – TSBF/CIAT
Catherine Gachengo, Patrick Mutuo and Cheryl Palm – TSBF
Bashir Jama – ICRAF
Africa2000 Network - Uganda
African Highlands Initiative (AHI)

Latin America (MIS consortia)
Experiments have been conducted in the hillside environment of Colombia to determine the nitrogen fertilizer equivalence of organic material from promising shrubby and tree legumes. Two provenances of *Calliandra calothyrsus* and two other locally available plants, *Tithonia diversifolia* and *Indigofera constricta* were used. *Calliandra calothyrsus* is a tree legume of interest throughout the humid and subhumid tropics as a result of its fast growth and tolerance to low pH soils. It is used in both Africa and Latin America. The two provenances have different forage qualities (i.e.. digestibility and tannin contents). Provenance San Ramon (22310) for example has lower soluble condensed tannins compared with provenance Patulul (22316) but the latter has higher digestibility on account of a lower fibre or cell wall content In this case digestibility seems to be more related to fibre level than to condensed tannin (polyphenol) contents. This difference was chosen to test the organic matter decision tree with material of different polyphenol composition. *Tithonia diversifolia* is regarded as a weed but has been used in Africa, for example, as a green manure because of its high nutrient contents, especially phosphorus. *Indigofera constricta* is a nitrogen fixing shade tree used in coffee plantations.

The experimental protocol utilized was similar to that described in the protocol document prepared by TSBF (Combined inorganic-organic nutrient sources: Experimental Protocols for TSBF-Afnet, SoilFertNet and SWNM 1999). A range of treatments combining 0-75 kg N/ha equivalents of both organic material and inorganic urea fertilizer-N was used with 0, 25, 50 and 75% of the total N applied as either the organic or inorganic material. The organic material used was a mixture of stem and leaf material in the same proportions that farmers use by slashing and applying material to the soil surface. This gave average N and P concentrations of 1.54 and 0.05% respectively for *C. calothyrsus 22310*, 2.14 and 0.12% for *C. calothyrsus 22316*, 1.38 and 0.18 for *Tithonia diversifolia* and 2.51 and 0.1% for *Indigofera constricta*.

The organic/inorganic combinations were applied as N sources for a maize crop with P and K fertilizer applied in non-limiting amounts. A N response curve for maize was obtained using a range of urea-N applications from 0 to 120 kg N/ha.

Litter bag experiments were used to determine decomposition rates and organic material half lives. For dry matter the half-lives were 77 days for *C. calothyrsus 22310*, 64 days for *C. calothyrsus 22316*, 35 days for *Tithonia diversifolia* and 21 days for *Indigofera constricta.*

Maize yields with 75 kg urea-N/ha were 4.76 t/ha and 3.78 t/ha with no N additions.
The effect of the combinations of the different sources of organic and inorganic N on maize production is shown in Table 1.

In terms of fertilizer equivalency the plant material was ranked in the following order: *I. constricta* > *T. diversiflia*> *C. calothyrsus 22310* > *C. calothyrsus 22316.* Compared to the application of 75 kg urea-N/ha *I. constricta* was 96% as effective followed by *T. diversifolia* with 63% effectiveness.

Table 1. Effect of combinations of organic and inorganic N sources on the production of maize.

N source	Organic-N Kg ha $^{-1}$ (%)	Inorganic-N Kg ha $^{-1}$	Maize yield kg ha $^{-1}$
Control	0	0	3779
C. calothyrsus 22310	75.0 (100)	0	4355
C. calothyrsus 22310	56.0 (75)	19.0	4044
C. calothyrsus 22310	37.5 (50)	37.5	4862
C. calothyrsus 22310	19.0 (25)	56.0	5096
C. calothyrsus 22316	75.0 (100)	0	3526
C. calothyrsus 22316	56.0 (75)	19.0	4211
C. calothyrsus 22316	37.5 (50)	37.5	4375
C. calothyrsus 22316	19.0 (25)	56.0	4594
Thitonia diversifolia	75.0 (100)	0	4552
Thitonia diversifolia	56.0 (75)	19.0	4469
Thitonia diversifolia	37.5 (50)	37.5	5166
Thitonia diversifolia	19.0 (25)	56.0	4500
Indigofera constricta	75.0 (100)	0	4853
Indigofera constricta	56.0 (75)	19.0	5254
Indigofera constricta	37.5 (50)	37.5	4561
Indigofera constricta	19.0 (25)	56.0	5138
Urea	0	30	4123
Urea	0	60	4724
Urea	0	75	4765
Urea	0	90	5269
Urea	0	120	4913

C. calothyrsus 22316 had a slightly greater decomposition rate in terms of dry matter and N and P release compared with *C. calothyrsus* 22310 and also had higher fertilizer equivalency values. This result also concurs with a greater *in vitro* digestibility of 22316 compared with 22310. Thus intraspecific differences can be detected with the proposed organic matter decision tree if the tissue analyses take into consideration soluble and condensed tannins and cell wall fibre contents.

Contributors:
Richard Thomas and Edmundo Barrios - CIAT

Activity 1.3. Decision support tool for phosphorus amendments (CNDC)

- Prototype decision tree for phosphate rock (PR) developed
- Database for PR trials using PR in SSA being compiled

The agricultural soils of sub-Saharan Africa (SSA) are naturally poor with low N and P content. Deficiency of P in some soils is so critical that without adequate application of P, investment in other agricultural inputs (e.g. N fertilizer, biological nitrogen fixation, irrigation, and improved varieties) may not be able to increase crop productivity. Combined with the absence of domestic P fertilizer industries, limited availability of foreign exchange for fertilizer imports, and socioeconomic constraints, the P fertilizer application rates by resource-poor farmers have been very low - 1.5 kg P_2O_5 ha^{-1} compared with 34 kg P_2O_5 ha^{-1} in Asia and 20 kg P_2O_5 ha^{-1} in Latin America. When economically used as fertilizers, the phosphate rocks (PR) found in Togo, Burkina Faso, Mali, Niger, Nigeria, Senegal, and Tanzania, would allow a saving of much-needed foreign exchange.

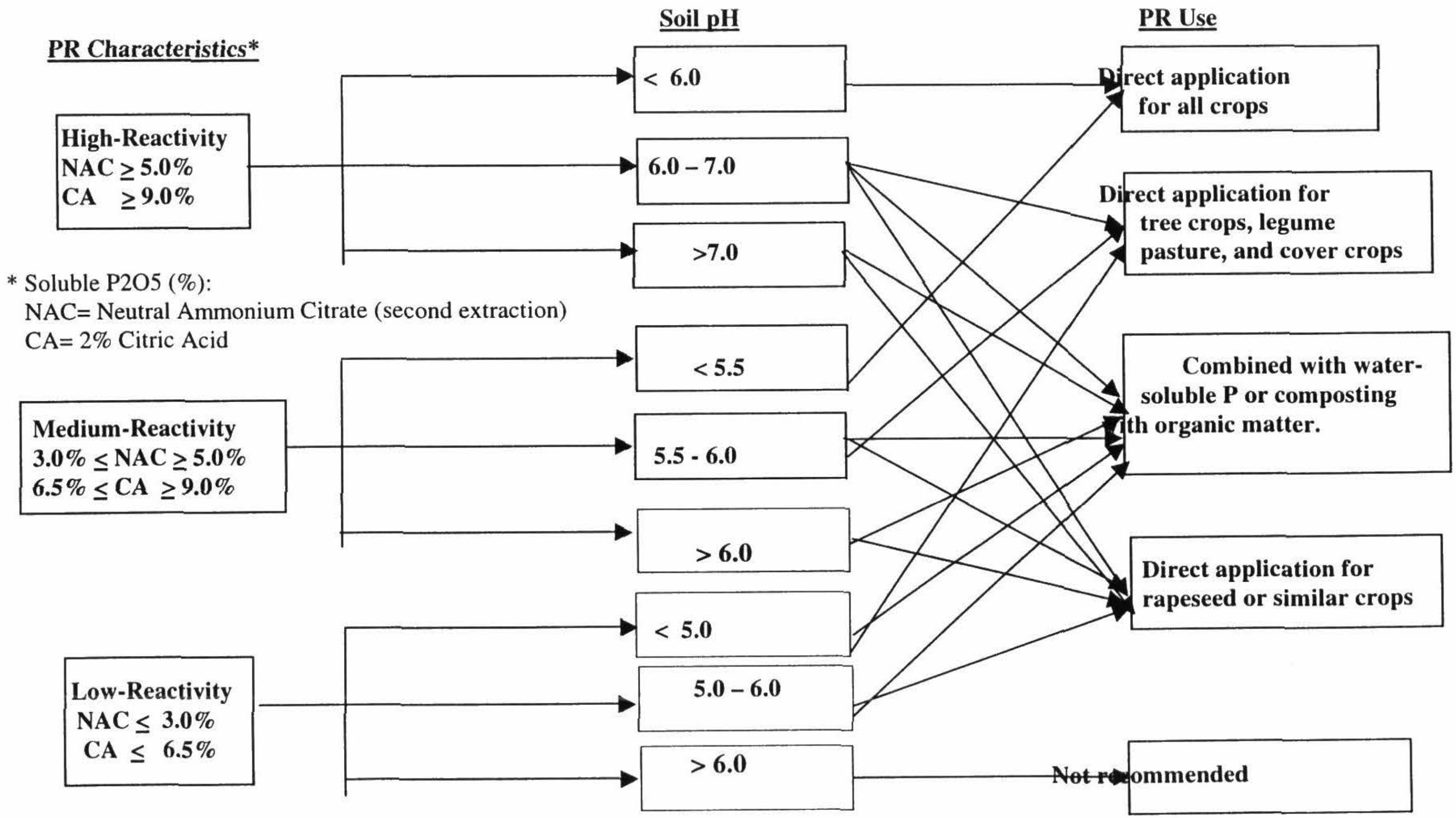
Based on previous and current research, IFDC has developed a decision tree to serve as guidelines for direct (and/or combined with imported P fertilizer) application of indigenous PR in different scenarios for crop production in SSA (Figure 2). The decision tree is being expanded to accommodate effect of soil types, texture, rainfall, and soil P status. The PR decision support system (PRDSS) once completed would target policy and decision makers and the private sector to find whether indigenous PR deposits could be exploited and in which form. The PRDSS will be available for testing and validation by early 2001.

A database comprising of all field trials conducted by IFDC and other institutions in SSA is being compiled. This database together with recently completed IAEA study on PR application will provide readily accessible information on performance of PR in SSA (initially) and Latin America. Such information will also be very useful for P model development and improvement (Activity 1.4). The relevance and adequacy of the PR decision support system would be increased through on-going and proposed work under CNDC and interconsortia activities of SWNM Program, and other IFDC projects in SSA.

Contributors:

Norman Chien, Henk van Reuler, and Upendra Singh - IFDC

Figure 2. A preliminary simple guideline to determine agronomic potential of phosphate rock (PR). Source: Chien 2000.



Activity 1.4 Improved crop models (CNDC additional funds from ACIAR grant to SWNM)

- Project implementation workshop held
- Improvements to models
- Initial training conducted
- Experiments chosen for validation of the model
- Initial modelling exercises conducted

CNDC is utilizing decision support tools to identify limiting factors, yield potentials, and management strategies to improve soil fertility in sub-Saharan Africa (Singh et al., 2000). The coarse texture, low organic matter content, low available soil P, and very low CEC (5-8 cmol kg^{-1}) of West African soils combined with erratic albeit high intensity rainfalls results in low nutrient use recovery independent of whether of the nutrient is applied as mineral fertilizers or from organic sources. Given the high potential for losses of N and even P and high input costs, the use of relevant DSS to help improve nutrient use efficiency, soil fertility, and crop yields is urgently needed.Decision trees for organic matter and phosphate rock management are under development. These decision trees offer the farmers in the region the options to choose local resources for increasing crop yields and/or improving soil fertility. The decision support tools are used to identify appropriate strategies for given agroecological and socioeconomic conditions.

Following the Nairobi mini-review in November and the SWNM Wageningen meetings IFDC and TSBF have been working together to improve crop models for use in SSA, particularly with respect to applications in integrated nutrient management. CNDC is using crop and soil simulation models that have been tested widely in the tropics, namely, APSIM, DSSAT, NuMaSS, and Quefts. The systems tool development, testing, and application will benefit other members of SWNM. Due limited funds, a joint workshop of CNDC (East and West Africa) and OSWU was not possible. The modelling workshop is planned for 2001.

Project Implementation Workshop

A project implementation workshop was held, the purpose of the workshop was to present the modules of APSIM and to identify if and why the current modules are not able to simulate soil N, P, and soil organic matter dynamics, and crop yields, and to develop plans for model modification and field verification trials. In addition, DSSAT and NuMaSS crop models and decision support systems were presented by representative of those modelling groups in order to share information and develop closer links with other modelling groups in SWNM.

MANURE MODULE, including SOIL ORGANIC MATTER

It was decided that N release from animal manures and plant materials are distinctly different in terms of critical values and thus must be studied separately. N content or C:N were agreed to be the primary indicators of decomposition and N release across a range of plant materials of different quality. However, other parameters (such as lignin and polyphenolics) are needed to explain the outliers observed in research results. Several datasets on N release patterns from decomposing plant materials were identified for the purpose of testing ASPIM over a broad range of C:N ratios, identifying outliers, and establishing algorithms. The primary datasets are from controlled laboratory incubations: Palm and Sanchez, 1991; Constantinides and Fownes, 1994, Handayanto et al., 1994. Then other datasets from field trials, including Mafongoya et al., 1994; TSBF/SWNM network trials; IBSRAM Acid Soils Network trials; and CIAT pot and field trials can be used for testing the modified version of APSIM.

Measurements for assessing plant resource quality include an extensive array of proximate analyses (lignin, acid-detergent fibre (ADF), total soluble polyphenolics, and a variety of condensed tannins). There is still need for work in identifying the best method for analysing polyphenols/condensed tannins as they effect decomposition and N release. The resulting decomposition is actually determined by the combination of proximate factors and an overall index would be best for estimating decomposition. Indirect methods that can serve as 'integrative measures' of resource quality include near infrared reflectometry – NIR (ICRAF); perfusion – (IBSRAM); and *in vitro* digestibility- IVDMD (CIAT). Plans were made for comparing the various indirect methods to the proximate analyses on a set of standard plant samples collected by TSBF.

It was recognized that C:N is also an essential parameter of animal manure quality. However, the critical C:N value at which net N mineralization occurs in manures is lower than for plant materials and is below the critical value currently in the APSIM manure module. There does not yet appear to be agreement on the appropriate critical value for C:N of cattle manure and may be quite variable depending on the constituent composition of the manure. Measurements for assessing manure quality are also still not agreed upon. Currently C:N, ash content, ADF, NDF, and soluble C and N are being advocated but further testing and correlation is necessary. The management of animal manures may be one of the biggest factors affecting manure quality. Some qualitative assessment of the type and duration of manure management may provide a proxy resource quality parameter. Data from incubation trials and field trials from KARI-Embu, KARI-Muguga, TSBF-Zimbabwe and the AfNet Network will be used for modifying and testing the APSIM manure module.

SOILP MODULE:

There was general consensus that understanding of soil P and P uptake by plants was not adequate. There is no universal means for characterizing soil P and little understanding of how various P pools relate in different soil types. Soil tests for P only capture 40 to 60% of the variability of response. Alternative approaches have been to measure P fractions of increasingly less solubility. The results of these efforts have not yet been convincing though all agree there needs to be some assessment of the labile P fraction. P sorption may help with understanding better the P dynamics. Labile P is variously interpreted to mean isotopically exchangeable P, or P in the colloid – solution equilibrium, or the P in equilibrium solution or reversible P. Non-extractable, non-reversible forms of P are considered to be nonlabile – and some workers further divide this nonlabile fraction. Measurements of labile P vary from soil to soil, but in most cases **resin** and **bicarbonate** inorganic P best represent labile P. Some NaOH-extractable inorganic P from recent applications may also be used to estimate labile P.

Several challenges were identified to help in resolving these issues:-

- Understanding of the fast sorption process and the loss of availability of added P
- Understanding the role of organic P; this is important in low-input systems, but how many fractions are necessary and how to measure them
- Deeper soil layers are more important for low-input systems compared to high-input where fertilisation of the surface layer overwhelms the available soil P
- The role of P-sorption processes, particularly in some tropical soils was highlighted as an important factor to include in our understanding of P uptake and how it is to be modelled.
- The distribution of roots is known to be important for uptake of P. It was stressed that concepts like root uptake efficiency (Imax) should be represented in models of P uptake
- There is good evidence that P stress changes DM partitioning, especially between tops and roots, but generally P stress physiology is not well understood. Very limited data exist on critical P concentrations in plant components or whole above ground plants through life of range of crops.

The point to remember is that for modelling purposes it is necessary to predict plant growth and P dynamics in the soil. The best approach in terms of modelling is likely to be to start with a simple approach, then include other fractions and processes as required to simulate P availability and crop uptake.

Several potential sites and experiments were identified for the P modelling purposes. Experiments in East Africa (TSBF/ICRAF) offer the most readily available datasets for testing the performance of the P model. Data from experiments in Latin America should enable estimation of critical P concentrations for maize and beans as function of stage of growth. In West Africa, much data from mid- to long- term P experiments comparing rock P sources with superphosphate. Also limited data on P response by millet and cowpea with series of harvests and determination of N and P concentrations in plants (Bationo, IFDC/ICRISAT).

Several other sources of data were mentioned. The issue of "ownership" of some of these data was discussed (but not resolved) particularly in the context of collaboration between modellers and "collectors of data", and also when the data had arisen from a network with numerous experimenters conducting trials at different sites. The sources included:

- ICARDA datasets on wheat, barley and chickpeas being used to evaluate the P model in DSSAT; similarly pearl millet and cowpea experiments in Senegal.
- CIAT experiments with maize, soybean, rice and peanut in S E Asia, and cowpea in Africa
- Carimagua, Colombia experiments (D. Friesen - CIAT/IFDC)
- West Africa – (Bernard van Lauwe - IITA)
- Southeast Asia – (Santoso, Lefroy – IBSRAM Acid Soil Network).

<u>Improvements to Crop Models</u>

Code modifications of APSIM modules to reflect organic resource quality parameters and soil P fractions needed to improve simulation capabilities.

Several trials in East and Southern Africa are investigating the factors that affect the quality of animal manures and how the various quality manures affect nutrient availability to crops. In addition, extensive datasets exist from laboratory incubation studies on the nitrogen release patterns of plant materials of varying quality. APSIM simulations are to be compared to the absolute and relative nitrogen release patterns from the incubation studies.

Currently in APSIM MANURE the decomposition of organic inputs are described in terms of three pools with differing rates of decomposition (sometimes referred to as carbohydrate-like, cellulose-like and lignin-like). The aim will be to explore whether the observed pattern of nitrogen release from diverse sources can be simulated successfully by varying the relative composition of these three pools. If this is achievable, the focus will shift to how the composition relates to the measured quality factors. Modifications to the model will incorporate changes so that decomposition and nutrient release can be related to the key quality factors that then become inputs for the model.

The soil P measurements identified at the workshop, and other promising measurements, are being made on selected experiments where response to P inputs are under study. APSIM SOILP will then be used to test its robustness for describing P dynamics, soil P fractions and plant growth under conditions of limiting P supply.

The focus is low input systems on soils of moderate to high P sorption. Initial effort is devoted to experimental sites in Kenya. However experimental plots from on-going trials covering a range of soil types in East and West Africa, Latin America, and Southeast Asia are accessible to the project and are being characterised in terms of soil phosphorus pools and associated plant growth following application of different P sources.

DSSAT Model Application

The Decision Support System for Agrotechnology Transfer (DSSAT) linked with the Organic Resource Database is now used to predict on a daily basis:

- N supply from organic sources
- N release pattern
- Synchrony with plant N demand

The model also incorporates the effect of tissue N content, lignin content, and polyphenolics on N dynamics. As expected this would improve nutrient use efficiency and reduce losses of nutrients, particularly N from organic sources.

The effect of four organic residues, maize stover (0.6% N, 8% lignin, 1% polyphenols), mucuna tops (3.0% N, 8% lignin, 1.8% polyphenols), pigeon pea stover (3% N, 18% lignin, 1.5% polyphenols), and leucena leaves (3% N, 11% lignin, 5.2% polyphenols) as N source, each applied at 2 t ha^{-1} were evaluated using the modified DSSAT model during the wet season at Planaltina, Brazil and Zaria, Nigeria. The Planaltina acid savanna soil is clayey Acrustox with 1.6% OC, pH 5.8 and 130 kg soil mineral N ha^{-1} at the start of the experiment. The clay loam Haplustalf at Zaria is less fertile with 0.3% OC, pH 6.0, and 43 kg initial soil mineral N ha^{-1}. Based on the amount and the timing of N release at 60 days after residue/green manure application (corresponding to silking in maize), 120 days after residue application (maturity stages in maize), and 322 days after residue application appropriate organic N sources could be selected (Table 2).

Table 2. Simulated N supply from organic sources at Planaltina, Brazil and Zaria, Nigeria without any crop (uncropped fallow).

	-----% N in Residues (Days after residue application) -----		
	60	120	322
Planaltina, Brazil			
Maize stover	45	22	11
Mucuna tops	13	7	3
Pigeon pea stover	66	50	34
Leucena leaves	32	18	9
Zaria, Nigeria			
Maize stover	57	36	19
Mucuna tops	21	12	6
Pigeon pea stover	63	50	28
Leucena leaves	36	23	11

* The percentage is calculated based on 60 kg N ha^{-1} applied as residue for all except maize (12 kg N/ha).

The mineral N supply, mineral N losses, N remaining in the residue at a given time, and the N balance on application of the organic residues without growing a crop is presented at 322 days after residue application in Table 3. N losses are high because the simulations were done without plants, but using pigeon pea or maize stover could reduce these. Maize stover would not be a good source of N because of its low N content and the tendency to immobilize large amounts of mineral N (Table 3). For mucuna tops, with high N concentration and fast N release, the timing of residue application must synchronize with plant N demand to avoid excessive N losses. The site characteristics (soil and weather) also play an important role. The N losses at Zaria under high rainfall and coarse textured soils are twice as high.

Table 3. Simulated N supply and losses from organic residues at 322 days after application of the residues at Planaltina, Brazil and Zaria, Nigeria for uncropped-fallow.

	N in Residues (at 322 days after residue application)	Soil Mineral N	Cum. N Loss	N immobilized
	%			
Planaltina, Brazil				
Maize stover	11	50	0	39
Mucuna tops	3	58	20	19
Pigeon pea stover	34	45	9	12
Leucena leaves	9	58	16	17
Zaria, Nigeria				
Maize stover	19	50	0	31
Mucuna tops	6	35	40	19
Pigeon pea stover	28	42	17	13
Leucena leaves	11	40	32	17

* The percentage is calculated based on 60 kg N ha^{-1} applied as residue for all except maize (12 kg N/ha).

When the above amounts of residues (2 t ha^{-1}), corresponding to 60 kg N ha^{-1} for all except maize stover, were applied to a maize crop grown during wet season at the two locations, increases in maize grain yield were simulated (Table 4). As expected grain yield increases over the control treatment (no residue application) were minimal for maize stover that had N content of only 12 kg N ha^{-1}. All green manure treatments under the Brazilian condition reached yields that corresponded to relative rainfed yield potential of 75% and higher. On the other hand, much greater quantities of organic residues and/or the residue application supplemented with inorganic fertilizers will be needed to reach such yield targets in the Northern Guinea Savanna in Nigeria.

These simulations were limited to the N supplying capacity of the residues. In the infertile soils of SSA, organic matter additions would also play critical role in improving water retention, reducing soil erosion, and improving nutrient recovery through their impact on CEC, root penetration, and soil organisms. In cooperation with IARS and ICASA work is in progress to incorporate the above effects into the existing crop simulation models. The above simulations also assumed that organic residues once applied stayed in the field. In SSA, anything from termites to cattle could consume and thus remove the organic residue from the target fields to elsewhere. It is thus very important for decision makers to consider abiotic, biotic, and socio-cultural factors into account when making recommendations for yield and soil fertility improvement. It is equally important to realize the limitations and the usefulness of the existing DSS.

As we continue to use the decision support tools in the ongoing research, extension and training programs in SSA we envisage the need to improve and make these tools more appropriate for the local conditions. For example, the option to use phosphate rock as P source, and the indirect contributions from organic matter to nutrient and water use efficiencies. Decision support tools are being used in the ongoing transect study in West Africa to conduct ex-ante analyses and extrapolate water and nutrient responses. To further promote use of systems tools for integrated nutrient management and soil fertility improvement an ecoregional-funded project with NARES and University partners have been started in West Africa (IFDC, 1999).

Table 4. Simulated grain yield and N uptake response to organic residue applications. The relative yield-gap with respect to rainfed yield potential (nonlimiting nutrient and disease- and pest-free condition) is also presented.

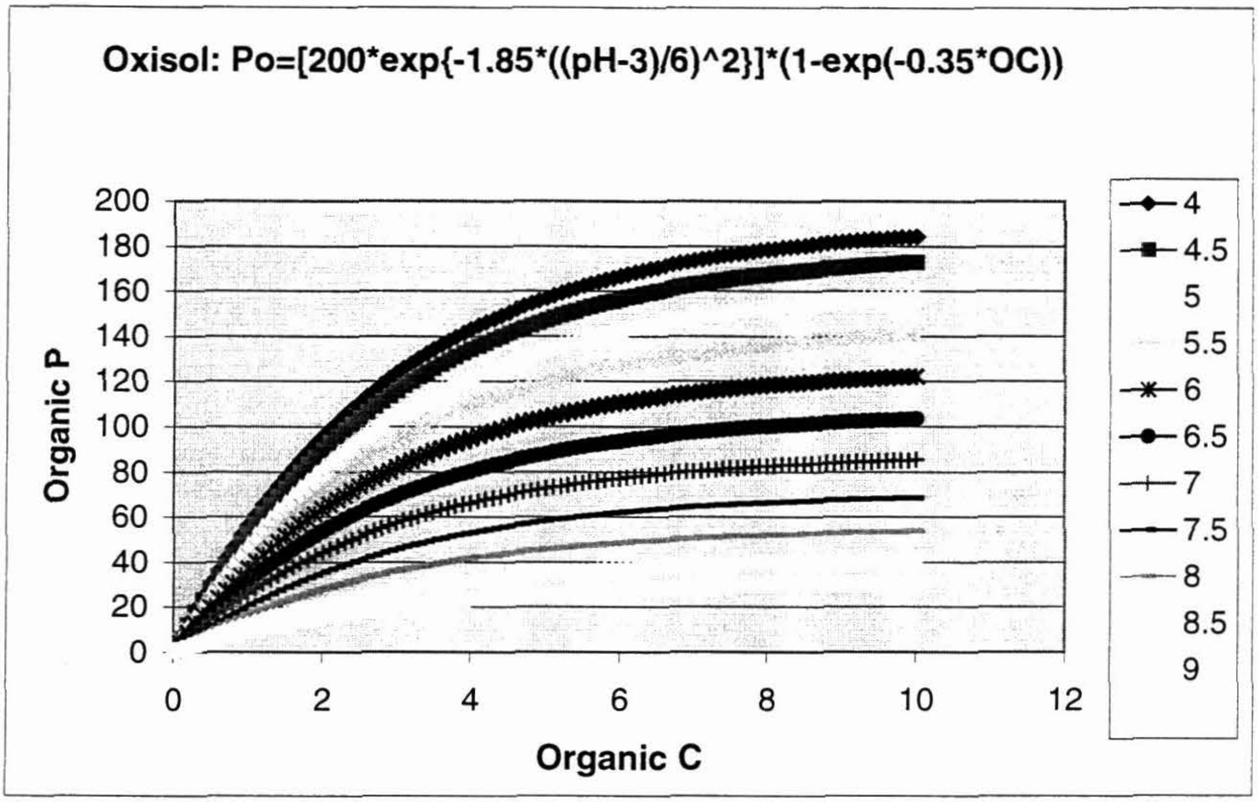
Residue Type	Grain Yield ($kg\ ha^{-1}$)	Total N Uptake ($kg\ N\ ha^{-1}$)	Rel. Rainfed Yield Potential (%)
Planaltina, Brazil			
Control	4600	87	66
Maize stover	4700	90	68
Mucuna tops	6000	122	87
Pigeon pea stover	5200	103	75
Leucena leaves	5800	116	84
Zaria, Nigeria			
Control	1050	21	14
Maize stover	1270	24	16
Mucuna tops	3270	52	42
Pigeon pea stover	2120	37	27
Leucena leaves	2904	48	37

Estimating P Model Input Data

One of the reasons for the low use of crop simulation models in SSA is availability and accessibility of data for model input. Many times the model input data are difficult to generate at field level. The P modules both in the DSSAT and APSIM require data on soil P fractions (pools). The P module in the DSSAT has: 2 organic pools (Active and Stable), 2 inorganic pools (Active and Stable) and a Labile P pool (plant available P). In

addition there is a P fertilizer pool (relatively short time for water soluble P sources) and a fresh organic residue P pool. The existing fresh organic residue data file contains tissue concentration for N, P, lignin, cellulose, starch, and polyphenolics and the decomposition their rates. The best way to improve the usability and applicability of the P model to many of the users in the developing countries was through a "hidden" expert system that would generate the P fractions for each of the pools. Soil data sets comprising of P pools, pH, organic carbon, texture, CEC, and soil test P values (different methods) were compiled for developing pedotransfer functions and the expert system.

Figure 3. Estimating soil organic P pool using soil pH and organic carbon content.



A series of regression equations with pH, organic carbon and soil depth have been developed for different soil types (oxisols, inceptisols, vertisols, mollisols, different textural groups, and old versus newly opened fields) for estimating organic P pool size (Figure 3). Unlike the soil C:N the soil C:P varies a lot; hence organic P pool could provide significant amounts of P for plant uptake (Table 5). Additional data sets are being compiled to validate the above relationships.

Table 5. Organic carbon to organic phosphorus ($C:P_O$) ratio of top soils as influenced by soil types, organic carbon content, and pH.

Soil Type	Soil pH	C: Po Ratio				
		Soil Organic Carbon Content (%)				
		0.5	1.0	1.5	2.0	(mean)
Oxisol	5.0	191	208	225	244	217
	6.5	292	318	344	373	332
Vertisol	6.0	135	138	141	145	139
	7.5	122	125	128	131	127
All Soils	5.0	79	82	84	87	83
	7.5	139	143	148	152	146

Performance of the P Model

The CERES models for maize, wheat and upland rice have been tested. The model correctly simulated the changes in soil P pools against data sets from ICARDA and IFDC/CIAT. It is likely, based on personal communication with Denis Friesen maize yields even with the highest P rate (50 kg P/ha) may have limited by factors other (subsoil acidity) than N, P or water. While adjustments could be made to the root distribution function to capture the above effect, the validation exercise becomes less than ideal. On-going and proposed field trials under CNDC will provide good quality data for thorough model validation.

Field trial (and laboratory) sampling, compatible with APSIM and DSSAT data requirements, for further testing the APSIM and DSSAT modules.

East and Southern Africa
As described in the model testing section above, 6 experiments in East and Southern Africa have been selected for testing the model. The data requirements of APSIM have necessitated additional sampling in these experiments, primarily to characterize soil mineral N and the soils' water holding properties. It has also been necessary to compile the weather records for the different sites.

Experiment 1: (Patrick Mutuo - TSBF). A joint ICRAF-TSBF experiment (NM15) at Maseno in Western Kenya has been chosen for simulating soil P and N and crop response in the SOILP Module. Treatments include 2 N sources (urea and Tithonia residue) with several P treatments (nil, 50P applied annually in March, 250P applied only in 1st year; P sources are TSP and Minjingu phosphate rock). This year in addition to the usual crop yield and soil data, the experiment was sampled for mineral N and water according to APSIM specifications. Climate data have also been compiled.
Experiment 2: (Rob Delve – TSBF/CIAT Uganda). An N experiment comparing different quality organic inputs at Kawanda, Uganda was chosen for testing the residue management section of the MANURE Module. Field sampling included soil and crop parameters as specified by APSIM. Climate data has also been compiled.
Experiments 3 and 4: (Alfred Micheni/Francis Kihanda – KARI-Embu). Long term (>10 year) manure experiments in Embu district comparing three rates of input (0, 5, 10 t/ha) have been chose for testing the MANURE Module. The two sites at Machanga (P responsive) and Mutuobare (not P responsive) provide an interesting contrast on account of their different soil P status. A single source of goat manure has been used throughout the experiments; this manure is of good quality (~ 26%C, 2% N and 0.48% P). The soils are currently being characterized and monitored according to APSIM specifications.
Experiments 5 and 6: (Nhamo Nhamo – TSBF-Zimbabwe). Experiments comparing the effectiveness of manure and N fertiliser (ammonium nitrate) at two sites (Mangwende and Romwe) in Zimbabwe have been chosen to test the MANURE Module. In these experiments P is not a consideration as basal P is applied. As with the other trials, soils and crops are currently being monitored according to APSIM specifications.

West Africa
Phosphorus model validation experiment has been undertaken by Institute of Agricultural Research, Ahmadu Bello University, Zaria and the Institut National des Recherches Agrcoles du Benin (INRAB). These experiments will provide soil P data, plant uptake, soil moisture characteristics, periodic plant sampling, and daily weather data for use by DSSAT and APSIM models. The treatments include water-soluble P and phosphate rock, P rates and N rates. The trials at Sekou, Benin are conducted in both the long and the short seasons.

Zaria Experiment: (Victor Chude and I.Y. Amapu). The experiment is laid out in a randomized complete block design with incomplete factorial in four replications. The treatment combinations three rates of N and two P rates and P sources (SSP and Sokoto phosphate rock). N rates are 0, 60, 120 and 180 kg N ha^{-1} applied to maize, SSP rates are 0 and 60 kg P_2O_5 ha^{-1} applied every year and 120 kg P_2O_5 ha^{-1} applied as rock Sokoto phosphate rock every two years.

Sekou Experiment: (K. Aihou and M. Adomou). The experiment is laid out in a randomized complete block design with incomplete factorial in four replications. The treatment combinations are 3 rates of N (0, 60, 120 and 180 kg N ha^{-1}), 2 P rates and P sources. The treatments for the two seasons were (1) N_0P_0 - N_0P_0, (2) N_0P_{TSP} - N_0P_{TSP}, (3) $N_{60}P_{TSP}$ – $N_{60}P_{TSP}$, (4) $N_{60}P_{PN}$ – $N_{60}P_0$, (5) $N_{120}P_{TSP}$ – $N_{120}P_{TSP}$, (6) $N_{120}P_{PN}$ - $N_{120}P_0$, (7) $N_{180}P_{TSP}$ – $N_{180}P_{TSP}$, and (8) N_3P_{PN} - N_3P_0. P_0 is without P fertilizer application and P_{TSP} and P_{PN} with 46 kg P_2O_5 ha^{-1} applied as TSP N_3P_{PN} - $N_3P_0$and 180 kg P_2O_5 ha^{-1} applied as rock phosphate (phosphate natural) to maize.

Latin America

Funding from this project has enabled CIAT to take additional measurements in some of their long-term experiments on N and P dynamics. Findings from these trials will be useful in refining the plant critical values and uptake patterns for the SOILP module and assist in the residue management section of the MANURE Module. Highlights relevant to this ACIAR project from these experiments are provided in Appendix 4.1.2.

Southeast Asia

The field experiments used in this subproject are the core experiments of the IBSRAM acid soils network. The field experiment was designed to assess the responsiveness to P, the comparative value of different inorganic P sources, the response to combinations of inorganic P with organic amendments, and, in some cases, the response to lime. The P responsiveness is established with readily available P sources, including triple superphosphate (TSP), single superphosphate (SSP), and SP 36 – a phosphate fertiliser used in Indonesia that contains 36% P_2O_5.. The inorganic/organic combinations included fused magnesium phosphate (FMP) and different phosphate rocks from North Carolina (NCRP), Christmas Island (CIRP), and rock phosphate from the Peoples Republic of China (CRP). The organic sources were chosen on the basis of what was available, or may become available, from within or outside the farming system.

Contributors:

East Africa:
Cheryl Palm, Herbert Murwira, Patrick Mutuo, Nhamo Nhamo - TSBF
Robert Delve – TSBF/CIAT
Alfred Micheni and Francis Kihanda – KARI-Embu

West Africa:
Pierre Dejean, Upendra Singh – IFDC
Kouessi Aihou, Mustapha Adomou – INRAB
Victor Chude, Ishaku Y. Amapu – IAR, Zaria

Latin America:
Idupulapati Rao and Edmundo Barrios – CIAT

Southeast Asia:
Rod Lefroy

Output 2 Improved technologies for increased production based on efficient use of water and nutrients adapted and applied by land users

Activity 2.1 Develop improved practices for fragile soils at different scales (MSEC, MIS, CNDC)

- Continued experimentation for refinement of cropping systems models in Nigeria and Benin
- Compared performance of phosphate rock versus commercial P fertilizers
- Field training continued on collection of minimum data sets and interdisciplinary research
- Model validation with data from Nigeria completed

Field trials were conducted over two years during 1998-99 at the Ahmadu Bello University Farm, Zaria (Lat. 11.1^0N and Long 7.4^0E), and Sekou, Benin (Lat. 6.7^0N and Long 2.2^0E). The Zaria location lies between the northern limit of the Guinea savanna and the southern limit of the Sudan savanna zones. It falls within the EPHTA benchmark area for the subhumid savanna. Zaria has a mono-modal rainfall distribution. The Sekou site is characterized by bimodal rainfall distribution and it represents the coastal/degraded savanna benchmark area. The experiments were designed to evaluate nutrient cycling in sole maize, maize-cowpea, sole cassava and sole cotton cropping systems. The data and results from Zaria are presented.

The sole maize system had four levels of nitrogen fertilizer application (0, 60, 120 and 180 kg N ha^{-1}), and two levels and sources of phosphorus fertilizer (0, 60 kg P_2O_5 ha^{-1}) as single superphosphate (SSP) and 180 kg P_2O_5 as ground Sokoto phosphate rock (SPR). The maize-cowpea system had a similar fertilizer treatment as in sole maize and all of the applications were made to maize only. The corresponding fertilizer levels applied to cotton were 0, 50, 100 and 150 kg N ha^{-1} and 60 kg P_2O_5 as SSP and 180 kg P_2O_5 as SPR. Both SSP and SPR were applied in 1998 and 1999. The nitrogen fertilizer rates for cassava were 0, 50 and 100 kg N ha^{-1} while phosphorus fertilizer rates were 30 kg P_2O_5 as SSP and 90 kg P_2O_5 as SPR. Potassium fertilizer at crop-specific recommendations was applied. All treatments were arranged in a randomized complete block design with incomplete factorial in four replications.

Maize hybrid, Oba Super2 – CV 8644-27 (single cross TZi 18 x TZi 35) was planted on ridges spaced 75 cm apart, with 25 cm between planting spaces (one plant per hill), giving a plant population of 53,333 plants ha^{-1}. Cowpea (Local Kananado) variety was planted at the same spacing as maize. Improved cotton (SAMCOT9) was grown on ridges at 0.75 x 0.5 spacing at two plants per hill and plant population of 53,333 plants ha^{-1}. Improved IITA cassava variety (TMS 92/036) adapted to subhumid conditions was planted on ridges at 1 x 1 m arrangement with a plant population of 10,000 plants ha^{-1}. All the plots measured 5m x 6m. Maize was planted in June while in the maize-cowpea system; cowpea was introduced at the time of physiological maturity of maize. Cotton was sown mid-June every year while cassava was planted every July. Nitrogen fertilizer in the form of urea was applied in bands in two equal split applications to maize, cotton and cassava only, the first at two weeks after planting and the balance side-dressed four weeks later except for cassava that received the second dose 11 months later due to a prolonged dry season. The phosphates and potassium fertilizers were band applied at planting. Maize stover, cowpea biomass, and cotton and cassava leaves were incorporated into the soil after harvest. Daily rainfall, sunshine hours, soil properties, solar radiation, maximum and minimum temperatures were measured at the experimental site.

Detailed data on soil properties, crop management, weather and crop phenology were collected during the growth period while maize harvest index, grain and stover yields, cassava tuber yield and shoot weight, seed cotton and stalk yields were recorded at final harvest.

Results presented in Figure 4 show that maize grain yield in the sole maize system responded significantly to the nitrogen rates and phosphorus sources in 1998 and 1999. This was expected in view of the low initial soil test N and P levels and the high responsiveness of maize to fertilizers. The effect of 180 kg P_2O_5 ha^{-1} as Sokoto phosphate rock (SPR) on grain yield was comparable to 60 kg P_2O_5 ha^{-1} as single superphosphate in both years. The rationale for tripling the rate of P in phosphate rock was to compensate for its lower water solubility relative to highly soluble single superphosphate. There were significant yield differences ($P = 0.05$) at the same rate of nitrogen between 1998 and 1999. The high yield values obtained in 1999 are attributable to the efficient management of residues after the 1998-cropping season. Similar trends were obtained for stover yield and harvest index (Fig. 4). The residues improved the quality and quantity of the soil organic matter, enhanced the soil water-holding capacity and increased the efficiency of applied inorganic fertilizer. Crop residues are a critical resource in the management of soil productivity in the Nigerian savannas. The treatment effects in the maize-cowpea system (Fig. 5) followed a corresponding pattern as in the sole maize system.

Response of cassava to the treatments (Fig. 6) also showed increasing tuber and shoot yield in 1998. The 90 kg P_2O_5 ha^{-1} as SPR gave consistently higher tuber and shoot weight than 30 kg P_2O_5 ha^{-1} as SSP; however, based on per unit of P_2O_5 applied, SSP outperformed the phosphate rock source. The 1999 crop has not been harvested for comparison of the results. Also, not enough data have been collected to simulate the cassava experiment. The performance of SPR relative to SSP was better with cassava than maize (Figs. 4-6).

Cottonseed response to nitrogen (Fig. 7) showed that there were yield increases from 1998 to 1999 indicating the effect of a build-up in soil fertility arising from incorporation of organic residue. The trend was clearer with the stalk yield. As with maize and cassava the performance of SSP per unit of P_2O_5 applied was superior to SPR.

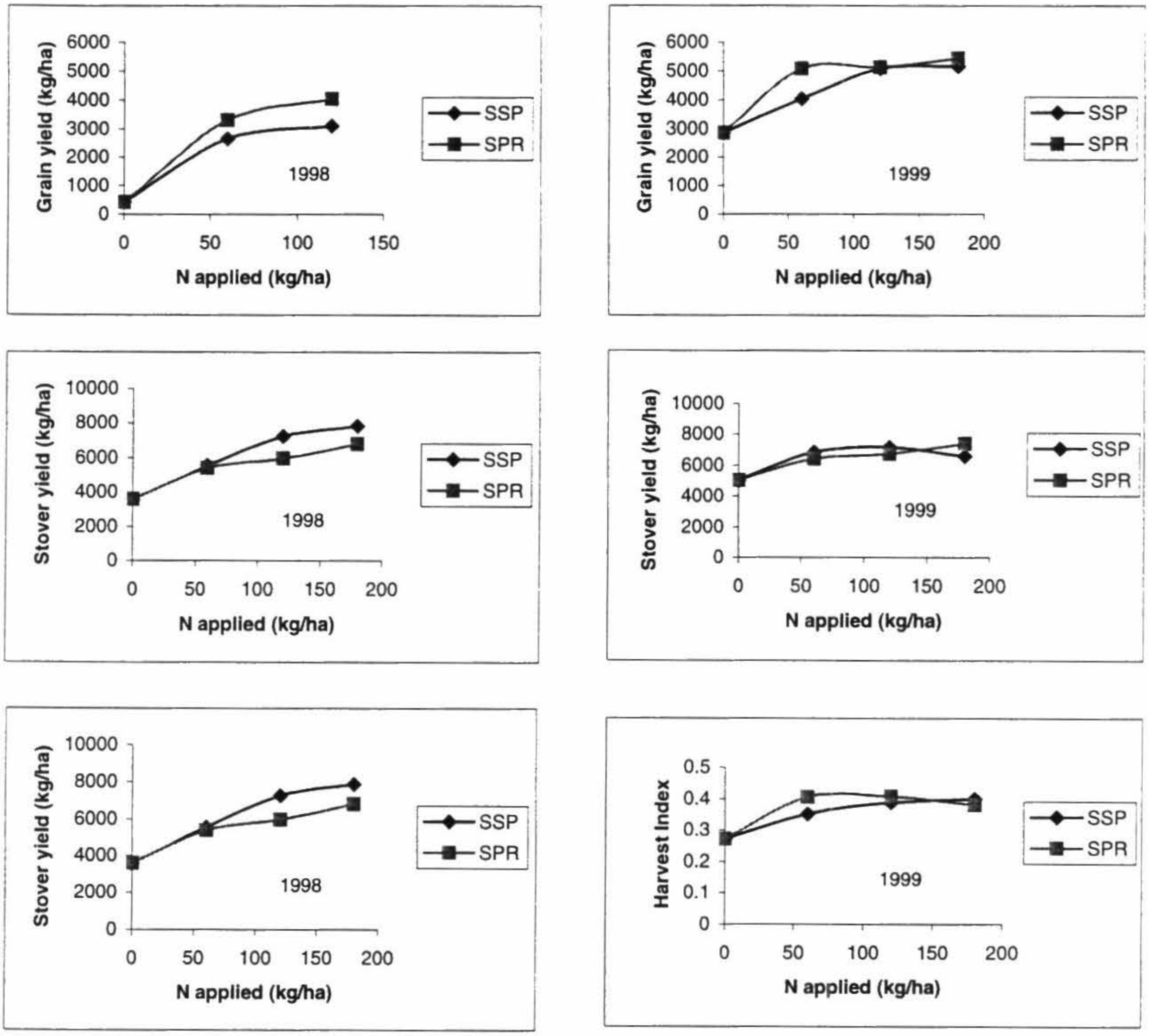


Figure 4. Maize response to N application with Sokoto phosphate rock (SPR) and single superphosphate (SSP) at Zaria for sole maize system. The SPR rate is 3 times that of SSP.

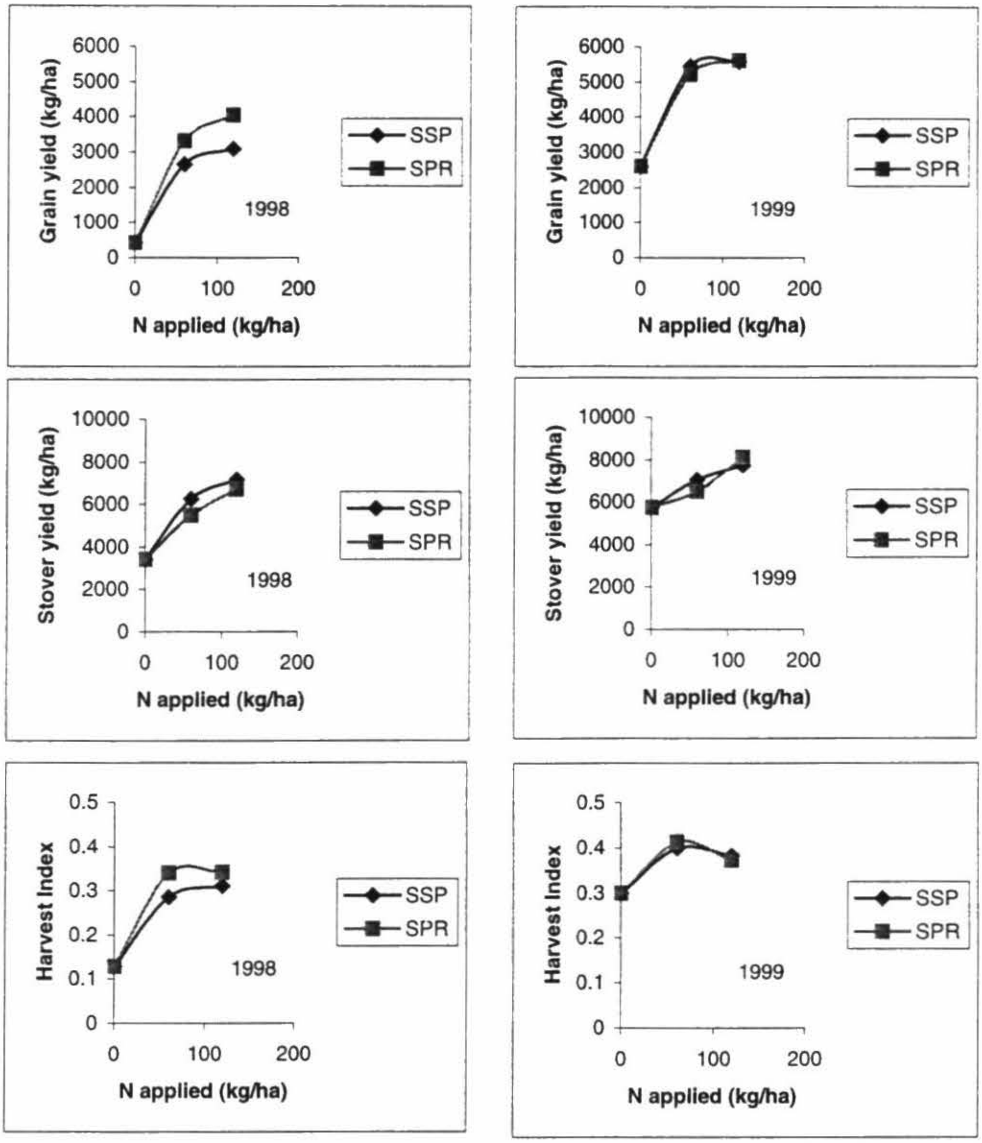


Figure 5. Maize response to N application with Sokoto phosphate rock (SPR) and single superphosphate (SSP) Zaria for a maize-cowpea system. The SPR rate is 3 times that of SSP. (Maize-Cowpea intercrop)

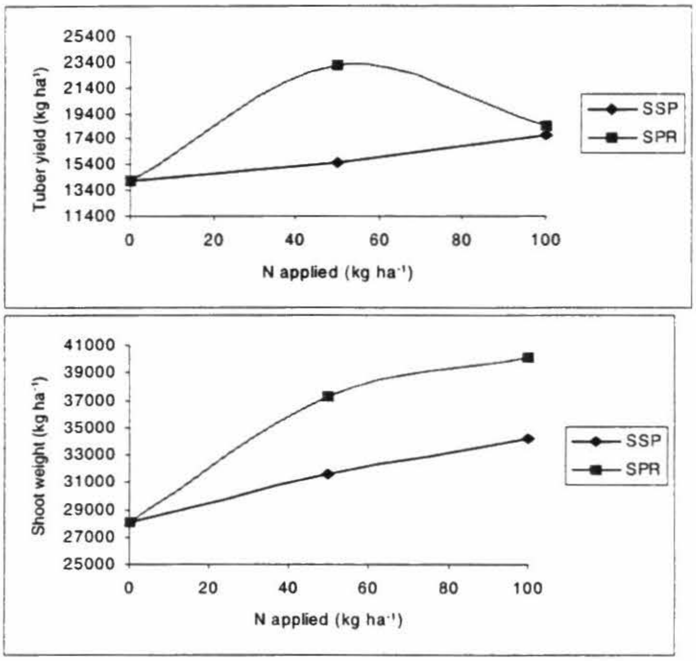


Figure 6. Cassava response to N application with Sokoto phosphate rock (SPR) and single superphosphate (SSP) at Zaria. The SPR rate is 3 times that of SSP.

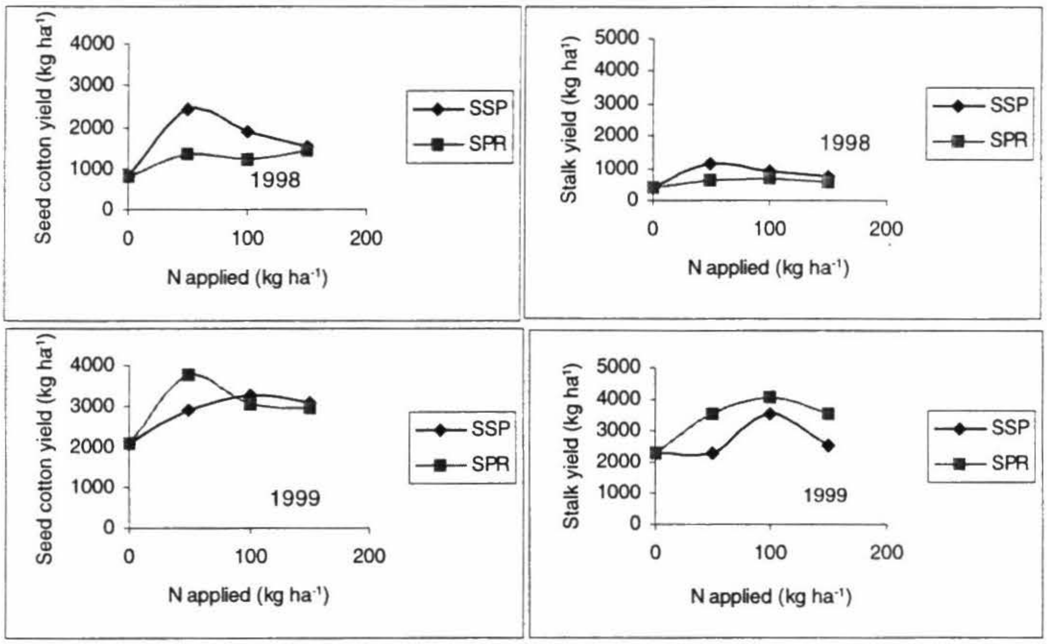


Figure 7. Cotton response to N application with Sokoto phosphate rock (SPR) and single superphosphate (SSP) at Zaria. The SPR rate is 3 times that of SSP.

Minimum data sets

The field trial exposed participating NARS scientists to practical experiences in carrying out systems-based inter - and cross-disciplinary research. Collection of full minimum data sets according to IBSNAT (1988) requires personal commitment and dedication. The task is enormous but achievable.

Model validation

To validate CERES-Maize in this study, the model was run using the same soil, weather, and management conditions as they relate to varying nitrogen fertilizer rates and only the high rate of P at 60 kg P_2O_5 ha^{-1} as SSP. A high P rate was chosen because the P submodel has not yet been fully developed for tropical conditions. Simulated outputs were then compared with the observed results.

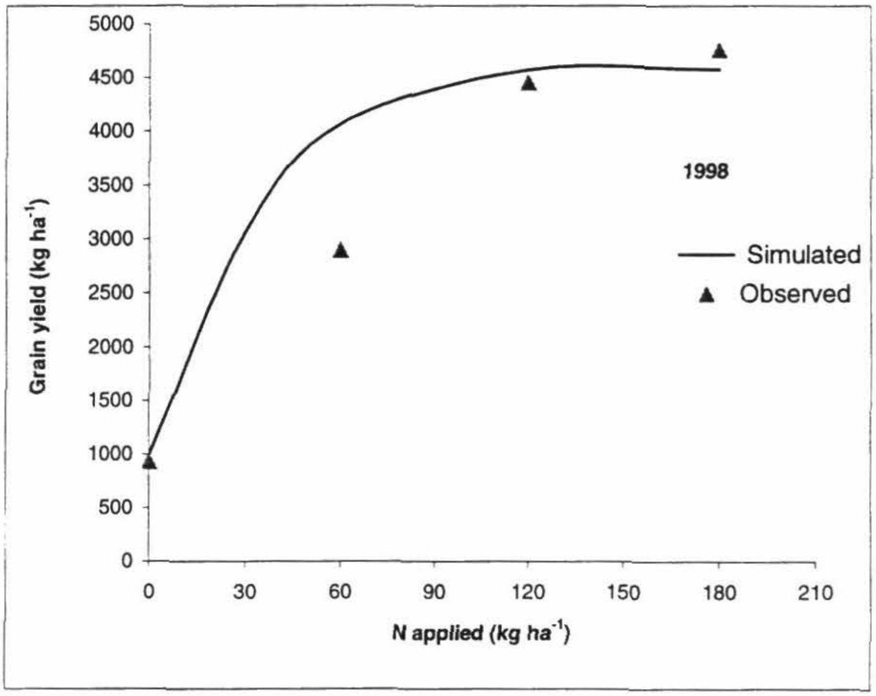
The model's performance for the various nitrogen rates (Fig. 8) shows that it generally over-predicted yields at all rates of N except at 180 kg N ha-1 in 1998, and in 1999 the over-prediction applied to all rates except the control. The lower observed maize grain yields might be attributed to the presence of unaccountable factors such as weeds, termites and deficiencies of nutrients other than nitrogen. It was however able to capture the build-up in soil fertility (residue incorporation and applied fertilizers) with a resultant increase in crop yields from 1998 to 1999.

Simulated yields were regressed linearly on observed yields; the regression accounted for approximately 84% of the variance in simulated grain yield (Fig 9). If the model were a perfect predictor, and if there were no measurement error, then all treatment data points would rest on the 1:1 diagonal line. The wide deviation of data points around the 1:1 line arises as a result of model and measurement errors. It is important to emphasise the fact that whereas the fertilizer treatments consisted of nitrogen and phosphorus, only the nitrogen sub-model was available for the simulation exercise.

The field experiments for the validation of models will run one more season for sole maize, maize-cowpea and cotton systems while the cassava trial will be concluded in 2002. It is envisaged that as more quality data are generated from the maize trial and used to improve the CERES-maize model, the gap between simulated and observed yields will narrow. The cassava and cotton models will also be tested for reliability at the end of data collection and analysis.

Contributors:

Victor Chude, Ishaki Y. Amapu – IAR, Zaria, Nigeria
Kouessi Aihou, Mustapha Adomou – INRAB, Benin
Upendra Singh, Pierre Dejean - IFDC



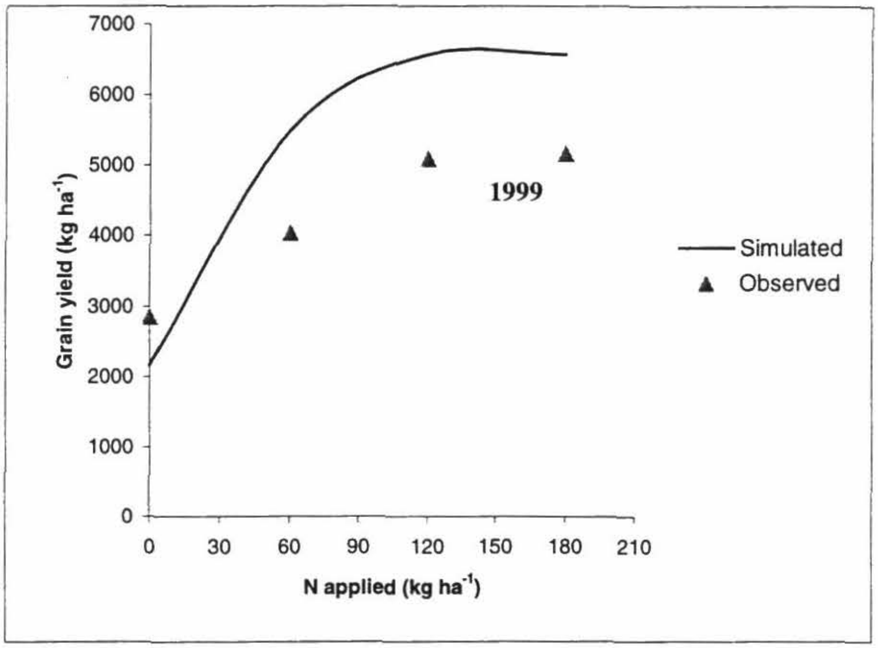


Figure 8. Comparison of observed and simulated grain yield over a range of nitrogen rates and at 60 kg P_2O_5 ha^{-1} as SSP.

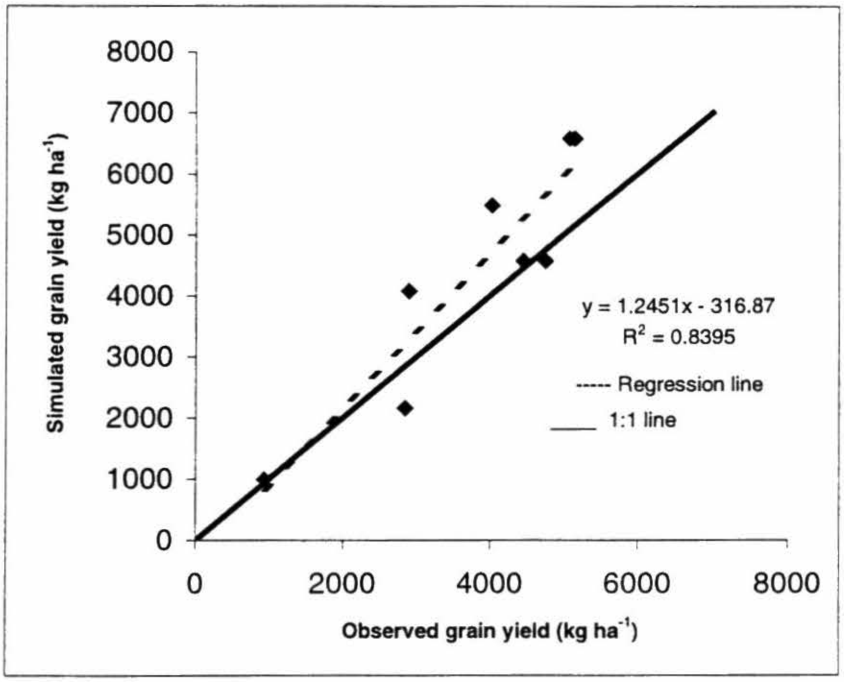


Figure 9. Comparison of observed and simulated maize grain yields at Zaria, northern Guinea Savanna, Nigeria

Activity 2.2 Comparative evaluation of water and nutrient constraints to crop production (yield gap analysis) and recommendations for improvements including closer matching of options to constraints (CNDC/OSWU). Additional support from the Ecoregional Fund and SWNM-BMZ Project.

- Work plan prepared
- Ex-ante analysis conducted
- Field trials established in Togo and Benin

A work plan for a West African transect-study - an interconsortia undertaking by CNDC and OSWU on "Contributing towards Utilization of Resources Effectively (CURE) in SSA" was prepared. The activity combines the serious problem of soil nutrient depletion with water availability/shortage in West Africa. It provides a framework for cooperative work between CNDC and OSWU partners and provides added value to the nutrient and water research undertaken by the SWNM Program.

Both CNDC and OSWU face similar problem – getting more production per unit of nutrient and water applied. This task becomes more challenging given both the low nutrient-holding capacity and low water-holding capacity of most soils. The combined transect study ensures that water, nutrient and their interactions are evaluated. The focus of the transect study is to achieve greater understanding and impact from present CNDC and OSWU research, and if necessary then initiate new research jointly. The yield-gap analyses will be conducted at various levels: (i) the yield-gap between potential production (non-limiting) and rainfed potential production would be used to identify the importance of water limitation and the possible management strategies would be selecting for appropriate planting date, varieties, irrigation, etc., (ii) the yield-gap between rainfed potential and nutrient-limited production would help identify the type and intensity of nutrient management intervention; and (iv) comparison of any the above yields with the actual yields at research stations and farmers fields may indicate the nature of constraints, effectiveness/ineffectiveness of technology transfer and/or adoption, and the need for socioeconomic input. The utility of this approach is not limited to interpretation and interpolations within transect but also extrapolations to other potential sites. The crucial question is that when we conduct trials whether at research stations or farmers' fields do we know the yield potential of the crop (genotype)? If not, then how are we recommending appropriate management practices? What are the key constraints – water, nutrients, pests and diseases, economics, socio-cultural? It is goal of the proposed transect study to take up the above issues and provide alternative management options to the farmers.

The proposed project will also take advantage of the expertise and on-going projects of IFDC and ICRISAT in the region. Many of the chosen transect sites are benchmark or pilot sites of the Ecoregional Program for the Humid and Subhumid Tropics of Sub-Saharan Africa (EPHTA). Thus the proposed work will benefit from some agroecological and socioeconomic data that have been generated by EPHTA, and in return complement the ongoing EPHTA and IITA work in the region. The proposed activity to its utmost extent will utilize the existing soil, climate, and crop databases, crop simulation models, and decision support systems. We hope that the transect study will provide the impetus and capture donor's interest for a full-fledged funding of the CURE Project.

The objectives of the proposed research is to fulfil the goals set under the SWNM Program, redress the issues on cooperation and integration raised by Rosswall Report, and attract donor-interest in integrated water and nutrient management for improved crop production and sustainable land management. The specific objectives are:

1. To establish a transect that quantifies water and nutrient deficiencies and also captures the effects of agroecological (soil, climate, crop) and socioeconomic factors on crop performance.
2. To identify the key causes of yield-gaps those exist for principal crops and prescribe alternative recommendations to overcome the yield-gap. Yield-gaps will be identified using (i) actual yield information; (ii) simulated yields under potential production system; (iii) simulated yields under rainfed production system; and (iv) simulated yields with water and nutrient limitations.
3. To quantify the synergistic effects of integrated water and nutrient management with respect to integrated use of organics and inorganics and thus develop management recommendations for improved use efficiencies of water, inorganic fertilizers, and organic amendments.
4. To develop management recommendations and methodologies for interconsortia and ecoregional applications.

Work Plan

The choice of field and "simulation" sites are based on the following criteria:

1. Have on-going trials/research under CNDC, OSWU, CNDC2 (SWNM-BMZ Project), COSTBox (Ecoregional Fund Project), and ICRISAT's Projects
2. Based on (1) these sites are characterized: soils, climate, crop, and socioeconomic data is (/would be) available
3. Represent a range of soil types, moisture gradient, different agroecological zones and socioeconomic conditions
4. Some sites where simulation studies were conducted in past e.g. Mali (Dutch Project) and Burkina Faso (USAID-FEWS) may be included as satellite sites for simulation studies with very limited or no field activity.

Pertinent information on some of the sites is presented in Table 6. An essential component of any research is thorough observation and data collection. Such efforts would facilitate (i) better understanding of the soil water and nutrient dynamics ; (ii) prediction and extrapolation of results across sites ; and (iii) transfer of technology at farm and village level with socioeconomic database. The transfer of technology and its adoption from research stations to farmers' fields are to large extent dictated by economics and sociocultural factors. The effect of such attributes are well known in qualitative terms but not well quantified. The proposed collation of both agroecological and socioeconomic data will narrow the information gap in combination with decision support tools.

Yield-Gap Analyses

Simulations for potential production, rainfed-potential production, and water and nutrient-limited will be done as an ex-ante analysis to identify possible yield constraints. The current status of production and technology-gap would be gauged from actual yield information. First information on the magnitude of the yield difference between non-limiting (non-stressed production) versus rainfed potential will be identified. Next management options to narrow this "gap" could be identified (e.g. planting dates, genotypes, soil constraints). By simulating crop production with both limiting water and nutrients the constraints due to nutrients could be estimated. Management options to improve water and nutrient use could be derived. Large yield-gap between simulated and actual at research station level could imply (i) effect of other constraints that were not taken into account by the model or the field researchers, thus forcing researchers/extensionists to match recommendations to constraints; and (ii) model is not suitable and its predictions should be used following validation of the model.

Table 6. Climatic characteristics and soil types at the trial sites.

	Benin	Nigeria	Togo	Niger	Mali	Burkina Faso	Ghana
Latitude (°)	6.7	11.1	10.3				
Longitude (°)	2.2	7.4	0.42				
Elevation (m)	105	686	110				
Length of growing period (days)	240	190	190				
Rainfall distribution	Bi-modal	Mono-modal	Mono-modal				
Mean growing period Temperature (°C)	26.9	25.0	27.6				
Mean annual precipitation (mm)	1137	956	1125				
Mean number of dry months (with less than 3 wet days/month)	3	5.2	5.0				
Mean ann. temp (°C)	27.0	24.5	27.9				
Mean mini.temp of coolest month (°C)	21.6	12.8	19.2				
Soil type	Oxisol	Ultisol	Alfisol				

As a tool to aid in decision making, the DSSAT model - CERES Maize - was used to determine the yield potential of two maize cultivars, TZB-SR (high-yielding hybrid, growth duration of 110-120 d) and DMR-ESR (improved composite, 95-100 d) at two sites in Benin, Parakou and Ina, using daily weather data for the last 10 years. These sites are about 70 km apart yet they have differences in rainfall distribution; hence, management recommendations may differ. Monthly plantings were scheduled for the first of the month; however, under water-limited simulation sowing within the next 30 days was allowed only as soon as the soil moisture content reached 40% -100% of the field capacity for the top 30-cm soil layer.

As evident from Figure 10, the optimum performance based on high grain yield (mean of 10 years) and low variance was obtained in general for May-August planting.

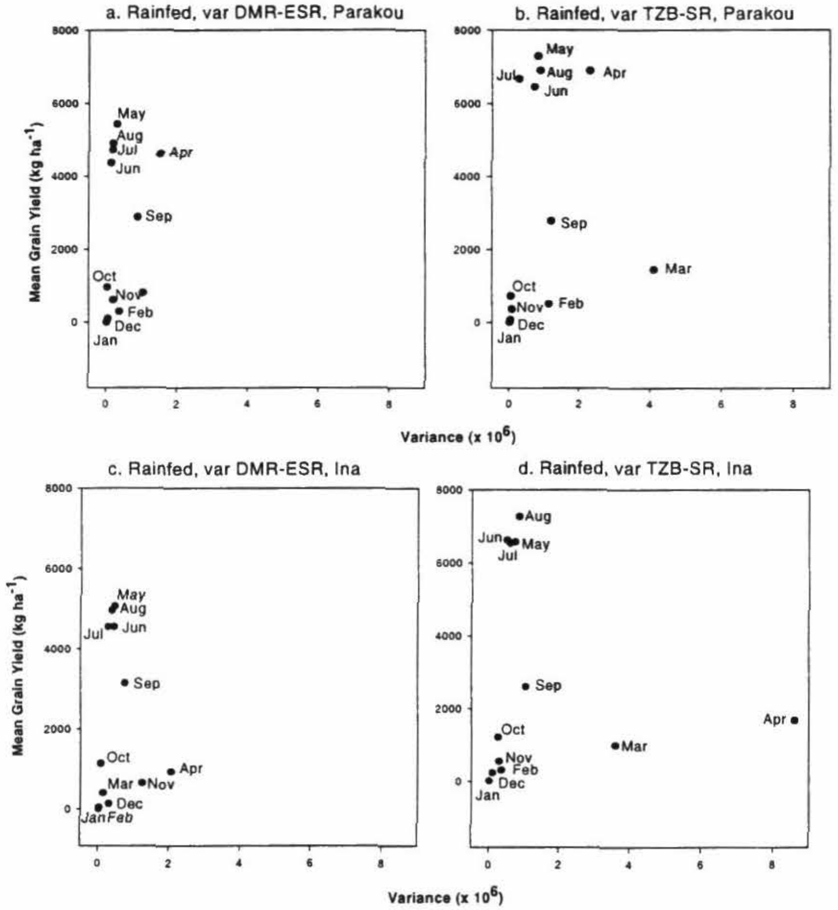


Figure 10. Mean-variance for rainfed potential yield at Parakou for maize cultivars (a) DMR-ESR and (b) TZB-SR, and at Ina for (c) DMR-ESR and (d) TZB-SR.

The choice of planting date was dictated by the maize genotype and the site. For example, April planting in Ina is highly risky independent of the varieties; however, the wider window of opportunity for planting at Parakou raises the possibility for double cropping (planting in April and August). The choice of genotypes will depend on a farmer's preference for high yield versus less risk. The yield potentials as dictated by the genotypes and the sites will thus drive nutrient management strategies.

In the above simulations we assumed nutrients were not yield limiting. A more typical West African situation is presented in Figure 11 where only partial nutrient requirement was met (25 kg N ha^{-1} and 10 kg P_2O5 ha^{-1}). For planting dates Between May-August, yields are not limited by water (rainfed potential yields without any nutrient limitations are near 100% of the potential yield). However, for the typical nutrient input scenario, the yields were less than 50% of the rainfed potential yield during May-August (Fig. 11). Under nutrient-limited conditions high-yielding hybrid maize achieved a lower grain yield than local/composite maize.

The examples presented are very simple applications of DSS, but such ex-ante analysis will be extremely useful because (1) the best rainfed planting times are identified, (2) for May-August planting, irrigation will not be necessary in most years, (3) grain yields are more limited by nutrient than water, and (4) nutrient recommendations will be dictated by the choice of genotype and site.

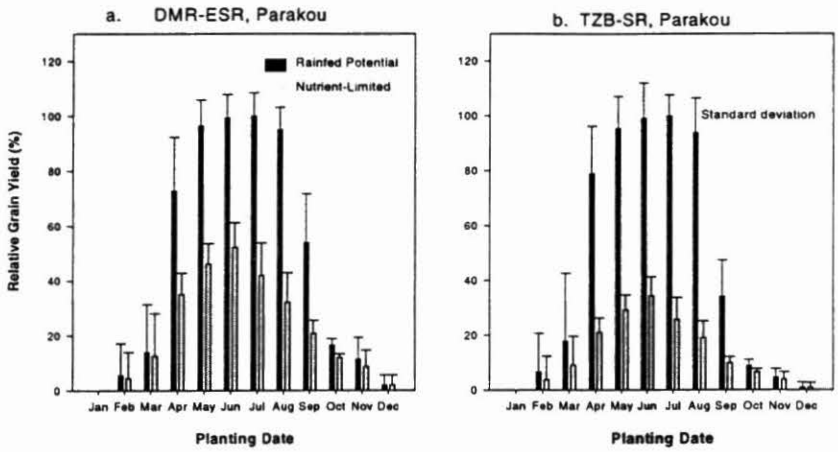


Figure 11. Relative grain yield (compared with potential yield without any limitation) for different planting dates under rainfed yield potential conditions and nutrient- limited low-input conditions with composite maize (a) DMR-ESR and (b) with hybrid TZB-SR at Parakou, Benin.

Integrated Water and Nutrient Management Trials

Ongoing and proposed CNDC and OSWU trials on research stations and on farmers' fields will be used to validate crop simulation models. A standardized data collection procedure will be used to allow testing of selected crop simulation models. The choice of the models will be dictated by the cropping systems, nature of constraints, and the accessibility of the model to NARES and ease of use of models.

A series of integrated water and nutrient management trials across the transect will help validate the models and test the proposed management options. The trials will capture the transect effects due to environmental conditions (and also socioeconomic conditions at limited sites).

Ideally the trials will include treatments of water and nutrients at each site. More important, however, will be the type of data collected from each trial; for example, data on rainfall, soil's water holding characteristics, rooting depth and/or soil water extraction, and nutrient uptake. Unfortunately, as the number of treatment increases so does the cost of collecting such detailed data. The detailed soil and plant data collection would be limited to selected treatments. Thus, CNDC and OSWU partners will be free to have some site-specific treatments in addition to a fixed number of (2-3) treatments with detailed data collection.

Constraints
Due to limited funds field trials have started at sites two in Benin- Ina and Sekou - using maize-maize and maize-peanut cropping systems, and in Tsagba, Togo with maize. Additional water and nutrients data are being collected from on-going trials at Zaria, Nigeria.

Contributors:
Andre Bationo, Tjark Bontkes, Pierre Dejean, Arno Maatman, Upendra Singh – IFDC
Agbo-Noameshie – ITRA, Togo
Mustapha Adomou – INRAB, Benin
Victor Chude, Ishaku Amapu – IAR, Zaria

Activity 2.3 Test alternative nutrient sources on-farm and evaluate DSS tools (CNDC/MIS)

- Continued participatory learning and action research in East Africa
- Coordination committee established to facilitate project activities
- Workshop on site selection and on participatory methods conducted
- Synthesis paper for testing alternative nutrient sources submitted
- DSS tool tested using primary and secondary data

CNDC is conducting on-farm trials in Uganda, Kenya, and Tanzania inconjuction with AHI activities in East Africa, and in West Africa in Togo and Benin through the BMZ funded project to the SWNM program entitled "Improving integrated nutrient management strategies in small scale farms in Africa". One major emphasis of this activity in the BMZ-funded project will allow a broader testing and dissemination of the decision support system.

In early 2000 a joint meeting between NARES, IARCs and farmers in Iganga District, Uganda linked farmers constraints and identified problems with technical management options for broader testing and comparing by the farmers. These options including organic and inorganic nutrient sources; legume cover crops; short term leguminous tree fallows and soil conservation practices. These options will be assessed according to farmers perceptions and criteria as well as conventional economic assessments. To achieve this 20 test farmers were chosen for detailed monitoring whilst a further 80 will evaluate the chosen technologies in a more qualitative way. A series of surveys have provided the baseline data that will be used for assessing impact.

At the western Kenya AHI benchmark site the SWNM project is assisting with farmer trials and evaluations of 5 soil fertility and soil conservation options, including four leguminous cover crops, three leguminous trees/shrubs; biomass transfer of high quality organic inputs; combined organic and inorganic nutrient sources; improved farmyard manure management; and fodder legumes for improved animal nutrition and manure. The trials are currently in the third season and have been evaluated jointly by farmers, researchers, and extensions groups. Four farmer field tours both with the community and with nearby communities have served for exchange of information and seed sources. In the coming year the trials will be assessed for their economic costs and benefits in addition to farmer perceptions and values of time, land and labour issues relative to agronomic benefits.

A summary of the farmers' assessments of the herbaceous and tree legumes for soil fertility follows.

Herbaceous Legume Cover Crops

The following criteria were generated during the discussions with farmers and later used to rank the three species in this LCC system:

1. Soil colour
2. Ease of establishment
3. Ease of germination (Viability potential)
4. Ease of weeding
5. Ability to control weeds
6. Amount of biomass production
7. Soil condition (Hardness)
8. Ease of cutting

Score sheet for legume cover crops species.

CRITERIA	REASONS	SCORE		
		Crotalaria ochroleuca	Mucuna pruriens	Canavalia ensiformis
Ease of establishment	seed size, more seed and more time	2	1	1
Ease of germination	seed viability and more time	1	3	2
Ease of weeding	dense ground surface coverage and difficulty in handling surface plant growth	1	3	2
Ability to control weeds	dense canopy formation with ability to suppress undergrowth	3	1	2
Amount of biomass production	number of leaves and size , ground surface coverage and shorter maturity period	3	1	2
Soil condition	Hardness	3	1	2
Ease of cutting and incorporation	difficulty in cutting leaves and stems	3	1	2
	RANK ORDER	3rd	1st	2nd

Thus the preferred legume cover crop was *Mucuna pruriens* followed by *Canavalia eniformis,* the least preferred was *Crotalaria ochroleuca.*

Farmers had a variety of views on issues relating to LCCs, some of which are summarised as follows:

Biomass production. This was considered to be best in Mucuna, followed by Canavalia. Crotalaria had a lot of leaf fall making biomass appear less, and those who observed this phenomenon considered that Crotalaria produced more biomass.

Pests and diseases. Caterpillars were a problem on Crotalaria pods. Ants eat Crotalaria but farmers were of the opinion that this may not necessarily be bad since ants recycle nutrients. There seemed to be a consensus that Crotalaria had more pests than Mucuna and Canavalia. No diseases were observed on the species.

Biomass incorporation. Farmers were eager to experiment on own generated labour saving methods of incorporating the green manures, e.g. uprooting and incorporating rather than cutting and chopping before incorporating.

Weed control. Mucuna and Canavalia species controlled weeds very well. Initially there were many weeds in the plots but after canopy formation most weeds were shaded off. Farmers felt that the species may control striga as well. Farmers felt that the species could control striga as well. Sesbania performed poorest in weed control due to its slow establishment. Some farmers were of the opinion that (i) Mucuna was best for weed control because of its creeping nature and good ground cover, and (ii) Mucuna biomass showed the best promise for improving fertility and moisture retention.

II: Improved Tree Fallow Species

The criteria developed by farmers for evaluation of improved tree fallow species were:
1. Ease of germination
2. Ease of establishment
3. Ability to control weeds
4. Soil colour
5. Amount of biomass production
6. Ease of cutting and Incorporation
7. Susceptibility to pest attack
8. Firewood quality

The best preferred species was *Crotalaria grahamiana* while *Sesbania sesban* was least preferred.

The farmers' general views on improved tree fallow species were as follows:

Labour demand. The farmers observed that (i) adoption of green manure could result in additional labour requirements which must be balanced by the additional benefits, (ii) planting Sesbania is more difficult because it must be drilled in furrows, and (iii) incorporation of Sesbania could be difficult due to the hard roots.

Germination and seedling vigour. Germination of seeds between farms was variable; germination of Tephrosia and *C. grahamiana* was easier than that of Sesbania, but that of *C. grahamiana* was poor on some farms.

Score sheet for improved tree fallow species.

CRITERIA	REASONS	SCORE		
		Tephrosia candida	Crotalaria grahamiana	Sesbania sesban
Ease of germination	Seed viability and more time	2	1	3
Ease of establishment	Seed size ,more seed and more time	1	1	2
Ability to control weeds	Dense canopy formation which suppresses undergrowth	2	1	3
Amount of biomass production	Number of leaves ,litter fall and surface ground coverage	2	1	3
Ease of cutting and incorporation	Difficulty in cutting leaves ,twigs and stems	3	2	1
Ease of root removal	Difficulty in removing tree stumps and roots	2	1	3
Ease of pests and disease attack	susceptibility to caterpillars attack to the seeds and pods	1	2	1
Firewood quality	fast burning and more smoke	1	3	2
	RANK ORDER	2nd	1st	3rd

Project Implementation in West Africa

The central theme of the project "Improving integrated nutrient management strategies in small scale farms in Africa" for West Africa is reversing soil depletion on small-scale rural farms through development of integrated soil fertility management (ISFM) technologies. The target areas are Central Region of Togo and Costal Region of Benin. Country meetings were organized with partners to explain the Log Frame of the project and to discuss institutional arrangement. All the potential partners in Togo (e.g. ITRA, ICAT, and DRAEP) and Benin (INRAB, CENAP) have realised the importance of the CNDC Project.

The choice of the two regions is evident from the site characteristics:
A. Central Region of Togo

- Inhibited by several ethnic groups –
    - the natives like the Kotokolis, the Tchambas, the Anas, the Koussountous, the Agnagas, the Adeles and the Kpessis
    - the migrants like the Kabyes, the Lossos, the Mobas, and the Peulh.
- Three types of soil in the Region-
    - class 'A' soils (of the best quality),
    - class 'B' soils (of medium quality) and

- class 'C' soils (of low quality). As a result of demographic pressures, these soils have reached an advanced stage of degradation.

- The Region has a tropical climate of the Sudano-Guinean type. The mean rainfall is 1200 mm per annum. The region is subdivided into 4 homogeneous zones (Tchamba, Blitta, Sokode, and Mô plain) with specific soil fertility problems.
- Many parts of the farming areas, especially those in which food crops are cultivated, are not easily accessible. This is true for the plain of Mô in the western part of Blitta. There are many small rural markets for food crops and cotton.
- *Tchamba zone* is the most productive zone. Cotton and food crops are grown over vast areas of land; mechanised farming is practised with power-driven machines and fertilisers are used on a large scale since the soils are very poor. Southward of this zone, are found new farmers who settle down with new farming practices on lands which, until 1990, belonged to the reserved Abdoulaye forest.
- *Blitta zone:* New lands are cleared. Extensive strategies/fertilisers are used. Output is quite low.
- A peculiar zone is the zone of ancient colonisation along the *Sokode- Soutouboua road* which has been very impoverished (as in Tchamba zone). There is considerable demographic pressure here. The farming system rotates around cotton. There is marked tendency towards the use of chemical fertilisers.
- *Mô plain:* This is a rich valley, which is hardly accessible beyond the mountain range.
- Potentials for agricultural production exist in the Central Region of Togo. Still some areas exist with large amount of uncultivated arable lands, for instance south Tchamba zone, Blitta zone and the Mô plain. In view of shifting cultivation practices and cropping systems based on no external inputs, there is the risk of rapid soil degradation.
- In some areas high population pressure has caused land degradation. This fact has led to high consumption of chemical fertilisers in recent years. This is the case in northern Tchamba and along the Sokode-Soutouboua trunk road. It is in the northern Tchamba zone that GTZ has carried out most of its activities. In this region, there are large farms, considerable work done by farmers to remove stumps, and rapid land degradation due to intensive farming and the use of very advanced farming techniques.
- All the studies that have been done are documented and reports are kept at the institutions operating in the region. It has been decided to assemble these reports into documentation set for the project.
- There is a lack of control of the composition and quality of the fertilisers used (this can even become worse when one considers the possible effects of liberalisation, such as the emergence of parallel markets for low quality fertilisers).

Partner institutions that are active in soil fertility management in the Central Region of Togo are ITRA/ICRA-SH, ICAT, DRAEP and others (e,g, NGOs).

- ITRA is a national research institute. Among its activities in the region are two programmes, which fit into the project. The first programme concerns: "Natural resources management " with a "fertilisation" component. The second is based on "The cotton farming system," also with a "fertilisation" component.
- ICAT is an extension institute, which has recent experiences in improved fallow (e.g., the use of pigeon pea, *Cajanus Cajan).*
- DRAEP has the duty of conducting the policy of Togo's Central Region in the area of agriculture, animal husbandry and fisheries. Its programme entitled "Increasing cultivated acreage while protecting the environment" can fit into this project.
- There are other organisations in the region, which can fit into the project. This is, for example, the case of FDR (GTZ), which deals with credit, an activity that may be of relevance in intensification strategies.

- All the potential partners (e.g. ITRA, ICAT, and DRAEP) have realised the importance of the CNDC Project.

B. Costal Region of Benin

- The coastal Savannah area of Benin is highly populated by several ethnic groups. These groups are Fons, Minas, Gouns, Adjas, Hollis and Djèdjè. Their principal activity is agriculture. The Nago people are important in the region but their main activity is commerce.
- Four types of soils characterise the coastal Savannah. The *ferralitic soils* (called 'terre de barre') are the most dominant. The demographic pressure on these soils has led to their depletion and degradation. The *vertisoils* (heavy clay soils) have a high agricultural potentiality. The *hydromorphic soils* in valleys have a high agricultural potentiality but their exploitation presents inundation risks and crop failures. The sandy soils in the littoral have a poor water holding capacity. The natural vegetation in this area consists of coconut and cashew trees.
- Climate is soudano-guinean, which consists of two rainy seasons and two dry seasons. The average rainfall ranges between 1000 – 1200 mm.
- Most of the villages can be reached at different periods of a year. The most important urban centres are in the Coastal Savannah zone, and there are many small market places for marketing agricultural products.

Three zones can be distinguished in the Coastal Savannah region of Benin according to the nature of the soils and the related soil fertility problems.

- ***The littoral sandy zone***. The average density of the population is 180 inhabitants/km^2. The main food-crops are maize, cowpea, and cassava. Floodplains are fertile in this zone while very poor sandy soils are the most dominant. Coconut and oilpalm trees play a crucial role in the rural economy of this region.
- ***The soudano-guinean zone on the 'vertisols'*** is located in the downstream of plateaux. Farmers cultivate maize, cowpea, and sugarcane in this zone. The soils are naturally fertile. The average density of the population is 35 inhabitants/km^2 of land that can be cultivated.
- ***The soudano-guinean zone on the 'Terre de barre'***. The average rainfall ranges between 1000 – 1400 mm. The principal crops are maize, bean, cassava and groundnut. Oilpalm trees play a crucial role in the rural economy of this region. The average density of the population is between 200 and 300 inhabitants/km^2. The two sites of the Fertilisers & Sustainable Agricultural Development (F&SAD) project, which is funded by the International Fertiliser Industry Association (IFA), are located in this region. One site (Banigbé) is located at the Eastern part, and the second (Akimè) at the Western part.
- The soudano-guinean zone on the '*Terre de barre*', where the two site the F&SAD project are located, is seriously degraded due to the destruction of the vegetation cover and the overexploitation of land. High population pressure is one of the most important causes of soil depletion.
- Ridging is a common practice in the eastern part of this region; oilpalm, cassava and groundnut provide 'cash' revenue. In the western part, minimum tillage is the common practice, cotton, cowpea and groundnut provide also 'cash' revenue. Yields are very low in this region. Fertilisers are progressively used but still in very small quantities to produce food-crops and cash crops.

Partner institutions that are active in soil fertility management in the zone soudano-guinean on the '*Terre de barre*' are the INRAB/CENAP, INRAB/RAMR and the CARDER.

- The Centre National d'Agro-Pédologie (CENAP) is the soil research centre of the national agriculture research institute of Benin (INRAB). The CENAP develops a programme on soil fertility management in Benin, which takes into account three areas: (1) the management of organic matter, (2) the recapitalisation of soils by using phosphate rocks of Togo, and (3) mineral fertilisation.

- The RAMR is the research-development unit of the national agriculture research institute of Benin (INRAB). This unit works on soil fertilisation. Their activities are based on Farming Systems Research/Extension.
- The Centre d'Action Régionale pour le Développement (CARDER) is in charge of rural extension and organisation of farmers. The CARDERs are the national and governmental extension organisation the region level.
- These potential partners' institutions in Benin have realised the importance of the CNDC2 project, which deals with major concerns.

A coordination committee has been set up to facilitate the implementation of the activities. Committee comprises of the following government institutions in the region: Regional Directorate of the Ministry of Agriculture (DRAEP), the Directorate of Extension Organization (ICAT) and the Regional Agricultural Research Center (ITRA/CRASH). The agreed project activities based on planning meetings with the partners are:

Objective 1: ISFM strategies identified and adapted to various circumstances using systematic learning with stakeholders

Activities-

1.1) Develop assumptions to guide sites selection.
1.2) Select the sites and identify stakeholders on the basis of potential pilot sites and in consideration of the primary linkages between stakeholders and the differences between farmers, both male and female, in terms of resources, gender, etc.
1.3) Develop an operational strategy for work between farmers and partners.
1.4) Characterise and diagnose ISFM problems, identify opportunities and the feasibility of ISFM options, choose the farms/pilot plots jointly with the farmers and the communities.
1.5) Prepare inventory of farmer and researcher ISFM strategies.
1.6) Develop tools and decision guides through the ISFM experiments conducted by farmers and researchers.
1.7) Increase the knowledge and capacities of farmers to enable them participate in the research on ISFM, including the principles of soil nutrient exchange.
1.8) Train farmers to participate in the identification of appropriate research themes and increase their aptitude for innovation.
1.9) Stimulate the exchange of information and experience through study trips by farmers.
1.10) Synthesise results, draw out lessons and generalise.

Objective 2: Strategies, methods and information about ISFM extension are disseminated to various stakeholders

Activities-

2.1) Develop extension strategies within the regions on the basis of farmers learning systems.
2.2) Develop tools and guides for use by farmers and extension workers to facilitate the dissemination of information.
2.3)Extend ISFM materials to stakeholders, including schools, if need be.
2.4) Check and find out the impact of ISFM messages (information, guides,).

Objective 3: The abilities of researchers and extension workers developed in order to facilitate farmers' initiatives

Activities-

3.1) Organise study trips to enhance the acceptance of new ideas by researchers and extension workers.
3.2) Sensitise and train researchers and extension workers in participatory research.

3.3) Train the basic supervisory staff in the principles of ISFM and in participatory methods.

Objective 4: Partnership enhanced through project coordination and management
The fourth objective relates to project control and evaluation procedures. A steering committee will be set up to undertake most of the activities. Decisions on the budget, project coordination and communication will also be taken principally by the steering committee.
Activities-
4.1) Form the project steering committee jointly with partner institutions.
4.2) Choose the coordination site.
4.3) Hold project annual meetings.
4.4) Develop a monitoring and evaluation plan for the project.
4.5) Prepare and distribute reports and publications.
4.6) Set up an address database for communications between participants.
4.7) Define a strategy for the exchange of data.
4.8) Monitoring and evaluation.

Characterization of zone and site selections in the Central Region of Togo has been completed. Three village-sites were selected based participatory inputs of the participants in the workshop. A training of workers in participatory methods for action-research in soil fertility management was also completed for the Sokode area. Immediately after the practical training a participatory diagnosis was conducted.

Constraints
Much of the activities in Central Togo were carried out using IFDC funds due to delay in donor funds. Full project activities in Benin will commence from next year.

Contributors:
Arno Maatman, Constant Dangbegnon – IFDC
CARDER, CRA-SH, DRAEP, ICAT, ITRA – Togo
CENAP, INRAB – Benin

Use and testing of the Organic Resource Database

TSBF have had accepted a synthesis paper - Organic Inputs for Soil Fertility Management in Tropical Agroecosystems: Application of an Organic Resource Database, resulting from analysis of the data within the ORD and our continuing work in the AHI benchmark sites. The synthesis adds more understanding to the critical levels of some of the factors influencing nutrient release and organic matter management and this new information will be incorporated into the decision support system development.

Some examples of the synthesis resulting from analysis of the data in the Organic Resource Database are given here. Box-and-whisker diagrams can be used to highlight differences in quality between different organic resources. Box-and-whisker diagrams indicate the median value of all samples in a particular category, the range in 50% of the data around that median (i.e. 35-50% and 50-75% quartiles) and the range in all the data. Using this approach to compare different organic resources shows that manure, crop residues, leaf litter, stems and roots all have a median value of less than 2%N (Fig. 12).

resource is the number of entries used in the analysis, i.e., there were 154 entries in the ORD for manures used in the box-and–whisker analysis. In contrast, leaves have a median value of 3.3% and have a wide range of values from less than 1% to over 5%. A comparison of fresh leaves from some plant families indicates that N concentrations less than 3% are found in the Euphorbiaceae, Gramineae, Myrtaceae and the Verbenaceae compared to greater than 3% in the Asteraceae and the Leguminosae (Fig. 13).

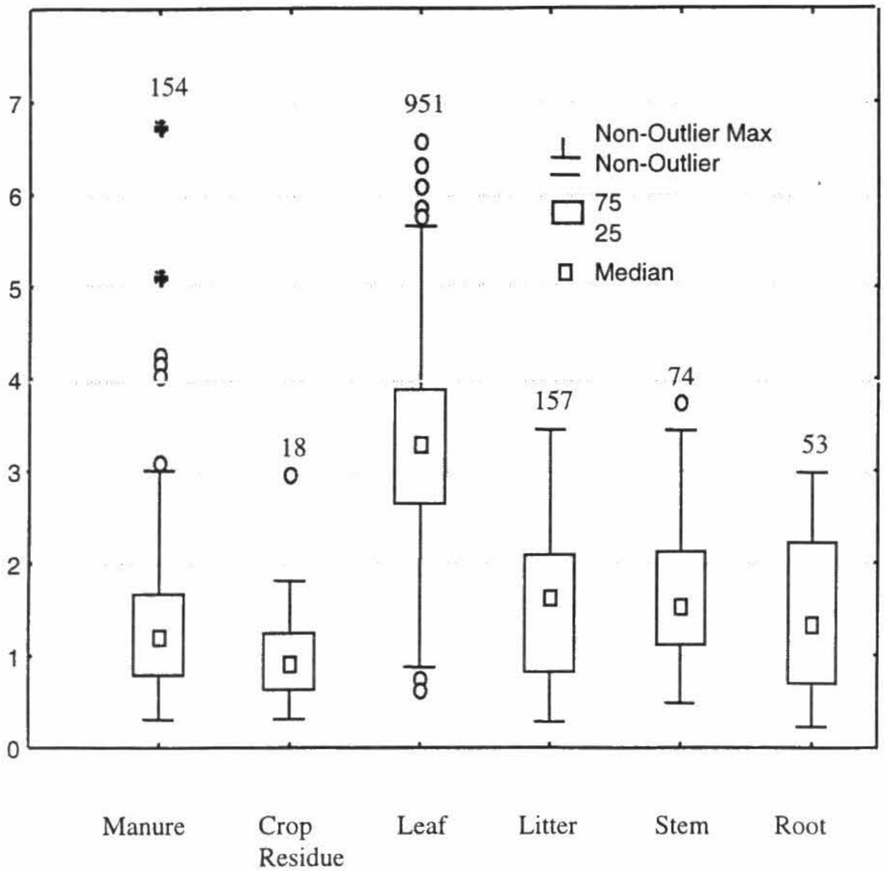


Fig. 12. N concentration (%) in different organic resources

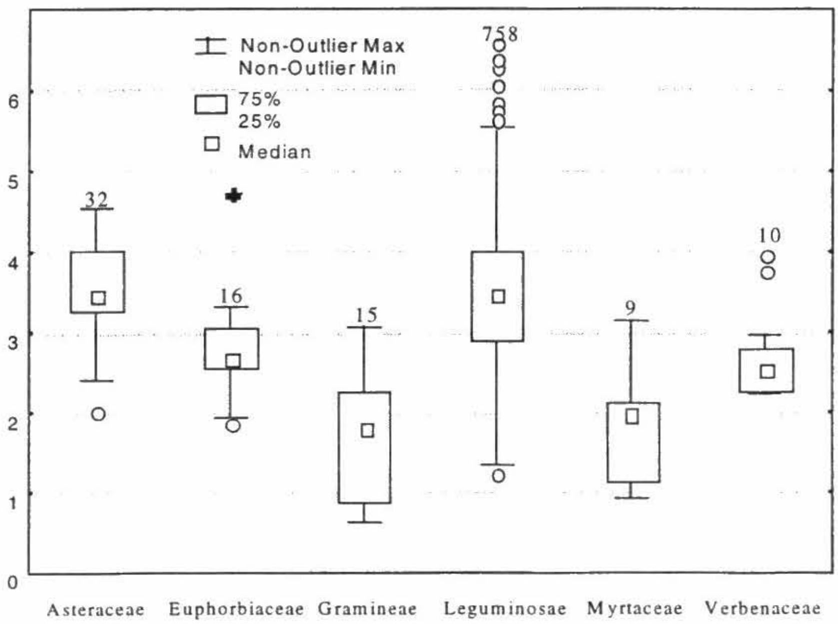


Fig. 13. N concentration (%) in leaves of different plant species

Note, that the number above each organic Another example is the use of the Organic Resource Database in estimating nutrient stocks, flows, and budgets: Nutrient flows and budgets are increasingly being used to diagnosis causes of nutrient depletion or excesses and to devise alternative nutrient management strategies to alleviate these problems. The standing stock of nutrients on farm, whether in the soil, vegetation, or storage facilities characterizes the nutrient resource capital of the farm and coupled with nutrient balances or flows could provide an index or measure of productivity or sustainability. The information needed to determine nutrient flows, budgets, and stocks are data intensive and expensive to collect. Nutrient data in ORD coupled with information on the stocks and flows of specific organic materials can be used to estimate the quantity of nutrients or make relative comparisons of those stocks and flows, thus reducing the amount of new data needed and cost for these analyses. Whereas the nutrient contents of the major crops and their components and animal manures is known and used for estimating nutrient budgets. ORD contains nutrient data on other farming system components, such as cover crops and agroforestry trees and shrubs that are important to nutrient management in many tropical agroecosystems.

As an example, nutrient data in ORD was coupled with information on the species composition and biomass of hedges in small holder farms in Western Kenya to estimate nutrient stocks and identify potential nutrient sources for soil fertility management. Hedges define arm boundaries in Western Kenya and elsewhere in East Africa, their use varies from livestock exclusion to fuelwood sources. Though they are pruned two to three times a year the prunings are used by few for soil fertility management. The species composition and biomass has been estimated for several hedge type categories in the area but not the nutrients contained in the hedges (Table 2). The nitrogen stock was estimated by using the weight of the hedges (kg m^{-2}), the proportion of the species in the hedges (61% *Tithonia diversifolia*, 24% *Lantana camara*, and 15% other species), the percent of leaves and stems of the different species, and the ORD nutrient contents for the species. The content of nitrogen in the hedge is 37.2 g N m^{-2}, over half of that is contained in the Lantana components of the hedge and one quarter in Tithonia. Forty percent of the N is contained in the leaves, the part that would be useful for soil fertility management through biomass transfer. Considering that the average width of the hedges is 2.1 m and that farms have an average of 275 m of hedges, the nitrogen stock in the hedges is 21.46 kg, with 8.65 kg in the leafy biomass. Though this does not seem like much N, the hedges can be pruned three times a year providing a total of 30 kg of N of leafy biomass, this is equivalent to 90 kg N ha^{-1} spread over 1/3 ha.

Table 7. Nitrogen stocks in vegetative hedges of farms in Western Kenya as calculated from biomass stocks (Lauriks et al., 1999; Nj'inga et al., 1997) and nutrient contents in ORD.

Hedge Species Composition[a]		Weight (kg m^{-2})	N (g kg^{-1})	N (g m^{-2})	Hedge N stock per farm[g] (kg)
Tithonia	Leaves[b]	0.20	28.4[d]	5.4	3.11
diversifolia	Stems[b]	1.78	8.0[e]	4.8	2.77
(61%)	Total[c]	1.98			
Lantana	Leaves[b]	0.19	37.2[d]	7.4	4.28
camara	Stems[b]	0.59	8.0[e]	14.2	8.19
(24%)	Total[c]	0.78			
Others	Leaves[b]	0.09	25.5[f]	2.2	1.26
(15%)	Stems[b]	0.40	8.0[e]	3.2	1.84
	Total[c]	0.49			
TOTAL		3.25		37.2	21.46

[a] = Lauriks et al 1999

[b] = Percentage leaves stems – Nj'inga et al 1997

[c] = Estimated from Lauriks et al (1999), 10.82 kg m^{-2} fresh weight, assuming 30% dry matter
[d] = ORD
[e] = Jama et al (in press) assuming woody tissue similar N
[f] = ORD average N of all non legume leaves
[g] = from Nj'inga et al (1997), 275 m of hedge per farm, average hedge width 2.1m

Contributors:
Cheryl Palm and Catherine Gachengo – TSBF
Robert Delve – TSBF/CIAT
Georg Cadisch – Imperial at Wye, University of London
Ken Giller – University of Zimbabwe

Output 3: Impacts of improved practices on production, the environment and socioeconomic conditions assessed

Output 4: Improved information communication exchange framework established and materials produced for stakeholders

Output 5: Stakeholders capacity for better SWNM enhanced

Activity 5.1 Training of NARES staff on SWNM technologies and use of DSS. Additional support from Ecoregional Funds.

- NARES capacity building on field minimum data set collection
- Training, evaluation, and standardization of laboratory procedures for soil and plant nutrient analyses
- Training on use of DSS for scientists and extensionists.

NARES partners continued to receive training on field data collection for process-oriented field trials. The quality of laboratory data and laboratory procedures were focus of small group training with NARES partners. Laboratory procedures were standardized and standard samples were analysed at 3 NARES laboratories and IFDC. Due to discrepancies in some analyses the need for standardization and quality control will be one of the major focus of the Ecoregional Funds study in West Africa in 2001.

Training and confidence-building in the principles of systems oriented research was achieved by simplified presentation of relationships in the models and the emphasis on the use of simulation models as one of many tools available for analyses and extrapolation of field results. A four-day workshop was organized in July for people from the research institute (ITRA), extension (ICAT) and IFDC; in total 16 people. The program was as follows:
- introduction about modeling and the COSTBOX project
- group discussion to identify elements that play a role in crop production - explanation and exercises of QUEFTS
- strong and weak points of QUEFTS using the results of the group discussion
- explanation and exercises of DSSAT
- strong and weak points of DSSAT using the results of the group discussion
- identification of present research activities that could benefit from QUEFTS or DSSAT
- application of QUEFTS and DSSAT to these activities
- groups discussion on how to integrate models in the research and extension organisations.

The participants were quite enthusiast about the workshop and came up with interesting suggestions as to how to proceed. A course manual and also a report on the workshop (in French). A unit is being created with ITRA that takes care of the models and the database. This could be the task of the Division of Biometrics, Informatics and Statistics. This unit would assist researchers and others in applying DSS in SWNM.

Contributors:
Tjark Bontkes, Pierre Dejean, Upendra Singh - IFDC

Activity 5.2 Farmer field schools for SWNM technologies

- 11 farmer exchange visits held
- 5 training events on N management and species selection
- More than 250 farmers in eastern Uganda and western Kenya testing legume cover crops, Tithonia for N management, and improved farmyard manure management
- Development of a training manual on participatory methods for Indicators of Soil Quality
- Training of partners in participatory method

The TSBF experiments highlighted in Activity 1.2 are demonstration sites as well as researcher designed/farmer managed experiments. These sites were used throughout 2000 for farmer exchange visits for other farmer groups from Uganda and Kenya to see the work and expose them to the new technologies. These exchange visits were organized and run by the local extension service and NGO's. In addition, activities reported under the BMZ project in Activity 2.2 will provide further exchange visits for farmers and front-line staff. In both projects farmer trainers have been recruited and are being trained.

Contributors:
Robert Delve – TSBF/CIAT
John Mukalama - TSBF
John Ojiem - KARI
Bashir Jama and Tom Ochinga – ICRAF-Kenya
Africa2000 Network – Uganda
National Agricultural Research Organization - Uganda
Makerere University, Kampala, Uganda

CIAT and TSBF held a training workshop in Uganda March 17-April 2, 2000, together with the Systemwide Participatory Research and Gender Analysis Program and the African Highlands Initiative. The general objectives of this workshop were to 1) evaluate the research process and training strategy offered by CIAT and 2) to evaluate the feasibility to adapt, expand and use the training guides developed by CIAT and specifically that relating to soil quality indicators. Participants enthusiastically received the concept of the training guides and associated "soils fair". Following this training workshop it was decided to produce a similar training guide for Eastern Africa. In addition, a similar training guide on the use of the organic matter decision tree is being prepared with the active collaboration of scientists from NARES in East Africa and this will be developed further during the meeting in Tanzania in October.

Contributors:

Edmundo Barrios and Vicente Zapata – CIAT
Robert Delve – TSBF/CIAT

Anthony Esilaba – CIAT-Africa
John Ojiem, Jean Louis Rakotomanana, Jeremiah Mowo and Taye Bakele – AHI
Joseph Ogunda – CARE-Kenya
Mateete Bekunda – Makerere University/AHI

IFDC organized a training program in participatory methods for partners working on "Improving Integrated Nutrient Management Strategies on Small Scale Farms in Africa" from Central Region of Togo. The focus was on the development of the capacities of researchers and extension workers to stimulate farmers' initiative. The success of this objective will depend on the skill of researchers and extension workers in adopting different research methods with farmers. The idea was to develop interactive participation among stakeholders.

Contributors:
Arno Maatman, Constant Dangbenon – IFDC
ICAT, ITRA, CARDER, CRA-SH, DRAEP – Togo

Output 6: Efficient program management, communication, monitoring and evaluation

4. Publications:

Chien, S.H., U. Singh, H. van Reuler, and D.T. Hellums. 1999. Phosphate rock decision support systems for sub-Saharan Africa. African Fertilizer Market 12(12):15-22.

Chude, V.O; I.Y. Amapu, U.Singh, H. Breman, and P.Dejean. Validation of the Decision Support System for Agrotechnology Transfer (DSSAT) software in the Northern Guinea benchmark area of EPHTA. Paper accepted for the international symposium 'Balanced nutrient management systems for the moist savannas and humid forest zones of Africa', 9-12th October 2000, Cotonou, Benin.0

Delve, R. J., Gachengo, C., Palm, C.A., Cadisch, G., Giller, K.E. The Organic Resource Database: Organic inputs for tropical agro-ecosystems. Paper accepted for the international symposium 'Balanced nutrient management systems for the moist savannas and humid forest zones of Africa', 9-12th October 2000, Cotonou, Benin

Murwira H K, Mutuo P, Jama B, Marandu A E, Mwale M, Nhamo N, Rabeson R, Snapp S, and Palm C. Fertilizer Equivalency of Organic Materials of Differing Quality. Paper accepted for the international symposium 'Balanced nutrient management systems for the moist savannas and humid forest zones of Africa', 9-12th October 2000, Cotonou, Benin.

Palm, C. A., Gachengo, C., Delve, R. J., Cadisch, G. and Giller, K. E. Organic Inputs for Soil Fertility Management in Tropical Agroecosystems: Application of an Organic Resource Database. In press Agricultural Ecosystems and Environment

Singh, U and P. Wilkens. 2000. Simulating nutrient stress effects on phonological development in maize. Pages 11-17. In: White, J.W. and P.R. Grace (eds) Modeling extremes of wheat and maize crop performance in the tropics. CIMMYT, Mexico.

U. Singh, J. Diels, J. Henao, and H. Breman. In press. Using Decision Support System for Adoption of Integrated Nutrient Management Techniques in Combating Nutrient Depletion. Proceedings of IITA Symposium, 5-9 November, 2000, American Society of Agronomy Meetings.

Individual publications by partners are under preparation for Journal publication. The network trial participants' publications will soon be published in a Special Edition of the African Crop Science Journal.

In addition several workshops were attended by TSBF staff in which the Organic Resource Database and the Decision Support System for Nitrogen were presented:

SWNM/TSBF Projects in Uganda: R. J. Delve, paper presented at the startup workshop for the DFID/UEA project Bridging research and development in soil fertility management – practical approaches and tools for local farmers and professionals in the Ugandan hillsides

IFAD funded results and planning workshop for TSBF/AFNET projects in Southern Africa: R. J. Delve and C. Gachengo, training session on the ORD

IFAD 2000 Meeting, Rome, Italy. H. Breman presented the phosphate rock decision tree.

Systemwide Livestock Program annual meeting: R. J. Delve, paper presented on the SWNM and the CND consortia

Sasakawa2000 tour of Uganda and Kenya: C. Palm and C. Gachengo demonstrated the Organic Resource Database and it used to the officers and country directors of Sasakawa2000 – several of them ordered copies of the database.

5. Staff list for 2000:

TSBF-
Cheryl Palm – Senior Scientific Officer
Robert Delve – Post-doc
John Mukalama – Research Assistant
Isaac Ekise – Research Assistant
John Obwego (Field assistant-Uganda)
John Baptiste Tumahirwe (MSc student-Uganda)
Matthew Kuule (MSc student-Uganda)
Michel Misiko – (MSc student – Kenya)
Ketray Okusi – MSc student – Kenya)

IFDC-
Upendra Singh – Senior Scientist (Soil Fertility Modeling)
Arno Maatman – Head, Input Accessibility Program
Tjark Bontkes – Coordinator, COST Box Project
Pierre Dejean – Specialist (Systems Modeling)
Costant Dangbenon – Scientist (Extension)
Norman Chien- Senior Scientist (Soil Chemistry)
Julio Henao – Senior Scientist (Biometrics)

Acronyms:
CARDER Centre d'Action Régionale pour le Développement Rural, Togo

CENAP	Centre National d'Agro-Pédologie, Benin
COSTBox	Client-Oriented Systems Tool Box (COST Box) for Technology Transfer Related to Soil Fertility Improvement and Sustainable Agriculture in West Africa Project.
CRA-SH	Centre de Recherche Agronomique –Savane Humide, Togo
DRAEP	Direction Régionale de l'Agriculture, de l'Elevage et de la Pêche, Togo
ISFM	Integrated Soil Fertility Management
ICAT	Institut de Conseil et d'Appui Technique, Togo
INRAB	Institut National des Recherches Agricoles du Bénin, Benin
ITRA	Institut Togolais de Recherche Agronomique, Togo

6. Donors:

ACIAR
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Theme 2. MIS - Manejo Integrado de Suelos (Integrated Soil Management Consortium)

1. Introduction and overview

The MIS consortium was created at a workshop in Honduras August 11-12, 1999 in order to focus efforts in the hillsides of Central America, a recognized hot spot for poverty and environmental degradation. This consortium now replaces the Managing Acid Soils consortium whose project in the Brazilian cerrados terminated in 1999 after 4 years of operation.

The MIS consortium met in Nicaragua in January 31-February 2, 2000 to develop its work program and logframe. This work was completed by an elected steering committee. The MIS logframe is presented as an Annex to this report.

Higlights of MIS activities:

- Operational Plan for the 200-2001 defined and approved by stakeholders.
- Exchange of information and systematization of experiences initiated.
- Collaborative activities with other SWNM consortiums identified.

Purpose:

Develop, adapt and disseminate improved options for the sustainable management of fragile soils in the Central American region

Rationale:

Hillsides comprise over 87% of the cultivated land in Honduras and over 40% in Nicaragua where ecological vulnerability to erosion, nutrient depletion and other degradative processes are high. In addition it is estimated that population of these areas will double in 35 years and that there are already 63 million has of degraded land in the region. Thus, there is an urgent need to stabilize the environment and increase productivity rapidly in order to meet the burgeoning demands.

Results:

Following a series of meetings with stakeholders including farmers, farmers organizations, NGO's . Ministries of agriculture and local universities it was decided to develop a inter-disciplinary and multi-institutional consortium to develop alternative management systems that contribute to the improvement of the quality of life of small scale producers. A second workshop was convened during Jan 31-Feb 2, 2000 to define the outputs and modus operandi of the consortium. The expected outputs include:

- Information on SWNM available for multiple stakeholders.
- Production systems efficient in the use of soil, water and nutrients.
- Technological innovations developed and disseminated with active participation of farmers.

These outputs were derived from an identification of common problems by stakeholders that included:

- Soil and soil organic matter losses.
- Water quality and availability constraints.
- Burning.
- Lack of knowledge of the role of biological processes and nutrient cycling.
- Inadequate use of fertilizers and lack of alternative sources.
- Limited use of alternative production systems/components.

- Lack of quantification of the biophysical and socioeconomic impact of traditional and improved land use practices.
- Inadequate policies on land use.

Agreed common sites for the consortium activity were the watershed of Rio Tascalapa and Lempira Sur in Honduras and Rio Calico and La Dalia in Nicaragua. The group elected a steering committee. It includes representatives from the NGO PRODESSA and The Universidad Nacional Agraria (UNA) both from Nicaragua, the National Program (DICTA) and the Escuela Panamerica el Zamorano both from Honduras with CIAT as the coordinator for CIAT.

The consortium recognizes that there already exists a large amount of information and practices on the integrated management of hillside soils but often this information is not readily available in adequate forms for the end user. Therefore we are collating this information and presenting it in easily understood formats using a variety of media. Better understanding of the driving forces behind land use is also required. For this reason we are characterizing constraints and potential use of fragile soils in the two countries. This work will identify opportunities and sites for technical interventions that are thoroughly ground in the socioeconomic and environmental context.

Participants of the consortium will develop a wider range of crop/tree and pasture options for use on fragile soils and will pay attention to soil and water quality, alternative sources of nutrients and integrated nutrient management practices including the management of soil processes. Four specific activities dealing with these issues have been included in the logic framework.

Emphasis will be given to the dissemination of new technological options via a focus on farmer-farmer exchanges and farmer experimentation. This will also include strengthening the research capacity of researchers and land users via decentralized training programs. A series of workshops have been planned for the present phase.

Inter-consortia collaboration in international agricultural research is a must for the SWNM. During the last meeting of the SWNM Program in Wageningen it was agreed that MIS will work with MSEC in the economic assessment of soil erosion and with CNDC on the validation and improvement of the decision tree for organic matter uses, testing of decision support tools for phosphorus amendments, crop/systems models and soil quality indicators.

Contributors: Miguel Angel Ayarza, Richard Thomas

Also reported here are the on-going collaborative activities previously reported under the MAS consortium on the development of decision support tools for the Colombian savannas, soil quality indicators and soil quality monitoring system, soil macrofauna and modelling. These are reported under the outputs and activities of the overall SWNM program logframe.

2. Highlights of progress in outputs of the SWNM logframe

Output 1

- Data from the long-term experiments on phosphorus cycling in the savannas have contributed to the development of an improved crop model (CERES) and have been made available to other groups via a multi-institutional collaborative project within the SWNM program.
- Testing of NuMaSS (nutrient management decision support system) decision support system using the data from field experiments indicated that in the Llanos of Colombia upland rice production is

considerably more profitable than either maize or cowpea given the yields obtained and the costs of fertilizer and the price of grain.

- Soil quality indicators have been identified for the savannas and hillsides agroecosystems have been incorporated into a guide that is being tested in Colombia, Central America and the East African Highlands.
- A preliminary version of a simple tool is available to farmers and those who assist them to diagnose the health of their soils and to establish their limitations for specific crops. The tool allows the storage of soil data for a series of georeferenced observation points that can be linked to a GIS and then analyzed with geostatistical or interpolation methods

Output 2

- A beneficial population of soil earthworms should consist of one or more epigeic species and one or more anecic species that construct vertical galleries, produce biogenic structures on the soil surface and mix plant residues with the mineral soil substrate.

Output 3

- A training course on the economic assessment of soil erosin and nutrioent depletion was held in Nicaragua in October 2000 with MSEC

Output 4

- The local soil quality indicator guide is available in Spanish and English and a version suitable for east African conditions is under preparation

Output 5

- Twelve field days were held in Pescador (January-September/2000), Cauca, Colombia with the participation of 276 visitors mainly farmers, extensionists and students from universities and schools; and one field day for Swedish Agricultural University (SLU) researchers was held in San Dionisio, Nicaragua.
- A methodological guide entitled "Indentifying and Classifying Local Indicators of Soil Quality. East African Version. Participatory Methods for Decision Making in Natural Resource Management." was prepared.
- A training course entitled: "Local Indicators of Soil Quality", was held in Mukono, Uganda and sponsored by the CIAT, SWNM and AHI.

Output 6

- A five-member steering committee was appointed for the MIS consortium with members from Nicaragua and Honduras
- The MIS consortium established its own webpage at www.mis@optinet.hn
- The MIS consortium has held two meetings during 2000.
- The first across consortia activity was the training event on economic costs of soil erosion and nutrient depletion held in October 2000.
- A joint post-doctoral fellow appointment with TSBf under the CNDC has entered its third and final year under the DFID-SWNM project.

3. Progress report on MIS activities reported under the SWNM logframe format

Output 1 Decision support tools for improved SWNm developed and evaluated in different agroecological zones.

Activity 1.3 Develop and test decision support tool for phosphorus amendments

1.3.1 Compile data bases to feed into simulation models and decision support systems

Highlight:

- Data from the long-term experiments on phosphorus cycling in the savannas have contributed to the development of an improved crop model (CERES) and have been made available to other groups via a multi-institutional collaborative project within the SWNM program.

Purpose:

To improve the phosphorus sub-model for the CERES and other simulation models, calibrate and test the new model

Rationale:

Crop simulation models are increasingly being widely used to estimate crop yields as affected by nutrients and water inputs as well as management practices and climatic conditions. A group of models, CERES for cereal simulation growth and CROPGRO for legume simulation, have been used successfully around the world for various purposes. A computer model for the simulation of phosphorus (P) in the soil and plant atmosphere has been developed and added to the two above crop simulation models to enhance their capabilities especially in tropical areas where P deficiencies are common. The models have been tested using data on maize, soybeans and upland rice grown under acidic tropical conditions in the Colombian savannas.

The phosphorus model

There are three inorganic and two organic P pools that are represented in the model (Fig.1). In addition, there are two pools that represent rapid and slow cycling plant residues as well as a fertilizer pool. The labile pool is the most dynamic pool, and a soil solution pool is defined as a fraction of the available labile pool. Crops take up P from the soil solution pool. The fraction of labile P in solution depends on the type of soil and can be changed in the soil chemical parameter file. The active pools serve as medium to slow release pools that replenish the labile pool. Finally the stable pools are very slow release pools, but will increase or decrease in size depending on the rate and frequency of P fertilizer application.

Pools Initialization:

To initialize the P pools, data on P fractions in the soil are needed. We used the sequential P fractions measured by the Hedley fractionation to initialize the pools. This sequential fractionation procedure extracts the different forms of P in the soil starting with labile forms and ending with the more stable forms. Both inorganic and organic forms of P are measured. We assigned the different fractions to corresponding P pools according to what is best described in the literature. The rates of transfer between pools are described in the chemical parameters file and the user can change those transfer rates when different soils are used.

Experiments and sites:

Two separate experiments were used for the calibration and the testing of the P model with maize and soybean from Colombia. Both experiments were carried out at the CIAT-CORPOICA Experiment Station, Carimagua (4' 30''N, 71,19' 'W) on the eastern savannas of Colombia. Rainfall averages 2240 mm annually, falling mainly form late March to mid- December. Mean annual temperature is 27 0C. Soils are well-drained silty clay Oxisols (tropeptic haplustox, isohyperthermic). The data used for genetic coefficients calibration were from the Culticore experiment for the maize variety "Sikuani", and the soybean variety "Soyica Altillanura 2". For upland rice data from the variety Sabana 6 was used. The data available were from three years (1994-1996) with a maize / soybean rotation (2 crops/year). The Culticore experiment was established in 1993 to investigate crop rotation and ley farming systems for the acid- soil savannas. Triple super phosphate fertilizer was applied at 60 and 40 kg P ha-1 for the maize and soybean crops, respectively. Other nutrients were applied at adequate levels. The data used to calibrate and test the P-model for the upland rice variety Sabana 6 were obtained from the Culticore on-station experiment at Carimagua and the Matazul on-farm experiments.

Carimagua:
Culticore experiment: Four years of data from 1993 till 1996 with the following treatments: Rice monoculture and Rice – Cowpea rotations. The Culticore experiment is a crop rotation experiment with an annual application of P fertilizers at 60 kg P ha-1. Rice monocultures received 100 kg N ha-1applied in 1994 as three split applications. No N fertilizer was applied for the other years. Rice-cowpea rotations had different amounts of residues leftover from the previous cowpea crop. The residues were broadcast and incorporated at 15 cm depth.

Matazul:
Residual phosphorus (RP): Four years of data. The RP experiment consists of 16 treatments of annual and one-time applications of P fertilizers with maize, soybean and upland rice crops. The annual applications range from 5 to 50 kg P ha-1. Other treatments had a one-time application in year one with rates ranging from 10 to 200 kg P ha-1. Data for rice production as well as uptake of P by rice at harvest are available. Data on P fractions are available for four treatments. However, soil and weather files are not available for Matazul.

Testing of the model for maize and soybean:
Data from the Residual Phopshorus (RP) experiment were used for testing the P model for both Maize and Soybean. The RP experiment included the annual application of P fertilizer at 0, 5, 10, 15, 20, 30, 40, and 50 kg ha-1 and the one time application of P at 10, 20, 30, 40, 60, 80, 120, 160, and 200 kg ha-1applied in 1993. Sequential files for the Maize-Soybean rotation for all treatments were constructed and simulations run in sequence for 4 years. The P pools were initialized once at the beginning of the simulation in the first year. Phosphorus fractionation data were used to initialize the pools in the first year.

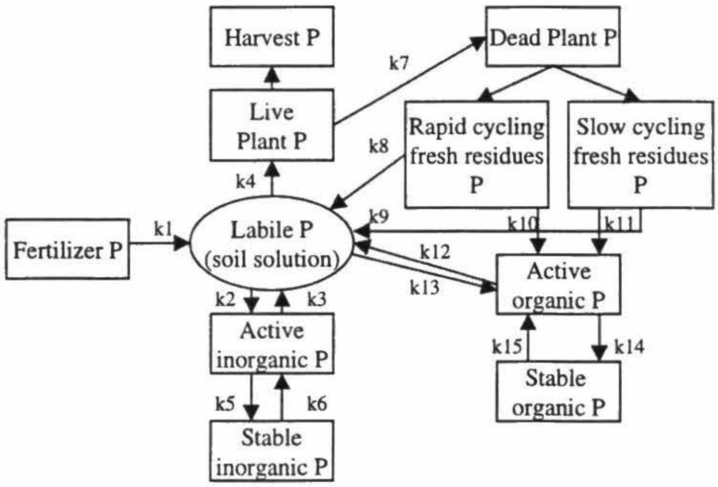

Figure 1. Phosphorus self-model for the CERES

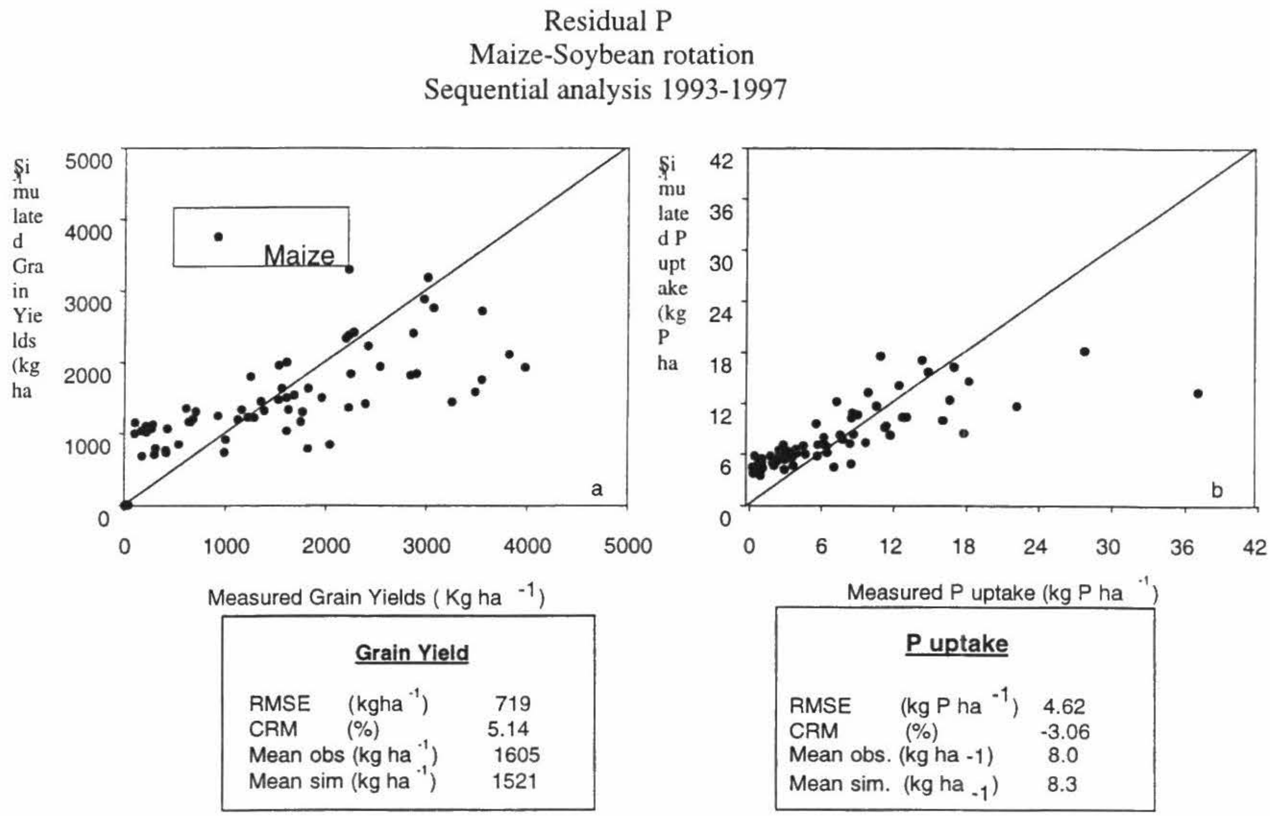

Figure 2. Measured and simulated Maize grain yield (a) and total P uptake (b) in a sequencial analysis done on maize-soybean rotation for all treatments.

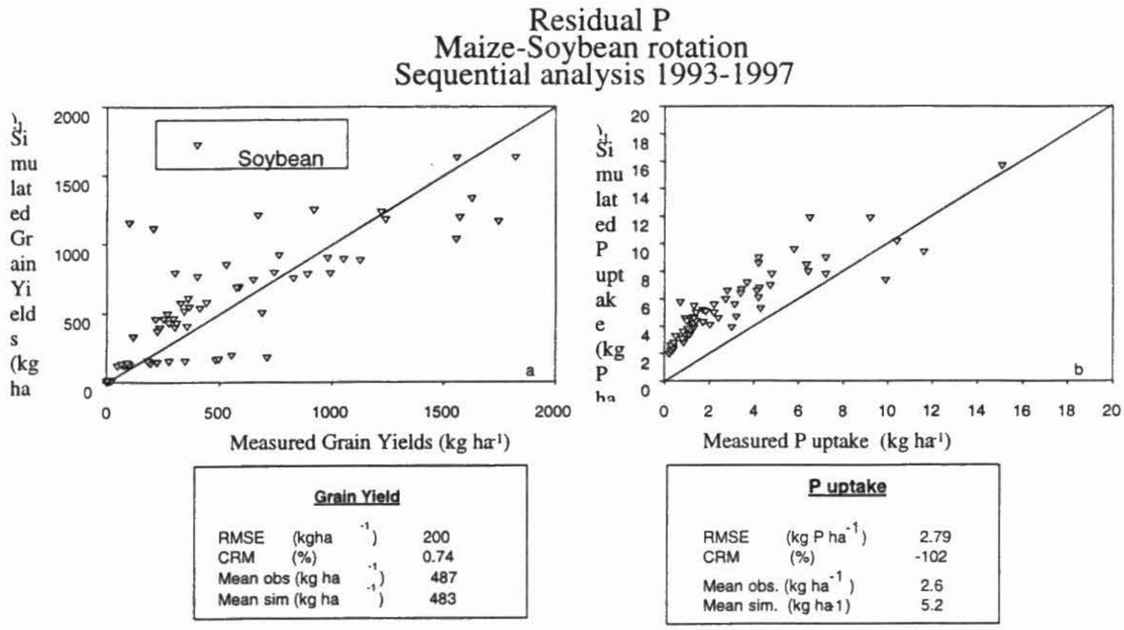

Figure 3. Measured and simulated Soybean grain yield (a) and total P uptake (b) in a sequencial analysis done on maize-soybean rotation for all treatments.

Testing of the model with maize and soybean

Parameters to test the model: The principal parameter used in the comparison of simulated to observed values is the root mean square error (RMSE) which estimates the variation, expressed in the same units as the data, between simulated and observed values. This parameter is defined by the following formula:

$$RMSE: = \left[\sum_{i=1}^{n} (S_i-O_i)^2 /n \right]^{1/2}$$

where O and S are observed and simulated values respectively. The RMSE can also be expressed as a coefficient of variation by dividing it by the mean of the observed values. The RMSE tests the accuracy of the model, which is defined as the extent to which simulated values approach a corresponding set of measured values.

The second parameter used is the coefficient of residual mass (CRM) which measures the tendency of the model towards overestimation. A negative CRM indicates a tendency of the model for overestimation. The CRM is defined by the following formula:

$$CRM = 100 * \left[\sum_{i=1}^{n} O_i - \sum_{i=1}^{n} S_i \right] / \sum O_i$$

Results:

Results from the sequential analysis for maize is presented in Figure 2 and for soybean in Figure 3. In general the model does a good job in simulating grain yields for both maize and soybean and P uptake for can not predict the extremely low amounts of P actually taken up by the soybean crop (mean observed P uptake is 2.6 kg P ha-1). One of the important conclusions is that one annual application of P fertilization on the Maize crop is not enough to sustain the next crop in rotation (soybean) even at the higher rates. This may be due to the acidity of the soil and the adaptability of the variety to acidic conditions. The RMSE is, in general, high for both crops for both grain yields and P uptake. This reflects the variability of the measured data. Although this experiment is designed to be a P response experiment , it is suspected that other uncontrolled factors affected crop yields and P uptake. Weeds were not controlled in these experiments, and some of the variability could be explained by the weed biomass production.

In its present form, the P model can be successfully used to answer 'What if' management type questions in the tropical acidic soils of Colombia. Management issues such as planting dates, rate and timing of P fertilizer addition can be tried out to achieve the best possible scenario.

Testing of the model with upland rice

In order to calculate the P demand by the rice plant during different growth stages, data for uptake of P by rice at optimum growing conditions are needed. Data from the literature regarding P uptake by upland rice with growth stage were collected and were used to construct a graph of percent P uptake in the dry matter with growth stage (Figure 4). This graph was used to estimate the demand by the crop in the model.

Genetic Coefficients calibration:

The data from the culticore experiment were used to calibrate the genetic coefficients for Sabana 6. There are problems with the variability of the replications in the treatments and the variability among the different years. For example there was a difference of 20 days for date of maturity for the crop between the different years. The best values obtained for the genetic coefficients are listed in Table 1.

The predictions from the various years for both treatments are presented in Tables 2a through 2c. The model gives good grain yield predictions for two years (1993 and 1995). Biomass yields are always over estimated by the model.

Table. 1. Genetic coefficients for variety Sabana 6.

Genetic coefficient	Calibrated value for Sabana 6
P1	500
P2R	100
P5	450
P2O	13.0
G1	36.6
G2	0.027
G3	0.50
G4	1.00

Table 2a. Some predicted and measured growth parameters from treatment 1, 1993

Variable	Predicted	Measured
Flowering date (dap)	74	63
Physiological maturity (dap)	110	109
Grain Yield (kg ha-1 at 14% moisture)	3015	3120
Grain number (grains m-2)	9602	9595
Panicle number (panicle m-2)	577	-
Maximum LAI (m2 m-2)	2.17	
Biomass at harvest (kg ha-1)	8859	8100
Harvest Index	0.293	
Final leaf number	20	-

Table 2b. Some predicted and measured growth parameters from treatments 1 and 2, 1994

	Treatment 1		Treatment 2	
Variable	Predicted	Measured	Predicted	Measured
Flowering date (dap)	73	78	73	78
Physiological maturity (dap)	110	120	110	120
Grain Yield (kg ha-1 at 14% moisture)	5476	2458	5333	3213
Grain number (grains m-2)	17441	9595	16987	14508
Panicle number (panicle m-2)	600	-	600	-
Maximum LAI (m2 m-2)	8.2		8.3	-
Biomass at harvest (kg ha-1)	16989	6528	16737	7473
Harvest Index	0.277		0.274	-
Final leaf number	20	-	20	-

Table 2c. Some predicted and measured growth parameters from treatments 1 and 2, 1995

	Treatment 1		Treatment 2	
Variable	Predicted	Measured	Predicted	Measured
Flowering date (dap)	73	78	73	78
Physiological maturity (dap)	107	103	107	103
Grain Yield (kg ha-1 at 14% moisture)	3180	3121	3772	3236
Grain number (grains m-2)	10129	14508	12015	9595
Panicle number (panicle m-2)	602		580	-
Maximum LAI (m2 m-2)	3.55		3.08	-
Biomass at harvest (kg ha-1)	9955	6321	10696	6761
Harvest Index	0.275		0.303	-
Final leaf number	20		20	-

Table 2d. Some predicted and measured growth parameters from treatments 1 and 2, 1996

	Treatment 1		Treatment 2	
Variable	Predicted	Measured	Predicted	Measured
Flowering date (dap)	73	81	73	81
Physiological maturity (dap)	108	123	108	123
Grain Yield (kg ha-1 at 14% moisture)	4979	2641	3815	3185
Grain number (grains m-2)	15859	-	12153	-
Panicle number (panicle m-2)	602		602	-
Maximum LAI (m2 m-2)	7.5		3.44	-
Biomass at harvest (kg ha-1)	15185	6531	11082	6686
Harvest Index	0.282		0.296	-
Final leaf number	20		20	-

The RP data from Matazul was intended for use as a test for the P model for rice. However several data are needed to establish the necessary files to run simulations:

a. Weather files for Matazul.
b. Soil file from Matazul.
c. Initial conditions for moisture and nitrogen for each year.

Phosphorus data are available for these experiments including soil P fractionation data for the different dates as well as yield data and uptake of P by the rice crop at harvest . However many data are still missing to run the model for these data sets. As a result only sensitivity analyses were done to show the response to P stresses in the model using the Culticore data.

Sensitivity analysis

Sensitivity analysis was performed on the Culticore data from 1994 and 1997. The analysis included testing the response of the model to different rates of P fertilizers as well as different initial condition of P.

Different rates of P application

Three-year data sets (1994 to 1996) from the Culticore experiment were used to run the model with different rates of P application ranging from 0 to 60 kg ha-1. The model responded well to the application of the different P rates showing increased response in terms of grain and biomass yields to the different rates of application. Figure 5 shows grain and biomass yield response to the different rates of P fertilizer application.

In 1994, simulations show a response due to P fertilizer application at all rates in comparison to the other years where the response flattens out at 20 kg P ha-1 in 1995 and at 40 kg P ha-1 in 1996. The model shows N stresses during these two years where no N fertilizers were applied. The increased response in 1994 shows the effect of adequate N fertilization on the P response of the crop. This however does not reflect accurately the measured values where in 1994 they were lower than predicted.

Different initial conditions for Labile P:

Sensitivity analysis was also run for different initial conditions for labile P for rice monocultures in 1994. Labile P in the model is equated measurable resin P. Figure 6 shows results of selected growth parameters with different initial conditions. These simulations were done with no P fertilization applied. Again the model shows response at all levels of labile P tested.

Conclusions:
Improvement of the genetic coefficients calibration is needed to improve the predictions of the model. This could be done with the experiments from Matazul with the high yielding treatment (optimum growing conditions) when the soil and weather files are available.

The sensitivity analysis done on the model shows it is responsive to different rates of P fertilizer applications as well as to initial conditions of labile P. Several growth parameters respond to P additions. Some of the growth parameters that do not seem to be affected by P fertilization are: flowering and maturity dates, panicle number and leaf number.

The model still needs to be tested with P response experiments such as the Phosphorous Residual experiment from Matazul.

References:
Internet: The P model software and documentation are published on the web. This will allow easy and rapid exchange of ideas and suggestions of users of the model. The model is published under the Nowlin chair web page at Michigan State University. The address is:
http://nowlin.css.msu.edu/software/P_model_form.html

References:
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Daroub, S.H., A. Gerakis, J. T. Ritchie, and J. Ryan. 1999. Predicting phosphorus availability to wheat in semi-arid areas using CERES-P. The annual meetings ASA, CSSA, SSSA. October 31- November 5, 1999. Salt Lake City, Utah. Agronomy Abstracts p. 41.

Collaborators:
S. Daroub, J. Ritchie and A. Gerakis, Michigan State University, S. Wood, IFPRI, M. Rivera, I.M. Rao, R. Thomas (CIAT), D. Friesen (IFDC).

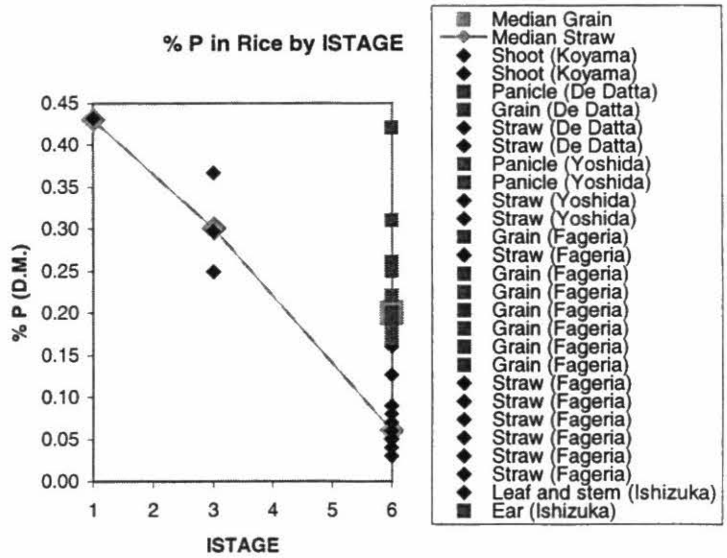


Figure 4. Percent P in dry matter with growth stage of rice. Data points are from the different cited references.

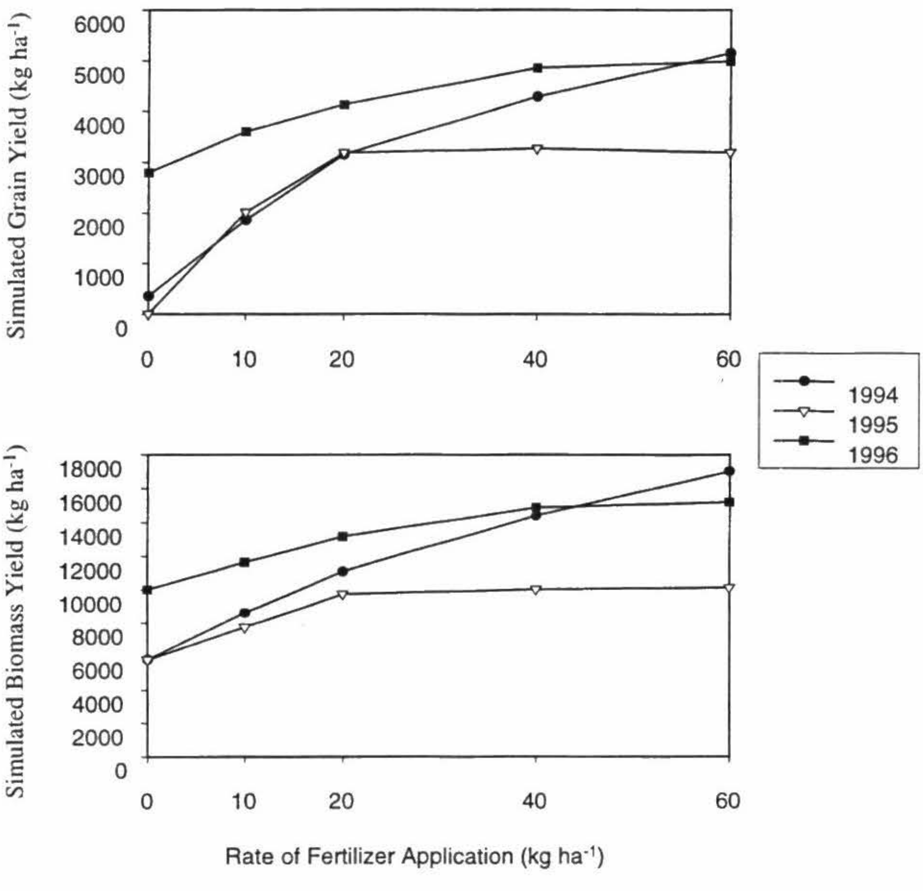


Figure 5. Sensitivity analysis with different rates of P fertilizer application done on the P version of CERES-Rice model using treatment 1 from the Culticore experiment.

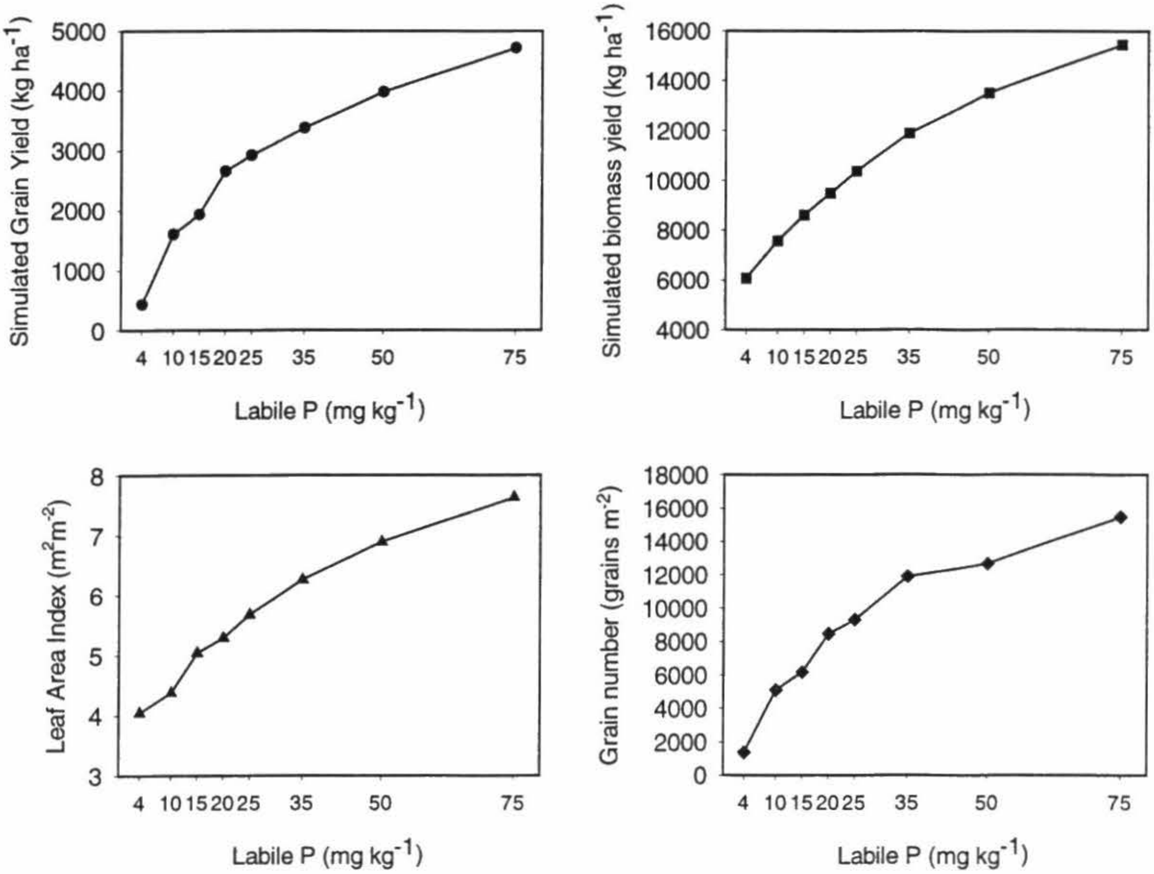


Figure 6. Sensitivity analysis done on treatment 1, 1994 Culticore experiment with different initial conditions of labile P.

1.3.2 Testing and refining coefficients of the P module NuMaSS and PDSS2

Highlight:

- Testing of NuMaSS (nutrient management decision support system) decision support system using the data from field experiments indicated that in the Llanos of Colombia upland rice production is considerably more profitable than either maize or cowpea given the yields obtained and the costs of fertilizer and the price of grain.

Purpose:

To perform a comparison of decision-aid predictions of fertilizer requirement (level 0 comparisons) and to perform a comparison of coefficients used in PDSS2 (phosphorus decision support system) and the P module of NuMaSS (nutrient management decision support system) to predict P fertilizer requirement (level 1 comparisons and testing).

Rationale:

A series of experiments have been carried out in the Llanos of Colombia. The purpose of these experiments was to determine the nutrient P requirements for several annual crops including maize, cowpea, and upland rice. Two of the experimental sites and three crops were selected to test the predictions of the PDSS2 and P module of NuMaSS with estimates of P requirements from factorial response curve experiments conducted in the field.

Results and Discussion:

Predictions of P fertilizer requirement:

Carimagua maize. As indicated in Figure 1, the PDSS2 prediction of P requirement for maize on this soil was slightly more than that estimated from the field-experiment, although the differences were not great. The experimental response curve is also shown in the Figure 1 and indicates a relation between the prediction and the field estimates. The predictions from PDSS2 are based on coefficients developed largely from experiments from the Brazilian Cerrado and from North Carolina.

Matazul cowpea and upland rice. A comparison was also made between the field estimates of P requirement for cowpea and upland rice Matazul and the PDSS2 predictions. As in the case of the Carimagua, this site is also located in the Eastern Llanos of Colombia (Figs. 2 and 3). The results were somewhat different than for the Carimagua site. PDSS2 predictions for cowpea tended to be somewhat less than that estimated from factorial response curve experiments conducted in the field. Results for the upland rice also suggest a slight underprediction of P requirements. This underprediction in the case of upland rice might have been related to the fact that the applied P was either applied before the former crop of cowpea or all applied before the previous crop. Estimates of 0.5*M* NaHCO3 - P were made from a relationship with Bray P 2. As indicated in Chen et al., 1997, estimating critical levels is also one of the major sources of error in the PDSS system. It may be that the critical levels for 0.5*M* NaHCO3 were from the Olsen while field measurements were from modified Olsen extractant. Critical levels and buffer coefficients for Olsen P for the EDTA modified method are higher than for the method that does not use EDTA.

Further results from PDSS2 analysis were included an economic analysis of the predicted P fertilizer estimates and the corresponding benefit / cost estimates and how the economic results vary with residual assessments of P applications. The results indicate that rice production is considerably more profitable than either maize or cowpea given the yields obtained and the costs of fertilizer and the price of grain. A simple summary is given in Table 1.

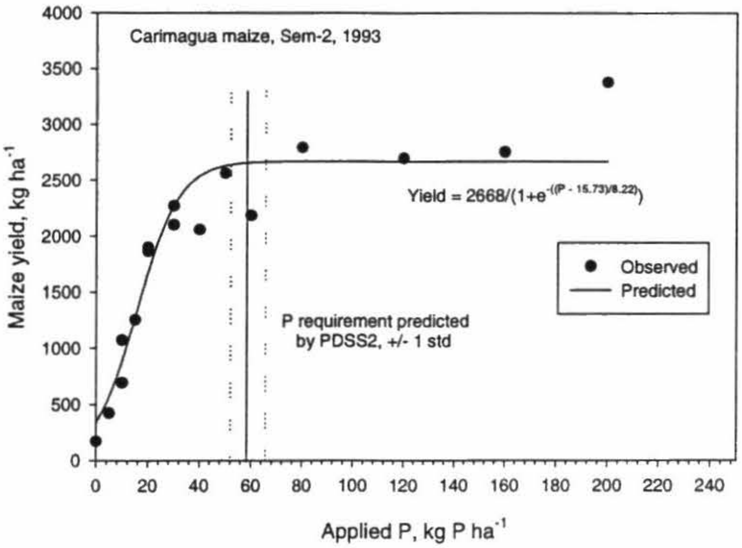


Figure 1. Comparison of P requirement estimated by PDSS2 with the experimentally determined P response curve. Carimagua maize, Semester 2, 1993. Conditions assumed in PDSS2, Initial P: 5.2, critical level 15, 42% clay.

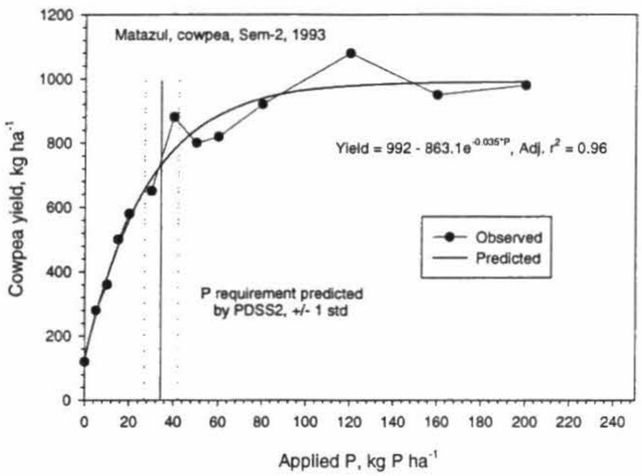


Figure 2. Comparison of the P requirement estimated by PDSS2 with the experimentally determined P response curve. Matazul cowpea, second semester, 1993.

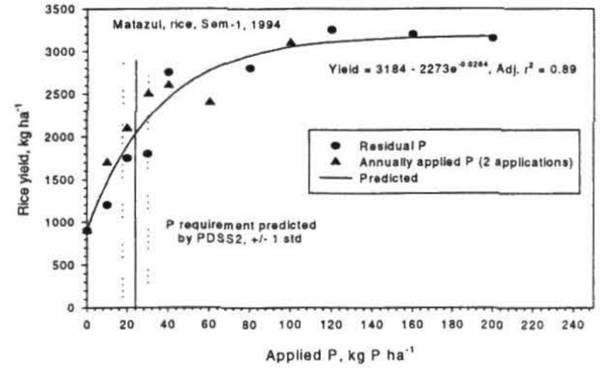


Figure 3. Comparison of P requirement predictions of PDSS2 with the experimentally determined response curve, Matazul, rice, 1994.

Table 1. Economic results of the calculation of benefit / cost ratios for three crops. Data from Matazul for the rice and cowpea, Carimagua for the maize.

Factors	Crop		
	Rice	Maize	Cowpea
Market Price ($/tonne)	400	357	516
Expected Yield (tonnes)	3.26	2.95	0.993
P requirement (kg P ha-1)	21	44	31
Benefit/Cost ratio	3.9	2.5	1.4

Likely one of the main reasons for the higher benefit / cost ratio for rice was the relatively high yield, good price at the market, and the lower P requirement. Maize yields seem very low and this together with the higher P requirements probably explain the predicted lower benefit / cost ratio. Cowpea yields were so low that the higher price did not compensate resulting in the lowest overall benefit / cost ratio. One caution seems important, however, and that is that in subsistence economies the market prices do not necessarily reflect the values, pride, and security of producing one's own food.

Impact:

Testing of NuMaSS using the data from the field experiments in the Llanos of Colombia indicated that in the Llanos of Colombia rice production is considerably more profitable than either maize or cowpea given the yields obtained and the costs of fertilizer and the price of grain. As a result of this testing, buffer coefficients and critical levels of Bray-2 P were subsequently included in PDSS2. Further studies are underway for level 1 testing, in which we will compare field estimates of the coefficients used in PDSS2 predictions with those generated by PDSS2: P critical levels for Bray P2 for maize, cowpea, and upland rice, P buffer coefficients for Bray P2 and 0.5*M* NaHCO3, coefficients for the slow reaction of fertilizer P with the soils at Carimagua and Matazul, and coefficients for the desorption of extractable P.

Contributors:
R.S. Yost (University of Hawaii, Hawaii, USA); D. K. Friesen (IFDC-CIMMYT, Nairobi, Kenya); J. I. Sanz, M. Rivera, and I.M. Rao (CIAT).

- Activity 1.6.1 Identify soil quality indicators, develop and test a soil quality monitoring system.

Highlight:
- Soil quality indicators have been identified for the savannas and hillsides agroecosystems have been incorporated into a guide that is being tested in Colombia, Central America and the East African Highlands as part of collaborative activities under the SWNM system-wide program.

Purpose:
To develop a user friendly soil quality monitoring system as a decision making aid for land users.

Rationale:
Soil degradation can occur rapidly with events such as severe storms and landslides. However the majority of degradation in farmers' fields occurs slowly, almost unnoticeably with the loss of topsoil organic matter and nutrients. The recuperation of degraded soil is always a slow and costly process with few exceptions such as nutrient depletion, soil surface crusting and sealing. Therefore land users and policy makers require sets of indicators to monitor the state of the land (soil and water) for use as early warning signals of degradation in order to make timely decisions on land management to reverse or prevent further degradation. Because soil is a multi-functional medium involved in the regulation of biogeochemical nutrient cycles, as a conditioner of the amounts and quality of water available to plants and as a bioremediator of agrochemicals and other xenobiotic chemicals, indicators of soil quality should also reflect these different functions. However whilst indicators and standards for air and water quality are already in place, the soil has been neglected. This is partly because a definition of soil quality is not as simple as that for air and water and is often laden with value judgements. Despite the on-going debate concerning soil quality and indicators, farmers and other land users already employ their own local or indigenous indicators (e.g. soil color, presence/absence of weed species) that are often far removed from scientific or technical indicators.

Development of a soil quality indicator guide.
Guidelines have been developed to help farmers and researchers recognize, understand and develop common sets of soil quality indicators (SQI's). Local knowledge is collated and new concepts and principles are added that incorporate scientific or technical indicators into a common language that can be of widespread value. This is especially important when the deterioration of soils is less evident to the land user e.g., invisible soil-borne pathogens, gradual erosion of the topsoil or acidification. The eventual aim is to develop a soil and water quality monitoring system that can be used by the land user for decision making over different temporal and spatial scales.

The development of local soil quality indicators starts with the application of a participatory method for identifying and classifying local soil quality indicators at the micro-watershed level. This process is included in a guide that promotes an understanding of soils through the different perceptions and experiences of the small-scale farmer. A theoretical framework is established using a simplified model of the origin of soils. Details of the guide have been published in Spanish and English as part of a set of nine guides for natural resource management (CIAT, 1999). Briefly the guide is in three sections. The first provides simple information on what soil is, how it is formed and indicators of soil quality. A series of practical exercises are outlined to enable an instructor to help participants develop skills for classifying soils. The exercises result in an understanding of the principal physical, biological and chemical properties of soils. The second section provides an explanation of soil quality indicators and how to identify and prioritize local indicators. Farmers are brought together in a meeting where they work in groups. Both a matrix and a classification system are used to prioritize their own indicators. The third section outlines how to organize a "Soils Fair" for farmers. This aims to help farmers develop skills in determining through simple methods, the physical, chemical and biological properties of soils and relate this to their knowledge of local soil management. A series of exercises and group work leads the participants through the identification and ranking of local soil quality indicators. During the training exercise local and technical indicators of soil quality were compared to technical assessment methodologies. An example of an outcome of this process is presented in Table 1.

The training tool has been developed for application by two groups. The first are professionals and technicians in private and public institutions and organizations working on NRM and sustainable development. They use the guide to support planning, follow up and evaluation of their initiatives. Some eventually become trainers in the use of the guides themselves. The second group consists of the inhabitants of watersheds or members of community-based organizations. They can work with NGO's and other organizations to use the methods and strategies and actively participate in the management of their natural resources. As part of the training in the use of the guide the participants should practice what they have learned. To facilitate this the development of "action plans" is encouraged. These are work plans orientated to the application of the decision-making guides by the participants in their particular sites. In Honduras for example there are five action plans that employ the soil quality indicator guide (Table 2). For Colombia, Honduras and Nicaragua over 50 institutions are participating in this process.

Table 1 An example of the integration of local and technical soil quality indicators and their ranking by farmers.

Order of Importance	Indicator	
	Local	Technical
1	Good plants, good crops, healthy looking, thick/Bad plants, bad crop	Yield
2	Land with chichiguaste, malva/Land with zacate	Vegetation type
3	Loose soil, porous,, powdery	Soil structure
4	New land (land use change from pasture to crops), less than 10 years of use/more than 10 years of use	Length of time used
5	Soil depth (half machete, 12 inches), thick/thin soil less than 4 inches	Effective soil depth

Table 2. Organizations and action plans that are utilizing the local soil quality indicator guide in Honduras.

Institution	Collaborating institutions/communities
Menonite Social Action Commission	Regional offices working with 3 communities (San Antonio, Limpia and Choloma
COHDEFOR Honduran Corporation for Forestry Development	Working with 10 community organizations in St. M. de Colon
AFE-COHDEFOR Watershed management section	Working with farmers in 5 critical conservation areas
Christian Commission for development	Working with technicians, agricultural facilitators, farmers and technical support committees
DICTA/SAG Science and Technology Division	Working with other institutions, technical personnel and farmer enterprises at country level

At the same time as the development of local soil quality indicators scientists conduct biophysical experiments under more controlled conditions either on- or off-farm to determine the most appropriate set of indicators for a particular agroecosystem. Ideally parameters should be identified that integrate physical, chemical and biological factors. For example and under certain circumstances, water infiltration can be used as an integrative factor as it is dependent on soil physical structure, particularly texture, soil chemistry (the relationship between soil surfaces) and soil porosity, all of which are affected by the activity of soil biota. To avoid the need to develop sets of critical values for each parameter and soil type work has been initiated using a native ecosystem such as the native savanna or forest for benchmark values and comparing values under different land management practices on similar soil types. For more widespread use it is recognized that critical values will need to be determined for different soil parameters.

To be useful to a variety of users including farmers, extension workers and policy makers, SQI's should be;

- i) relatively easy and practical to use under field conditions by farmers, extension workers, specialists and scientists.
- ii) relatively accurate, precise and easy to interpret.
- iii) cost-effective to measure.
- iv) sensitive to variations in management and climate.
- v) able to integrate soil physical, chemical and biological properties and processes and serve as basic inputs for estimation of soil properties or functions that are more difficult to measure directly.
- vi) correlate well with ecosystem processes, plant and animal productivity and soil health in a predictable way.
- vii) components of existing soil data bases.

Table 3 shows an example developed from research undertaken in the savanna agroecosystem of Brazil and Colombia. In this environment the soil constraints are;
loss of organic matter, limited water availability during short dry periods in the wet season, compaction and surface sealing, wind and water erosion, depletion of soil nutrients and acidification and associated aluminum toxicity. Another example is from the East Africa highlands where loss of organic matter, wind and water erosion and depletion of soil nutrients are the main constraints (Table 4).

The identified indicators are ranked according to their ease of use on-farm. Appropriate indicators can then be brought into the training exercises with farmers on the development of local soil quality indicators with the appropriate level of simplicity e.g. earthworm biomass from Table 3. Thus both scientific and local knowledge can be brought together into a user-friendly and user-devised soil quality monitoring system in order to build social capital and help land user decision making on the use of their natural capital.

Currently the soil quality indicators are being validated by additional on-farm and on-station trials in both the Colombian savannas and hillside agroecosystems of Colombia, Honduras and Nicaragua. At the same time the guideline for the identification of local soil quality indicators is being disseminated in Latin America and Eastern Africa. Training events for extension workers, researchers and farmers are being organized in Latin American and African countries. The guideline for local soil quality indicators is being adapted for African conditions by local organizations.

Table 3. Soil quality indicators for the savannas.

Indicator	Methodology	Easy of use	Sensitivity to land use change	Suitability for on-farm use	General suitability
Aggregate size distribution/stability	Aggregate stability	+	+++	-	+++
Extractable organic carbon	Lab extractions & colorimetry	+	++	-	+
Permanganate-Extractable N	Lab extractions & colorimetry	+	++	-	++
Microbial C/total C	Microbial biomass	+	++	-	+
Free/easily accessible POM	Organic matter fractionation	++	++	-	++
Water infiltration rate	Ring infiltrometer	+	+	-	++
Earthworm biomass	Soil sampling/hand sorting	++	+++	+	+++
Earthworm termite ratio	Soil sampling/hand sorting	+	+++	+	++
Soil pH	pH strips	+++	+	+	+
Porosity	Pore size analysis	+	++	-	++
Compaction	Hand held penetrometer	+++	++	++	++

- not easy/suitable/sensitive

+ little suitability/sensitivity

++ moderately easy/suitable/sensitive

+++ good suitability/sensitivity

Data in Table 3 taken from Thomas and Ayarza (1999).

Table 4. Soil quality indicators for the East African Highlands.

Indicator		Methodology	Easy of use	Sensitivity to land use change	Suitability for on-farm use	General suitability
Local	Technical					
Presence of Earthworms	Biological activity	Soil sampling, hand sorting	+	+++	+	++
Good crop	Fertility	Lab extractions & colorimetry	+	++	-	++
Dark green plant colour	Leaf colour or nutrient status	Lab extractions & colorimetry	+	++	-	++
Deep soils	Effective depth	Soil sampling	++	+	+	+
Not salty/ salty i.e. visible at surface	Electrical conductivity and pH	Lab extractions & pH strips	++	+	-	+
Smell or rotting vegetation	Redox potential	Lab extractions	+	+	-	+
Black soil colour	OM content	Lab extractions, OM fractionation	++	++	+	++
Easy to cultivate	Texture or compaction	Hand held penetrometer	+++	++	++	++
Presence of good indicator weed species	Soil fertility or weed diversity	Farm surveys	+++	++	++	++
Good water retention-	Water holding capacity or infiltration	Ring infiltrometer	+	+	-	++

- not easy/suitable/sensitive
+ little suitability/sensitivity
++ moderately easy/suitable/sensitive
+++ good suitability/sensitivity
Data taken from Barrios et al,. (In preparation).

- Contributors

E. Barrios, R. Thomas, M. Trejo (CIAT), R. Delve,)TSBF/CIAT).

1.6.2: Preliminary version of a simple database tool for soil diagnosis in the flat high plains (*altillanura plana*) of the Colombian *Llanos*

Highlights:

- A preliminary version of a simple tool is available to farmers and those who assist them to diagnose the health of their soils and to establish their limitations for specific crops
- The tool allows the storage of soil data for a series of georeferenced observation points that can be linked to a GIS and then analyzed with geostatistical or interpolation methods

Results

The field component of the tool consists of a form to fill in with the characteristics of the soils that are measured in the field: Geographic coordinates, tangential resistance to cutting, penetrability, effective depth, pH, texture, color, and apparent density. If resources allow laboratory tests, then additional fields can be filled: effective density, organic matter content, and hydraulic conductivity. In the office of the agriculture extension service, the farmer has access to the database tool, which has been programmed in Microsoft Access, a very commonly used database management system. The farmer or an extension agent fills the electronic version of the field form using the computer and automatically fills a database table with the field data. The values in the resulting fields are compared with critical and optimal values for the type of soil being considered, which are stored in a separate table. These critical values are based on experimental data obtained in CIAT and CORPOICA test plots in the Colombian *altillanura plana*, in Carimagua (Culticor experiment), Matazul, and others. After this comparison is made, a report is generated, indicating how the measured values fall within the critical and optimal ranges, or if they fall outside. The tool will later be improved so that the report also interprets these results in terms of possible causes, possible solutions, and level of degradation.

The user then has the option of evaluating the level of restriction that the studied soil shows for specific crops. The soil requirements for these crops are still in development and stored in a separate database, which is linked to the tool. The user chooses the crop, and the soil properties are compared with the crop's soil requirement. As before, a report is generated with a diagnosis of how the measured soil properties fall within the optimal and critical values for the chosen crop. The user can generate as many crop reports as wanted and can save them in a text file.

Soil properties for many points, as well as their corresponding diagnosis, can be entered in a single table. Because the table also stores the geographic coordinates of each point, it can be exported to text format and imported in the MapMaker software. The resulting coverage can be overlaid onto digitized aerial photographs or satellite images. Soil properties can then be queried on screen. Soil property values can be interpolated from the ones in the database to form a grid surface.

Impact:

The use of this tool should lead to better soil management by farmers and to choosing the most suitable portions of land for intensification efforts. This should result in a decrease in soil losses and an increase in agricultural productivity. This tool makes available to farmers and agriculture extension agents the results of years of scientific research on soil physics in CIAT.

Contributors:

Yolanda Rubiano, Edgar Amezquita, Nathalie Beaulieu, Arturo Franco

Output 2. Improved technologies for increased production based on efficient use of water and nutrients adapted and applied by land users.

Activity 2.1 Characterize soil biodiversity and develop strategies to manage beneficial soil biological processes.

2.1 Nature's plow: Soil macro-invertebrate communities from the Neotropical savannas of Colombia.

Highlight:

- A beneficial population of soil earthworms should consist of one or more epigeic species and one or more anecic species that construct vertical galleries, produce biogenic structures on the soil surface and mix plant residues with the mineral soil substrate.

Purpose:
To develop guidelines for the management of beneficial soil biota through an evaluation of the effect of agricultural systems on the structure and abundance of soil macro-invertebrate communities. In addition to characterize the community structure, population dynamics and species ecology of earthworms in natural savannas and introduced grasslands, and evaluate the effects of a functional group, i.e. the ecosystem engineers, on soil properties at different spatio-temporal scales in the eastern plains of Colombia.

Rationale
Soils host extremely diverse and abundant populations of invertebrate communities. The study of the macro-invertebrate biodiversity in soils and the possible use of biological resources were neglected during the green agricultural revolution. The management of these communities and the benefits derived from their activities is considered part of the second paradigm of soil fertility management whereby there is more reliance on biological activity than on purchased inputs. However our knowledge on the management of soil biota is still very meager as are details of the composition and structure of their communities and responses to disturbances or specific soil conditions. We have completed a detailed collaborative study that includes the first in-depth field approach to soil biological studies in the savannas of South America (Colombian llanos).

Summary
Studies on soil macrofauna communities with a special emphasis on earthworms, their biology, ecology and their effects on physical and chemical processes from different land uses in the Colombian llanos have now been completed. These are reported in detail in two Ph.D. theses (one from Juan J. Jiménez, entitled "Estructura de las comunidades y dinámica de las poblaciones de lombrices de tierra en sabanas naturales y perturbadas de Carimagua, Colombia", Universidad Complutense, 1999, and the other from Thibaud Decaëns entitled "Rôle fonctionnel et résponses aux practiques agricoles des vers de terre et autres ingénieurs ecologiques dans les savanes colombiennes" Université Pierre et Marie Curie - Paris VI, 1999).

The majority of the research was done at the Carimagua (CIAT – CORPOICA) experimental station. The main hypothesis tested was to consider earthworms as a resource suitable for management for beneficial means in sustainable agroecosystems where biological resources can be considered potential indicators of soil health and fertility.
An inventory of biological resources including abundance, diversity and ecology, and an evaluation of their impacts on soil and plants was produced for the savannas of Carimagua. The composition of the soil macrofauna communities in natural and agricultural systems, as well as the assessment of their basic biology, population dynamics, adaptive survival strategies and earthworm life cycles have been described. In addition the effects of earthworms as a group of ecological engineers on the soil physical, chemical and biological properties at different spatio-temporal scales are detailed. The main results and discussion on options to conserve and use the biological resources in the soil under different land management practices are presented here.
Main findings include:
- Macro-invertebrate populations clearly responded to perturbations induced by soil management. Earthworms are favored by pastures and moderate grazing and fire but their importance decreases with overgrazing. The long-term association of *B. decumbens* and Kudzu (15 years) is of high value with respect to the conservation of soil quality and biodiversity as it maintains the taxonomic richness of the savanna. Annual crops have a dramatic negative effect on earthworms and arthropod populations with a spectacular decrease of biomass, population density and taxonomic richness.
- The original species richness of earthworms in the savanna was conserved in pure or legume-based improved pastures and no aggressive peregrine earthworms invaded these agroecosystems. The earthworm community at Carimagua was comprised by species of the main ecological categories, of different size and precise adaptive strategies for the severe environmental conditions. When the savanna was converted

into improved pasture differences in density and biomass, (10-fold greater under improved pastures) were significant mainly due to a large increase in populations of the large anecic *M. carimaguensis*.

- Fourteen macro-invertebrate species produce epigeic biogenic structures in savanna soil of Carimagua, eight types of ant nests, three types of termite mounds, one type of termite plate and two types of earthworm casts. Casts produced by an endogeic species and *M. carimaguensis* (anecic) are formed by aggregates of large size that were more stable than soil aggregates of comparable size in the case of the anecic species. Three types of structures produced by soil ecological engineers have been identified: (i) compacted structures enriched in organic matter (earthworm casts), (ii) slightly compacted structures with enriched organic matter (termite mounds) and (iii) granular, non-compacted structures with low organic matter contents (termite plates and ant nests). From the typology of biogenic structures a functional classification approach of soil fauna and their effects on ecosystem functioning can be assessed.
- Carbon content in casts increased significantly over time resulting in a build up of a rather active but physically protected C pools. When total casting activity per ha is considered we estimate as much as 8.6 tons C ha-1 yr-1 is accumulated in surface earthworm casts on improved grass/legume pastures in comparison with 0.6 t C ha-1 yr-1 in the native savanna. Because of the large quantities of soil processed by earthworms in the pastures, the global effects on soil fertility and plant production are extensive, especially in the context of soil organic matter management, which is a fundamental step in improving agroecosystems sustainability and decreasing CO_2 emissions to the atmosphere.
- The effects of the absence of the deep-burrowing *M. carimaguensis* on soil properties and plant growth was associated with high soil compaction, low C contents, high Al saturation, low herbaceous biomass and high weed biomass in pastures, although main factors influencing soil properties were pasture type and age. The loss of one species, especially when it is associated with an important decrease in biomass, resulted in significant losses in ecosystem function. Attention should be paid to managing earthworm populations in tropical agroecosystems in order to profit from their impacts on soil fertility.

The resource

The soil macro-invertebrate communities in the native savanna at Carimagua are characterized by a high taxonomic richness and population density with termites (47% of the total) and earthworms (31%) comprising the most abundant groups. Representatives of various groups such as earthworms (Oligochaeta), termites (Isoptera), ants, wasps (Hymenoptera), beetles (Coleoptera), spiders (Arachnida), millipedes (Myriapoda), rounded worms (Nematoda), harvest flies (Homoptera), sucker beetles (Hemiptera), isopods (Isopoda) and flies and mosquitoes (Diptera) were also recorded.

However, a characterization of the macrofauna in any ecosystem ought to be accompanied by an evaluation of the biogenic structures and the organisms responsible for their formation. In addition the biogenic structures represent the main focus that unites the biodiversity of the organisms with functional performance in the ecosystem. The main functional groups are represented in the savanna communities i.e., litter transformers such as beetles and epigeic earthworms, and ecosystems engineers such as termites, ants and earthworms. In agreement with the high species richness of the savanna, we found a high functional diversity at Carimagua with 14 different types of superficial biogenic structures produced by soil ecological engineers: 4 termite structures, 8 types of ant nests and 2 types of earthworm casts.

When natural ecosystems are replaced by agroecosystems the extent of the changes in earthworm communities will depend largely on the amplitude of the environmental changes in the soil induced by agricultural practices. For example, species richness decreases dramatically when the tropical forest or savanna is converted into agricultural monocultures. On the other hand slight changes are observed when the agroecosystem is functionally similar to the original ecosystem such as the introduction of improved pastures after natural grassland savannas or an agroforestry system following a natural forest. The loss of biodiversity of earthworm communities can result in an alteration of ecosystem functioning.

Effect of agricultural intensification on ecosystem engineers

Agricultural practices can be classified from less intensive (use of fire, low animal stocking rates) to more intensive (regular use of machinery, application of large amounts of inputs and heavy grazing). Agricultural intensification and associated practices such as the elimination of native vegetation, mechanization and use of pesticides, results in environmental changes, i.e., microclimate and trophic resources, that decrease a large part of the soil biodiversity. Agroecosystems are known to have a reduction in plant and animal communities compared with natural systems. The concept of agricultural intensification includes the changes to the structure of the agroecosystems associated with the transition from traditional agriculture to a more intensive agriculture. This intensification involves three types of changes: (i) the more frequent use of the soil in a plot, i.e., an intensification of the resource use; (ii) the specialization of productive species i.e., loss of vegetation cover diversity and (iii) the use of inputs such as fertilizers and pesticides and mechanization.

The different agroecosystems studied in Carimagua can be classified as a function of the degree of agricultural intensification. This can be expressed as an index (preliminary assessment in Decaëns, unpublished) that facilitates a visualization of intensification in the savannas:

$$IA = US + FT + ARP + ME + CA + UF + PS$$

where IA is the degree of intensification, US is the degree of use of the soil for crops, FT is the degree of fertilization, ARP is the degree of use of agrochemicals to control pest and diseases, ME is the degree of mechanization, CA is the animal stocking rate, UF is the degree of soil utilization and PS is the level of productivity of the system. IA ranges from 0 to 7 while the others range from 0 to 1. With this index we can rank the different systems studied in Carimagua according to a gradient of intensification (Figure 1).

The taxonomic richness of the soil macrofauna varies along this gradient, mainly varying in (a) both intensity and frequency of perturbations, and (b) the productivity of the system (quantity and quality of the resource).

In general we can assess the effects of agricultural practices using this index and can distinguish two main contrasting agroecosystems: pastures and annual crops. Pastures not only maintain earthworm species richness but also increase their populations (Jiménez et al., 1998), i.e., the carrying capacity is greater. This process occurs in various stages, firstly pastures provide an organic fertilization via animal excretion with dung being a high quality organic resource for earthworms and litter transformers. Dung then encourages a rapid decomposition and incorporation of litter into the soil via the ecological engineers and through its ingestion when mixed with mineral soil (anecic earthworms) or soil with different amounts of organic matter and roots (endogeic earthworms). The quantity of roots under pastures is much greater than that under native savanna (Rao, 1998), thus favoring an increase in the populations of endogeic earthworms such as *Andiodrilus* n. sp. and also influencing the amounts of carbon accumulated at depth in the soil (Fisher et al., 1994; 1997).

In some cases the combination of agricultural practices favors the above processes. For example in rice-pasture agropastoral systems (Sanz et al., 1999) where pastures, established with the sowing of upland rice, benefit from the inorganic fertilizers applied to the rice crop. In the case of organic fertilization associated with grass-legume pastures there is an increase in both the quantity and quality of the organic matter. The beneficial effects of forage legumes in pastures includes an increase in nutrient cycling and biological nitrogen fixation (Thomas, 1992, Thomas et al., 1992).

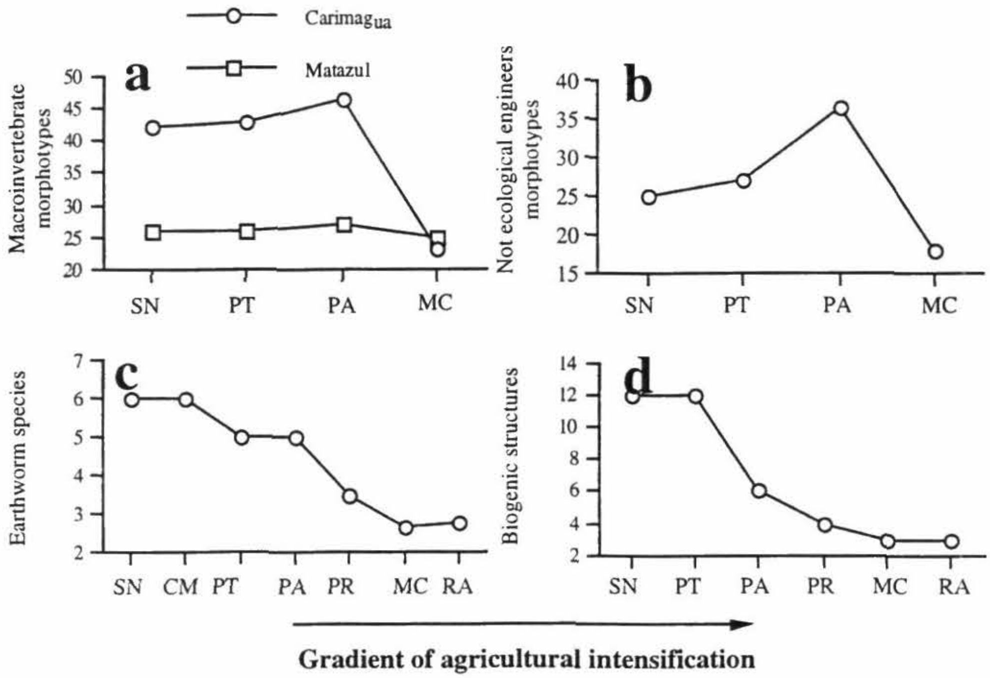
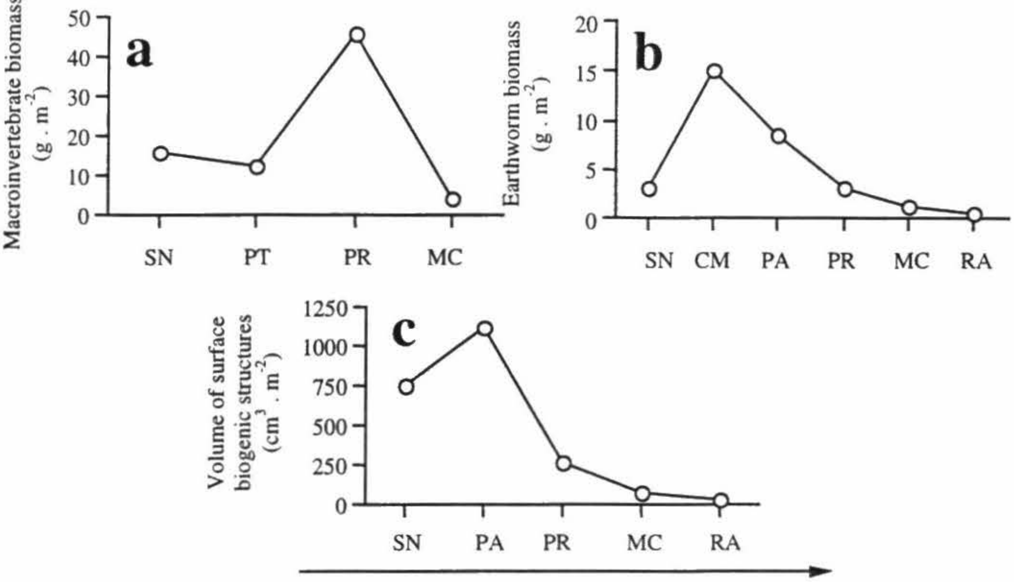


Figure 1. Number of morphotypes of macro-invertebrates (a), of macro-invertebrates that are not engineers (b), of earthworms (c) and of ecological engineers that produce structures on the soil surface (d) along a gradient of agricultural intensification. SN = native savanna; CM = cashew nuts (*Anacardium occidentale* L.); PT = traditional pasture; PA = old introduced pastures; PR = newly introduced pastures; MC = crop monocultures; RA = annual rotations (Decaëns unpublished).

Agricultural intensification generally affects all groups of invertebrates. In Carimagua only the most intensive system, annual crops, significantly reduced taxonomic richness (number of species in the macro-invertebrate communities (Figure 1a). The species richness of litter transformers was greatest in moderately intensive systems (Figure 1b). These results differ in principle from Swift et al. (1996), who suggested that agricultural intensification results in a systematic reduction of biodiversity (Decaëns, unpublished). This type of result however may not be general, as studies done at the Matazul farm did not show a significant decrease in taxonomic richness across a similar intensification gradient.
The number of earthworm species decreased progressively from the native savanna to monocultures (Figure 1c). Finally, the number of biogenic structures identified on the soil surface, which are often linked to the number of ecological engineers that create structures onto the soil surface, decreased rapidly with intensification.



Gradient of agricultural intensification

Figure 2. Macro-invertebrate biomass (a), earthworm biomass (b) and quantity of biogenic structures on the soil surface (c) along a gradient of agricultural intensification (SN = native savanna; PA = long-term introduced pasture (= intensive); PR= recent introduced pasture (= intensive); MC = monocultures; RA = annual rotations; CM = Cashew nut trees; PT = traditional pasture (Decaëns, unpublished).

In terms of quantitative analyses, the most favorable systems for soil macrofauna activity were the moderately intensive systems. Total biomass of macro-invertebrates, such as earthworms, increased in areas with trees or with introduced pastures (Figure 2a, b). The quantity of biogenic structures also varied in the same way (Figure 2c). These results could explain the observed variations in species richness of the functional group of litter transformers (Figure 1b). *M. carimaguensis* modifies conditions for other organisms through the creation of biogenic structures, with an increase in the abundance of certain groups of arthropods. Therefore the activities of the ecological engineers could be one the factors responsible for the increase in taxonomic richness of the litter transformers in moderately intensive systems (Decaëns, unpublished).

Earthworm species from the savannas of Carimagua did not respond equally to agricultural intensification. Generally earthworm density increased in moderately intensive systems and decreased in intensive systems even though the extent of the changes varied widely according to the particular species (Decaëns, unpublished). In intensively managed pastures, Ocnerodrilidae n. sp. responded rapidly to the improved trophic conditions, whereas the other species decreased in density with a variable recovery from perturbations (Figure 3).

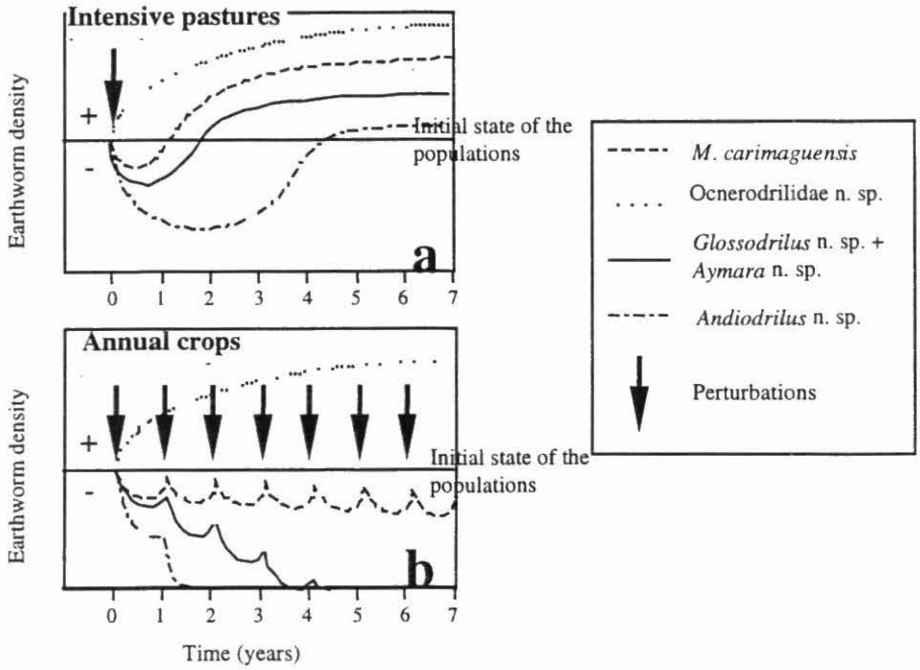


Figure 3. Response of different earthworm species in Carimagua to perturbations resulting from agricultural practices (tillage, pesticides): (a) in an improved pasture and (b) in a crop monoculture .

The rate of increase in density depends on the resources used with Ocnerodrilidae n. sp. and *M. carimaguensis* being the most responsive. Ocnerodrilidae n. sp., is a species with a rapid and strong demographic growth that is little affected by tillage. *M. carimaguensis* has the ability to move over the soil surface and consume materials enriched in organic matter (dead roots, leaf litter, organic residues of diverse nature such as surface casts of other earthworm species and invertebrates). In annual crops there is no enough time for the species to recover their initial densities following perturbations and the majority disappear from these systems.

Life cycles

The study of ecological processes and functions associated with biodiversity constitutes the basis for both the understanding and management of natural and human intervened ecosystems. In general, earthworm communities are sensitive to climatic and edaphic factors within a hierarchical scale that determine the availability of food resources and the microclimatic conditions. Under this assumption there is always a potential risk of changing communities due to alterations in natural ecosystems. The capacity of the fauna to respond to these changes can be used to manage their activities.

In terms of the biology and ecology of the savanna earthworm species we tested the following hypothesis (Jiménez, 1999): (i) the replacement of native savanna with introduced pastures results in a drastic reduction in species richness and diversity that could originate the depletion of native species; (ii) if these are able to adapt to the new agroecosystem the community structure will change; (iii) the management and increase in primary production of pastures influences the abundance and biomass of earthworm species increasing or reducing their populations.

The change in the natural ecosystem (native savanna) influenced the functional structure (hypothesis i) of the earthworm communities but had little effect on species richness (hypothesis ii). In the introduced pastures at Carimagua the same species were found as those in the native savanna without any presence of exotic species. It was the difference in community structure that changed, i.e., the relative contribution of the different ecological categories and their effects on the agroecosystems. *Andropogon gayanus* and *Brachiaria decumbens*, alone or in association with the forage legumes *Pueraria phaseoloides*, *Brachiaria humidicola*, alone or in association with *Arachis pintoi* or other legumes were agroecosystems that conserved the native earthworm community at Carimagua. These results are exceptional because generally disturbances to natural systems results in a decrease or disappearance of the native species. It is more usual to observe the appearance of pantropical species with a wide range of tolerance to physico-chemical properties (peregrine species) such as *Pontoscolex corethrurus* Müller and *Polypheretima elongata* Perrier (Table 1).

Table 1 Macro-invertebrate species richness in a primary forest and pasture of *Brachiaria humidicola* Rendle in Manaus, Brazil (Barros et al., 1998) and in a native savanna and introduced pasture of *B. humidicola + P. phaseolides* at Carimagua in the Colombian savannas (Decaëns et al. 1994).

	Tropical Forest ***(Manaus, Brazil)***		Savanna ***(Carimagua, Colombia)***	
	Forest	Pasture	Savanna	Pasture
N° morphospecies	151	48	31-57	42-55
Common spp. (%)	15		54	
Total biomass (g fresh weight m-2)	51.5	51.2	15.3	28.8-62.5
Biomass *P. corethrurus* (%)	0	90	0	0

It seems that the main factor determining the maintenance of the native fauna is the structural and functional similarity between the original ecosystem and the derived one. One of the causes for the establishment of exotic populations of earthworms is the colonization of vacant niches left by native species after habitat alteration. The abundance of only two of the savanna species were increased significantly by the introduction of improved pastures in Carimagua (hypothesis iii, Jiménez, 1999). The biomass of *Andiodrilus* n.sp. was increased three-fold (from 0.82 to 2.39 g fresh weight m-2) while the biomass of *M. carimaguensis* was increased more than a 10-fold (from 0.47 to 50.74 g fresh weight m-2). Extrapolating these values from the plot to the ecosystem level a density of 2.000 ind ha-1 for *Andiodrilus* n. sp. and of 182.000 ind. ha-1. for *M. carimaguensis* is obtained.

3.1 Adaptation to drought

The tropical savannas are ecosystems that are subjected to a strong pattern of rainfall and drought with a dry period ranging from 3 to 9 months. This pattern strongly influences the type of savanna in terms of soil humidity and vegetation, which in turn determines the dynamics and activity of earthworm populations. These result in different adaptive strategies, feeding regimes, localization in the soil during the dry period, size etc. in response to the severity of the environment in order to avoid population extinction. There are three main types of ecological categories that are the responses of the organisms to the limiting soil factors; little or no nutrient reserves, compaction and unfavorable climatic conditions

There are three population parameters all explained by climate variations that define the structural function of the earthworm communities in Carimagua: abundance, degree of activity and vertical distribution in the soil profile. Species adapt to such conditions through changes in their activities and population demographic structure (development parameters such as growth, fertility and death). In Carimagua the seasonality appears as the determining factor of activity of the populations and of the diverse adaptive strategies to confront these conditions (Jiménez, 1999).

Based on these observations in Carimagua three groups of species can be distinguished:

a) Small sized species superficially located during their activity and with a quiescence phase including, *Aymara* n. sp. (epigeic), *Glossodrilus* n. sp. (endogeic) and Ocnerodrilidae n. sp. that shows a deep vertical distribution with the exception of the first two species.
b) Medium sized species superficially located with no special adaptation to drought, e.g., *Andiodrilus* n. sp. (endogeic).
c) Large sized with a diapause in deep layers of the soil, e.g., *Andiorrhinus* n. sp. (endo-anecic, without diapause) and *M. carimaguensis* (anecic).

4. Effects of the engineers on soil properties

The effects of ecosystem engineers on soil processes have been addressed under three main hypotheses (Decaëns, 1999):

(1) The ecological engineers produce biogenic structures that are species specific.

(2) The ecological engineers show significant effects on soil processes and on other soil organisms via the biogenic structures.

(3) Agricultural intensification produces contrasting effects on the communities of ecological engineers that alter their impact and can result in variations in community composition.

The testing and validation of these hypotheses has resulted in the establishment and description of the functional role of the ecological engineers in the soils of the Colombian savannas and an evaluation of the effects of agricultural practices on their populations.

4.1. M. carimaguensis as a soil ecological engineer

By definition, ecological engineers are organisms that show the facility to alter the availability of resources for other living organisms through the production of biogenic structures (Jones et al., 1994). Numerous macro-invertebrates comply with this definition of ecological engineers. *M. carimaguensis* corresponds to a particular type of ecological engineer. This species in effect modifies the environment by passing materials (leaf litter, humus and soil) from one physical state to another. This transformation is achieved mainly through a mechanical process (creation of macropores, incorporation of leaf litter into the soil and the formation of stable aggregates). The structures produced, i.e. galleries and casts, constitute a resource (microhabitat and trophic resource) that is directly available to macro-invertebrates and plant roots. In a more indirect way *M. carimaguensis* transforms the soil from its initial physical state into a bio-perturbed state through a series of modifications of the physical properties, the organic matter dynamics, the availability of nutrients and finally, a positive effect on plant growth.

In summary *M. carimaguensis* has three types of effects as a soil ecological engineers by producing the biogenic structures (Decaëns, 1999): (i) they serve as a trophic resource for *Andiodrilus* n. sp. and Ocnerodrilidae n. sp. that ingest them, and as a spatial resource as it creates space for certain macro-invertebrates, for example the galleries and/or under the casts; (ii) they physically modify the availability and quality of the resource in an even more indirect way, through the modification of the soil structure, organic matter dynamics and nutrient availability to plants; (iii) they transport some organisms and allows them be in contact with the resource.

The functional attributes of a species or functional group are considered at different levels of organization through the hierarchical systems. As the scale of observation increases from the nearest to the furthest, the levels describe the same processes. A first ascending approximation has shown that the biogenic structures produced by *M. carimaguensis* have influenced the soil structure, the dynamics of soil organic matter, the macrofauna and the growth of plant roots. In an descending approximation the effect of *M. carimaguensis* in the ecosystem continues to be appreciable, if not marked, i.e. it remains progressively marked by the effects produced by other communities of organisms and by environmental factors that regulate soil processes through the hierarchical scale.

4.2. Typology of the biogenic structures

The soil ecological engineers of Carimagua produce biogenic structures with particular physico-chemical characteristics that are species specific and that are generally different to those of the surrounding soil. This opens the possibility of a new classification of ecosystem engineers based on the functional attributes of the biogenic structures without taking account of the taxonomic aspects (Decaëns unpublished)

As we have mentioned before *M. carimaguensis* produces visible effects at different scales in some ecosystem processes measured. Its activities decrease soil compaction, an effect that balances the compacting effect produced by the production of large compact excretions. In addition the effect of

Ocnerodrilidae n. sp., and its probable marked and important effects on the structural stability of the soil even if its effects on plant growth are small must be considered in further studies.

5. Management guidelines of beneficial fauna

The research presented here and those from the literature guards against making general guidelines for the management of soil macrofauna. Certain practices such as improved pastures can undoubtedly result in increased populations of soil macrofauna. However, these can be beneficial as in the case of *M. carimaguensis* in the Colombian savannas or detrimental, e.g. *P. corethrurus* in Amazonian pastures, where the loss of a diverse soil fauna is responsible for pasture degradation and not the presence of this peregrine species. The similarity of the original ecosystem and the derived agroecosystems tends to be the major factor determining the survival and adaptation of native species, their resilience and stability within the boundaries of ecosystem management.

It is clear that there needs to be an understanding of the general biology and ecology of the macrofauna in any particular environment before guidelines can be established. This involves labor-demanding activities that have restricted the number of studies to a few in the tropics. Such an understanding needs to focus primarily on the main species that are ecological engineers as the effects of these species tend to dominate other effects of changes in macrofauna populations. The case of *M. carimaguensis* in the Llanos is an exception to date in that increased populations that result from pasture introduction tend to have an overall beneficial effect. This is a unique example where conservation, productivity and sustainability of an agroecosystem is maintained and improved.

The spatial arrangement of pastures alongside cultured plots can result in a faster recovery of the macrofauna populations in the cropped plots. This management practice needs further exploration especially when the beneficial species, that can be more rapidly established, can also help reverse some of the degradative effects of cropping on the soil structure. This may help avoid the need for expensive machinery-intensive solutions to soil degradation problems. Earthworms then can be considered a resource that can be harnessed to achieve better ecosystem health.

The spatial arrangements of plots that conserve earthworm populations alongside those that tend to reduce populations are an example of indirect management. Figure 4 shows how this technology is an example of the management options currently available.

Even though a large number of species that can be called ecological engineers exist and that these can affect physical changes in the environment, not all of the changes will have important ecological consequences. Some ecological engineers have only small effects on the ecosystem. These effects can be very marked with some engineers via the action of their functional domain. This depends on a series of factors that include population density, local and regional spatial distribution and the type and formation of physical structures that they produce. However it is important to identify the species present in the soil, the structures they produce and to describe in detail the mechanisms through which the ecological engineers affect the soil environment. The trophic interactions and indirect interactions can be included in predictive models of the effects of the ecological engineers. There models will be particularly useful for agroecosystems that the aim to improve the sustainability of the systems through an increase and/or diversity of the soil macrofauna. The models could also be used to investigate hypotheses on the function of biodiversity in agroecosystems.

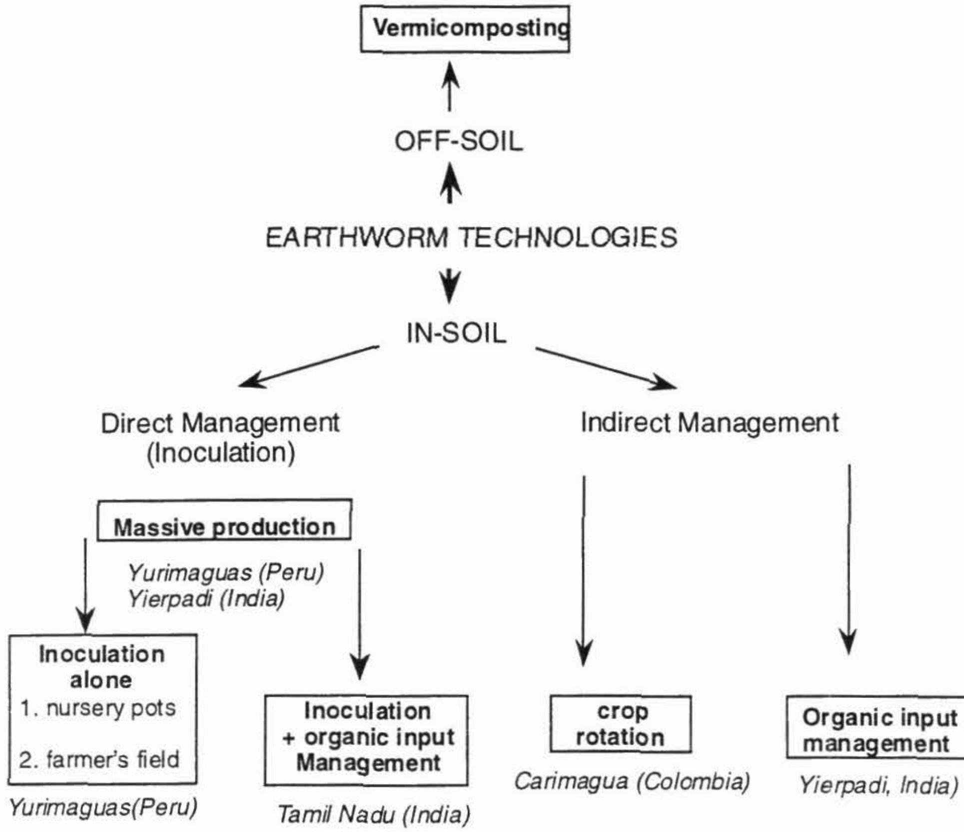


Figure 4. Management alternatives for earthworm technology (Senapati et al., 1999).

We have learned that the management of earthworm biodiversity in agroecosystems should favor a community that consists of one or more epigeic species and one or more anecic species that construct vertical galleries, produce biogenic structures on the soil surface and mix plant residues with the mineral soil substrate. Additionally there should be one or more endogeic species that feeds on the soil organic matter, root exudates and plant roots and that forms horizontal galleries. The earthworm community in Carimagua is such a community and it is possible to suggest a management of these communities in the agroecosystems studied.

The management options for earthworm activities should consider the following aspects:

- The community of soil ecological engineers in the agroecosystem should be the same as that in the original ecosystem (normally a natural ecosystem).
- The engineer organisms in the soil and in particular, *M. carimaguensis*, influences different processes of soil fertility.
- The activities of the soil engineers are well developed under improved pastures and strongly diminished in monocultures.
- The effects of the engineers are manifested over time through the biogenic structures that persist in the environment even after the disappearance of the organisms that form the structures.

Both Ocnerodrilidae n. sp. and *M. carimaguensis* are the only species that tolerate the intensification associated with continuous monocropping. Ocnerodrilidae n. sp. is a polyhumic endogeic that tolerates tillage because of its small size. *M. carimaguensis*, in addition to its survival strategy for the unfavorable dry season during which time it occupies the deeper soil layers, also has the ability to migrate to the soil surface. The colonization by *M. carimaguensis* of earthworm-poor plots could be facilitated by inoculation of the plots. Crop rotations associated with a monoculture and a pasture phase of several years can also favor the development of significant populations of earthworm species. An agricultural system that conserves earthworms could be established by: (a) native pastures that serve as reserves of biodiversity,

(b) forages used as protein banks that result in the establishment of an large biomass of earthworms; (c) annual crops in rotation with pasture phases of various years length (protein bank) and/or with forages that maximize the phenomenon of migration. With this type of system the presence of the biogenic structures would be qualitative and quantitative indicators of the state of the populations of ecological engineers.

An important challenge for the near future is the identification of sustainable agroecosystems that maintain acceptable levels of diversity and biomass to optimize the activities of soil macrofauna. The research reported in the forthcoming CIAT working document is an example of the opening the "black-box" of soil biota and subsequent development of management guidelines. To be acceptable and adoptable by land users however these studies need to be combined with a larger multidisciplinary approach that includes indigenous farmer knowledge, farmer experimentation and socio-economic studies in order to achieve a diverse, productive and healthy soil via a process that increases the number of viable options for the land user.

6. Acceptance of practices by farmers

Any new management practice for the manipulation of soil organisms must be acceptable to the land user and often requires development and adaptation by the land users themselves to be successfully taken up. Our knowledge on farmer perceptions of soil organisms is still very limited. For example, recent studies on farmer perceptions of earthworms showed great variation in both farmer knowledge and use of earthworms in their agricultural systems. While farmers in Mexico were relatively well informed on the importance and benefits of earthworms in soil fertility, farmers in the Congo were poorly informed. Gender differences were also apparent in Mexican studies. It is likely that farmer knowledge of microscopic organisms is even less than that of the larger, visible organisms with perhaps only plant disease symptoms being obvious indicators of the presence of detrimental organisms. Encouragingly however farmers in Mexico were able to distinguish three or four types of earthworms on the basis of size, color and habitat but this was probably the first report of such distinguishing abilities.

In order to gain a much wider acceptance of the concepts of beneficial soil biota and of the management practices that can encourage the build up of significant populations in farmer fields, there is a need to develop a common language between farmers and scientists on soil biota. Also required is the development of simple user-friendly guidelines for the management of beneficial organisms. Farmers need to be able to distinguish for example between compacting and non- or de-compacting earthworm species. They need also simple and rapid surveying methods to be able to at least have a semi-quantitative estimate of macrofauna numbers. Scientists need to establish or verify threshold levels of organisms or populations that are required for significant effects on soil processes and plant production.

These tools and decision guides need to be developed by farmers and scientists together, incorporating the existing indigenous knowledge and where it does not exist, educational material suitable for readers and non-readers is required. Examples of such material are available. For example a series of guides for the management of natural resources up to the watershed level has been produced (CIAT, 1999). These provide examples of how to identify and develop an approach to the goals of resource management and how to encourage the development of user-friendly material by land users and other stakeholders such as extension workers and non-governmental organizations. Training modules on soil biota are currently being developed.

7. Future research needs

To synthesize the knowledge gathered in these studies a model of indirect management of earthworm activities is being developed with the objective of optimizing the beneficial effects of earthworms in the agroecosystems (Figure 5; Mariani, unpublished). The aim of the model is to establish a permanent fauna activity in the soils of different agroecosystems.

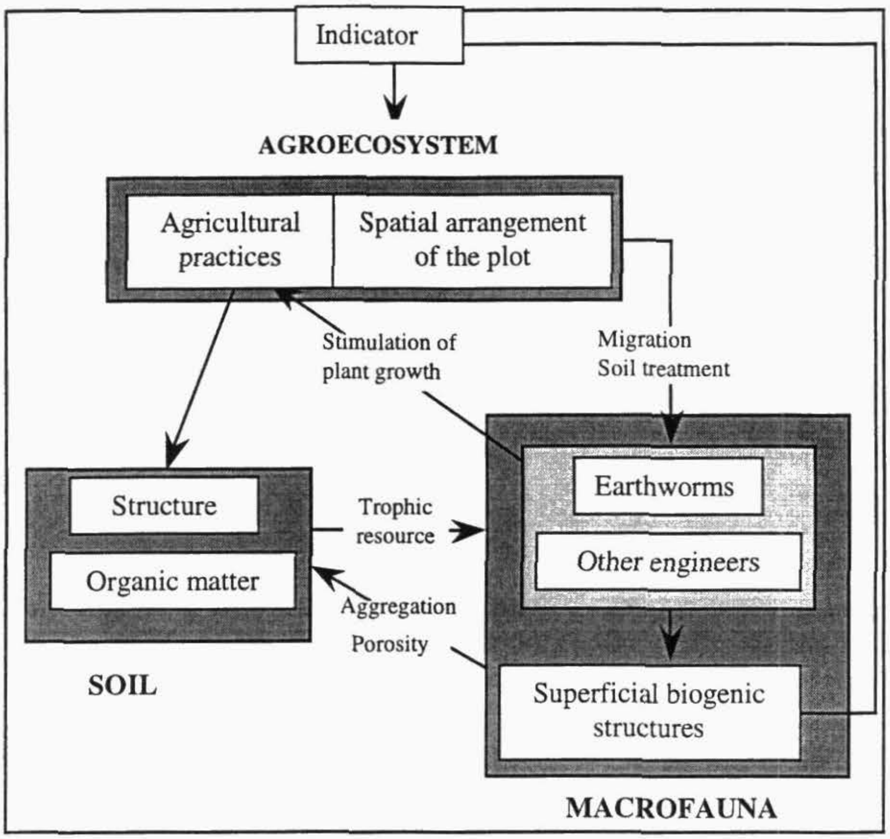


Figure 5 Proposed management model for earthworm populations and other engineers (Mariani, unpublished)

The monitoring of the biogenic structures produced by soil ecosystem engineers is a first step to understanding the links between biodiversity and its functioning. Together with this preliminary approach it is necessary to strengthen the efforts to understand the functional aspects of these structures through studies at different spatio-temporal scales, from the scale of the structure to the plot or population. The dynamics of the biogenic structures during ageing and the accompanying effects on different soil properties should be also considered. Then soil ecosystems engineers may be classified according to their effects on soil structure and nutrient dynamics, on the biodiversity of other soil organisms and on primary plant production. The development of alternative management options requires further detailed studies if we wish to prevent or reverse soil degradation through the directive use of the activity of the ecosystem engineers that have a significant and positive impact on soil structure and fertility. In addition the conservation of a diversified soil fauna with epigeics, endogeics and anecics will also favour the none ecoystem engineers, i. e. epigeic species or litter transformers. We can therefore optimize and increase soil beneficial organism activities within the scale of the plot and/or agroecosystem.

Within the **scale of the plot** the carrying capacity of selected species might be increased. To achieve this objective we need to know the sensitivity of different species to agricultural practices such as tillage, the use of fertilizers and pest control and to different feeding regimes.

At the **scale of the agroecosystems or land management practice**, studies are needed on the capacities of key species to migrate from pastures and the native savannas with high levels of biodiversity to land management systems such as cropland with low levels of biodiversity.

Biogenic structures can be used as an **index of engineering activities** in cultivated plots. This could be an indicator that can serve as a proxy for the more laborious measurement of populations of ecosystem engineers. If the dynamics of the biogenic structures are understood, i.e. their production and degradation, it may be possible to establish critical densities that can be used as early warning indicators of the effects of a change in agricultural practice.

The difficulties of studying scales greater than that of the size of the biogenic structures has been a handicap and hence most of the chapters on the effects of ecological engineers have been done at this scale. Studies that establish the functional role of soil organisms and options to optimize these activities through an integrated management model in agroecosystems are still required.
Firstly it is necessary to characterize the biogenic structures produced by other earthworms in order to test the hypothesis that the effects noted on soil processes are indeed hierarchically regulated. Weed dynamics and activities of earthworms are also worthy of further study, as is the role of earthworms in the dispersion of mycorrhizal propagules and in the stimulation of microflora.

There is a need to investigate the role of macrofauna in the degradation of tropical pastures especially in the Brazilian "cerrados" where, unlike Carimagua, there is evidence of physical, chemical and biological degradation. The causes of degradation are not clearly known for pastures of the humid tropics (Fisher et al., 1995). The possible contribution of endemic species that are adapted to the changes in the ecosystem, ought to be considered in order to design practices with less damaging effects on the ecosystem. With this knowledge it may be possible to improve sustainability via the manipulation of the biological resources that could maintain the fertility of natural ecosystems and achieve high levels of primary productivity on infertile soils.

The bio-indicators of diversity and soil quality are important themes that ought to be considered as a priority for further research. An index is estimated from the presence and abundance of the most sensitive groups of macrofauna and related to agricultural practices in order to evaluate the value of biodiversity in terms of the maintenance of soil physical properties, the conservation of organic matter and primary production. It may be possible to estimate an indirect index through multi-variate analysis that establishes the relation between biodiversity, structural function and physical and chemical properties of the soil. These studies taken together will result in a better management of the agroecosystems where productivity, sustainability and conservation of the natural resources are integrated.

Finally the adoption of practices that encourage or stimulate the establishment and /or maintenance of significant macrofauna populations requires efforts in training and the encouragement of farmer research. This will vary from country to country and from region to region. A common language for land users and scientists needs to be developed so that the principles and concepts for the management of beneficial soil organisms can gain widespread acceptance and be further developed by the land users themselves.

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Contributors:

J. J. Jiménez, M. J. Fisher, R. Thomas (CIAT), T. Decaëns (Université de Rouen), L. Mariani, P. Lavelle (IRD).

Output 3. Impacts of improved practices on production, the environment and socioeconomic conditions assessed.

- A training course on the economic assessment of soil erosin and nutrioent depletion was held in Nicaragua in October 2000 with MSEC.

***Output 4.* Improved information and communication exchange framework established and materials produced for stakeholders.**

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- The local soil quality indicator guide is available in Spanish and English and a version suitable for east African conditions is under preparation

Output 5. Stakeholders capacity for better SWNM enhanced.

- Twelve field days were held in Pescador (January-September/2000), Cauca, Colombia with the participation of 276 visitors mainly farmers, extensionists and students from universities and schools; and one field day for Swedish Agricultural University (SLU) researchers was held in San Dionisio, Nicaragua.
- A methodological guide entitled "Indentifying and Classifying Local Indicators of Soil Quality. East African Version. Participatory Methods for Decision Making in Natural Resource Management." was prepared.
- A training course entitled: "Local Indicators of Soil Quality", was held in Mukono, Uganda and sponsored by the CIAT, SWNM and AHI .

Output 6. Efficient program management, communication, monitoring and evaluation.

- A four-member steering committee was appointed for the MIS consortium with members from Nicaragua and Honduras
- The MIS consortium established its own webpage at www.mis@optinet.hn
- The MIS consortium has held two meetings during 2000.
- The first across consortia activity was the training event on economic costs of soil erosion and nutrient depletion held in October 2000.
- A joint post-doctoral fellow appointment with TSBF under the CNDC has entered its third and final year.

4. Publications 1999-2000 supported by MAS/MIS funding

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8. Decaëns T., Mariani L. , Betancourt N., Jiménez J.J. Earthworm effects on permanent soil seed banks in Colombian grasslands. Submited to Ecography.

9. Decaëns T., Jiménez J.J., Barros E., Chauvel A., Blanchart E., Fragoso C., Lavelle P. Soil macrofaunal communities in permanent pastures derived from tropical forest or savanna. Submited to Acta Oecologica.
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5. Staff and partners

CIAT:
R.J. Thomas, Soil Microbiologist
E. Amezquita, Soil physicist
E. Barrios, Soil Biologist
I.M.Rao, Plant nutritionist
M. A. Ayarza, Agronomist/Soil Chemist

Post-doctoral fellows:
J.J. Jimenez
T. Decaens

MIS Steering Committee:

Pedro Pablo Orozco, PRODESSA, Nicaragua
Matilde Somarriba, UNA, Nicaragua
Elizabeth Santacreo, DICTA, Honduras
Martha Andrews, Zamorano, Honduras
M. Ayarza, CIAT

Partners:

NARS:
CORPOICA – Popayán, Colombia; R. Torres
CORPOICA – Montería, Colombia; S. Cajas
CORPOICA – La Libertad, Colombia; A. Rincón, R. Valencia, D. Aristizábal, E. García, J.H. Bernal.
CORPOICA – Macagual, Colombia, C. Escobar
EMBRAPA-CPAC, Brazil: L. Vilela, D. Resck, C. Magno da Rocha, A.G. de Araujo, J.E. da Silva.
EMBRAPA-CNPAB, Brazil; R. Boddey, S. Urquiaga, B. Alves
APDC (Associaçao de Plantio Direto No Cerrado), Brasil: Prof. Ronaldo Trecenti

NGO'o:
CIPASLA, R. Rivas
CENIPALMA, P.L. Gómez, F. Munevar
CENICAFE, H. Rivera, S. Suárez
CORPOTUNIA, W. Cifuentes
CRC (Corporación Regional del Cauca), J. Chavez
FEDEARROZ, G. Preciado, A. Castilla, A. Salive
CIPAV, E. Murgueitio, S. Siadieagien
CIDIAT, Venezuela – R. Lopez

COLCIENCIAS, G. Urrego
INPOFOS, Ecuador – J. Espinosa
MONOMEROS COLOMBO-VENEZOLANO, R. Guerrero
CENIPALMA, P.L. Gómez, F. Munevar

Regional Universities:
Lavras, Brazil; Prof. A.S. Lopes
Uberlandia, Brazil; M. do Schneider, R.S. do Carmo Lima

Specialized Institutions:
Bayreuth University; Prof. W. Zech, W. Wilcke, J. Lilienfein, A. Freibauer, H. Neufeldt, R. Westerhoof, T. Renz, T. Thile, S. Fuhrmann, V. Laabs, W. Amelung.
Cornell University, USA; Prof. J. Duxbury, F. Fernandes
Michigan State University, USA; Prof. J. Ritchie, S. Daroub
University of Paris/ORSTOM, France, Prof. P. Lavelle
University Bangor, Wales, UK; F. Sinclair
Technical High School, Univ. of Zurich, Switzerland; A. Oberson, M. Frossard
Agricultural University of Norway, Norway; Prof. B.R. Singh
University of Hohenhein, Prof. R. Schultze-Kraft, D. Leihner
ETH, Zurich, Switzerland

International Agricultural Research Centers:
CATIE, Costa Rica; D. Kass, J. Beer
ICRAF, Kenya; P. Smithson
IBSRAM, Thailand; R. Lefroy
IFDC, USA; D. Friesen

National Universities:
Universidad Nacional de Colombia, A. García, E. Madero, E. Escobar, M. Sánchez, M. Prager.
Universidad de Nariño, Hugo Ruíz
Universidad del Cauca, Popayán, P.Cerón
Universidad de los Llanos, G. Romero
Universidad del Tolima, H.F. Libreros
Universidad de Caldas, W. Chavarriaga
Universidad Distrital de Bogotá, G. de las Casas
Universidad Centro Americana, Managua, Nicaragua, A. Grijalba
Universidad Nacional Agraria, Managua Nicaragua, M. Somarriba
Escuela Agrícola Panamericana Zamorano – Honduras, M. Andrews

6. Donors:

BMZ, Germany, DFID-UK, ACIAR, Australia, Ministry of Foreign Affairs for The Netherlands and Norway, SDC, Switzerland

April 25, 2000
Annex I. Logframe of the MIS consortium

Output 1 **Information on the practices and policies for the management of soils, water and nutrients compiled and available to decision makers at different levels**	**Milestones**	**Completion date**	**Responsible**	**Funds required**	**Observations**
Activities:					
1.1 Characterize the fragile soils of Honduras and Nicaragua as a function of biophysical and socioeconomic conditions.					
1.1.1 Define the geographic targets in Honduras and Nicaragua and evaluate land degradation risk.	Map of fragile soils available in a digital format.	04-9/2000	Executive committee	5.000	Requires short-term consultancies
1.1.2 Collate biophysical and socioeconomic conditions in the prioritized reference sites.	Information collated and systematized	04-9/2000	CIAT, FAO	1000	Requires help on systematization
1.2 Collate, analyze and systematize available information on the management of soil ,water and nutrients in the region					
1.2.1 Develop a user-friendly system for the soil database of Honduras as an aid to decision making.	Decision tree available in CD ROM	04-9/2000	CIAT	5000	Workshops will be necessary to consult MIS partners
1.2.2 Prepare a state-of-the-art article on the management of fragile soils in Honduras and Nicaragua.	Article submitted for publication.	06-11/2000	Executive committee	5000	Requires short-term consultancies
1.3 Organize methodological and technical workshops and seminars to identify demands and opportunities for research.					
1.3.1 Organize a forum on methods to systematize experiences of soil, water and nutrient management.	Innovative forms of systematized information identified	09/2000	To define	8000	Requires an identification of an organizer
1.3.2 Attend fora and workshops to identify options and demands for research.	Options and demands for research identified	Pending	Executive committee	2000	Participation of the consortium members required
1.4 Facilitate exchange of information amongst the consortium members and other consortia through e-mail, bulletins and technical visits.					
1.4.1 Design a consortium WEB page with periodic update.	Information produced by the consortium is readily	05/2000	R. Thomas	500	Logistical support from CIAT

Output 1 **Information on the practices and policies for the management of soils, water and nutrients compiled and available to decision makers at different levels**	**Milestones**	**Completion date**	**Responsible**	**Funds required**	**Observations**
	available				
1.4.2 Prepare bulletins on consortium activities three times per year.	Consortium members and others become familiar with the consortium activities.	05- 09-12 /200	R. Thomas	500	Logistical support from CIAT
1.4.3 Document experiences of watershed management by consortium members	A document on the synthesis of watershed management experiences	2001	To be identified	5000	Proposal required.
1.4.4 Promote the creation of thematic network discussions with members of the *SWNM consortia*.	Electronic network on watersheds established.	06/2000	Executive committee	200	Identify collaborators

Output 2 **Production systems with improved use of soils, water and nutrients.**	**Milestones**	**Date of completion**	**Responsible**	**Funds required**	**Observations**
Activities:					
2.1 Develop improved practices, biophysical and socioeconomic indicators for the sustainable management of soils, water and nutrients at the farm, microwatershed and landscape level.					
2.1.1 Identify and adapt soil degradation indicators with an emphasis on soil structure, organic matter and biological activity.	Research proposals supported	Pending	Consortium members	5000	Research proposals
2.1.2 Organize an international workshop on methods for the economic evaluation of erosion and loss of nutrients.	Experiences from MSEC disseminated and analyzed	Pending	Executive committee	8000	Workshop organized with MSEC
2.2 Develop crop/tree/pasture options that are productive and more efficient in resource use.					
2.3.1 Select and test multiple purpose annual and perennial species for soil and water conservation and nutrient recycling.	Promising system components identified	Pending	Consortium members	10.000	Research proposal
2.3.2 Characterize the existing production systems in consortium reference sites.	Baseline database produced	04-08/2000	CIAT, FAO ADDAC	2500	Short-term consultancies
2.3 Determine the impact of traditional and improved systems on soil quality and water availability at the level of the watershed.					
2.4.1 Study the flow of water and nutrients in traditional and improved systems at the level of the micro-watershed.	Proposed prepared and sumitted for funding.	12/2000	University of Bayreuth (Germany)	10000	Partial funding from MIS
2.4.3 Quantify the effect of some promising systems (cover crops, quezungual, etc) on soil quality and water availability.	Methods discussed and implemented in the field	06/2000	Consortium members	10000	Proposal for funding
2.4 Alternative sources of fertilizer researched and validated at the farm level.					
2.5.1 Study the efficiency of combinations of inorganic and organic resources for the production of crops.	Field experiments established in reference sites.	05/2000	CIAT, FAO, ADDAC	10000	Proposal for funding
2.5.2 Validate the decision tree for organic material with TSBF.	Validation data available	06/2000	CIAT	2000	Participation of TSBF

Output 3 **Technological options disseminated and adopted by small scale producers.**	**Milestones**	**Date of completion**	**Responsible**	**Funds required**	**Observations**
Activities:					
3.1 Prepare/ validate, adapt and disseminate guides and manuals for the management of validated options					
3.1.1 Exchange guides and manuals for the management of soils, water and nutrients with other consortia of the SWNM.	Materials available for future evaluation	Pending	Executive committee		Interchange of information with other consortia
3.2 Stimulate the participation of different actors in the process of research and diffusion of the options for the management of soils, water and nutrients.					
3.2.1 Workshop to identify participatory methods to evaluate the options for better SWNM..	Perceptions of the producers included	10/2000	Executive committee	10000	Define the themes and participants
3.3 **Increase the awareness of all sectors of the environmental impact of mismanagement of soil and water resources.**					
3.3.1 Participate in fora and other events to present the results and advantages of integrated soil management..	Consortium products disseminated	Permanently	Consortium members	2000	Support is given to participation in events where MIS is represented.
Output 4 **Efficient participatory management of the consortium**					
4.1 Four working group meetings of the executive committee per year.	Workplans revised	03- 06-09-12/2000	Executive committee	15000	Alternating meetings to be held in participating countries
4.2 Define the functional roles of the executive committee.	Functional roles defined and approved by the consortium.	06/2000			
4.3 Prepare an annual report of the consortium activities.	The SWNM becomes familiar with the MIS consortium activities	09/2000			

Output 3 **Technological options disseminated and adopted by small scale producers.**	**Milestones**	**Date of completion**	**Responsible**	**Funds required**	**Observations**
4.4 Revise research proposals.	Proposals evaluated and financed.	05- 08/2000			
4.5 Revise publications produced by consortium members.	Quality control system established. Data sharing document agreed on.	08/2000			
4.4 Management of the consortium funds and budgets.	Budget managed efficiently				
4.5 Analyze and approve proposals presented by consortium members.	Proposals prioritized and approved.				
4.6 Organize meetings and workshops	Interchanges of information and results achieved.				

Theme 3. Managing Soil Erosion Consortium

I. Introduction and overview

The year 1999 ended with a comprehensive review and evaluation of the progress of MSEC during the 4th assembly held in the Philippines. From then on, other related reviews were participated in by the consortium at the beginning of 2000. The IBSRAM internal program review (IPR) was held from January 17-20 in Bangkok. Together with the other programs of IBSRAM, the accomplishments and plan of work of MSEC were presented and reviewed by the Management, the Research Team and two members of the IBSRAM Board. With the other consortia, it was also reviewed during the SWNM Program Review conducted from 21-23 February at ISRIC, The Netherlands. From 29-31 March, Dr. Thomas Rosswall visited IBSRAM to complete his review of the four consortia under the SWNM initiative. In addition to assessment of the accomplishments of MSEC, recommendations on how it could effectively link with the other consortia and add value to the system-wide programs of the CGIAR was made. From 25-28 May, Dr. John de Boer of Winrock International also visited IBSRAM to evaluate the impact of ADB-supported projects on natural resources management. MSEC was a major focus of the review.

The comments and recommendations during these reviews were valuable inputs to further refine the MSEC plan of work for the year 2000. The new log frame developed for the SWNM program further supported the identified outputs of MSEC (Table 1a, 1b). The log frame listed six major outputs: 1) Decision support tools and guidelines, 2) Improved technologies and land management systems, 3) Methodology for assessment of impacts, 4) Information and communication strategies for improved dissemination and sharing of results, 5) Enhanced capacity of the NARES, and 6) Improved program management, monitoring and evaluation.

The first four outputs are addressed by implementing MSEC's activities on catchment research and information dissemination and sharing. A strong focus on governance as a built-in mechanism of MSEC implementation addresses the output of improved program management, monitoring and evaluation. Enhancing the capacity of the NARES is addressed through MSEC's human resources and institution development component.

2. Highlights of progress in outputs of the SWNM logframe

Output 1. DS Tools and guidelines for improved SWNM developed and ...

1.1 Methodologies for economic assessment of soil erosion developed and tested

- The methods for the economic assessment of the on- and off-site impacts of soil erosion has been prepared and published as ISLM No. 2
- Based on these methods, a draft guideline for socioeconomic site characterization has been prepared.
- Draft guideline discussed during the meeting with the NARES in April and July in Bangkok. It now serves as the basis for the data collection being conducted in the field
- Analysis of the results and evaluation of the guideline is ongoing

Output 2. Improved technologies for increased production .....

2.1 Improved practices for fragile soils at different scales developed

- Representative of model catchments in Indonesia, Laos, Nepal, Philippines, Thailand and Vietnam have been fully characterized and instrumented for soil erosion and hydrological measurements. At least four micro-catchments of different land uses within the selected catchments have also been characterized and instrumented.
- The benchmark survey and characterization, calibration of the catchment sites and the conduct of the on-farm research are ongoing. These activities are expected to generate the needed information to identify alternative technologies and land management systems that will be acceptable to major stakeholders.
- Analysis and evaluation of indigenous technical knowledge and related land use policies are also being done.
- Interventions will be introduced later after getting some baseline information and consultation with the farmers.

Output 3. Impacts of improved practices on production etc. assessed

3.1 Common approach to impact assessment elaborated and impact studies conducted

- The IBSRAM ISLM No 4 publication (IBSRAM's impact: Making the difference in sustainable land management research) is being reviewed and adapted for application in evaluating IBSRAM projects. The paper "A framework for impact assessment: Its application to evaluating IBSRAM programs" is prepared for presentation at the International Conference on Impact of Agricultural Research and Development in Southeast Asia from 24-26 October 2000 in Phonm Penh, Cambodia.
- A literature review of impact assessment of the participatory approach to sustainable land management research is also being done.

3.2. Apply methodologies for economic ....

- The developed methodological guidelines for the economic assessment of soil nutrient depletion will be applied by IBSRAM-Africa to urban and peri-urban agriculture in the frame of a FAO funded economic environmental impact assessment (10/2000 – 12/2001)

Output 4. Improved information dissemination and communication ....

4.1 Analysis of successful catchment management studies conducted

- Literature review in preparation.

4.2 Develop and disseminate user friendly information on SWNM practices

- IBSRAM-Africa published a framework for the economic assessment of soil nutrient depletion (ISLM 7). *Target group: Scientists*
- IBSRAM-Africa published a farmer version of IBSRAM's ISLM 7 "tool" on the economics of soil nutrient depletion. *Target group: Farmers*
- IBSRAM-Africa prepared a policy brief related to ISLM7 addressing the economics of soil nutrient depletion (*Target group: Policy makers*) and posted it on IBSRAM's web page.

- Various MSEC reports and information have been prepared for donors and readers of IBSRAM's Highlights 2000, IBSRAM's Newsletter (no 55, 56 and 57), and the *Sustainable Land Management Network* (SLMNET) electronic listserver.

- MSEC produced the following technical papers for meetings and conferences

    a. Bricquet, J.P, T. Phien, and T. Tran Duc. 2000. Impact of agricultural practices on erosion: A case study of Vietnam. Paper presented at the 1st Symposium on gully erosion under glogal change. 16-19 April 2000. Leuven, Belgium.
    b. Maglinao, A.R. and F.W.T. Penning de Vries. 2000. Participatory research on catchment management: The IBSRAM experience in Asia. Paper presented at the Integrated Watershed Development and Management (IWDM) Planning Worshop. 8-7 August 2000. AIT, Bangkok, Thailand.
    c. Bricquet, J.P., T. Phien and T. Tran Duc. 2000. Impact of agricultural practices on erosion. A case study of Vietnam. Paper presented at the International Symposium on Sustainable land Management: paradigms for the New Millenium. 8-10 August 2000. Kuala Lumpur, Malaysia.
    d. Janeau, J.L., J.P. Bricquet, A. Boonsaner, A. Chanthavongsa and T. Tran Duc. 2000. Soil erosion and land use changes: Tools and results after one year of study in Laos, Thailand and Vietnam. Paper presented at the ISCO Conference, 22-27 October 2000, Buenos Aires, Argentina.
    e. Bricquet, J.P., T. Phien and T. Tran Duc. 2000. Are agricultural practices responsible of erosion? A case study of Vietnam. Paper presented at the ISCO conference, 22-27 October 2000, Buenos Aires, Argentina
    f. Agus, F., J.P. Bricquet, Sukristiyonubowo, T. Vadari and T. Enters. 2000. Managing soil erosion in Kaligarang catchment of Java, Indonesia. Paper presented at the ISCO Conference, 22-27 October 2000. Buenos Aires, Argentina.
    g. Maglinao, A.R. 2000. A framework for impact assessment: Its application to evaluating IBSRAM programs. Paper presented at the International Conference on the impact of Agricultural Research and Development in Southeast Asia. 24-26 October, Phnom Penh, Cambodia

5. Stakeholders capacity for better SWNM enhanced

5.1 NARES staff trained on SWNM ...

- Twelve (12) NARES MSEC partners attended the training workshop on GIS, Economic Valuation of Environmental Impacts and Statistical Techniques, in Bangkok from 24-29 April 2000. While the participants voiced the limited time that has been provided, they mentioned that they learned a lot from the workshop.
- From 5-7 July 2000, MSEC conducted a follow-up meeting on socioeconomic site characterization and on-farm research in Bangkok. This time, 13 NARES partners presented the initial outputs of their socioeconomic site characterization and further learned on how to data collection and analysis, looking at both on-site and off-site effect of erosion. They were also familiarized with the guidelines for socioeconomic site characterization and reviewed their outputs vis a vis this guideline.
- In addition to conducting regular training programs, MSEC also conducts a less formal in-country training-demonstrations during the monitoring visits to the sites. These have been done during visits to Indonesia, Laos, Nepal, Philippines, Thailand and Vietnam sites.
- MSEC-CIAT/MIS training (23-27 October?).....

Output 6. Efficient program management, communication, monitoring and …

6.1. MSEC has already a scientific coordinator (Dr. A. Maglinao)

6.5 Regular meetings of scientific groups,….

- Regular monthly meeting of the MSEC group at IBSRAM has provided better interaction and sharing of ideas within MSEC, also as basis for any correspondence with the SWNM program coordination. Regular visits to the MSEC sites are still another major activity to monitor progress and anticipate problems in implementation.

6.6 Across consortia exchange…

- MSEC-CIAT/MIS training (23-27 October?)…..

3. Progress report on MSEC activities.

A. Catchment Research

- Representative or model catchments in Indonesia, Laos, Nepal, Philippines, Thailand and Vietnam have been selected, characterized and instrumented for soil erosion and hydrological measurements. A total of 30 gauging stations (weirs, flumes, sediment traps) have been set up in the experimental sites. Measuring devices such as automatic water level recorders and weather stations have also been installed.
- The biophysical and socio-economic characterization of all sites are now analyzed in accordance with the guidelines that was prepared. The essential attributes that need to be considered in the analysis and evaluation of both primary and secondary data have been identified. A more in-depth discussion of the analysis was done during the MSEC planning workshop nducted from 5-7 July 2000.
- Calibration and monitoring od the catchments are now going on in all countries. As calibration is going on, data collection is intensified as required in the conduct of on-farm research following the guidelines that has been prepared for the purpose. Initial results of the research have shown the significant influence of land use and land management on soil erosion and hydrology of the catchments.

B. Information Dissemination and Sharing

- Prepared a farmer version and a policy brief of IBSRAM's ISLM 7 "tool" on the economics of soil nutrient depletion (by our Africa office).
- Prepared news articles for the IBSRAM Newsletter (NL 55, 56 and 57) and for IBSRAM's *Highlights* 2000
- At least 3 papers prepared and presented in international conferences and meetings.
- Three related papers were submitted and accepted for presentation in the ISCO conference from 22-27 October in Buenos Aires, Argentina.
- At least 14 research topics under four major categories of agro-ecological characterization, land use and hydrology, socioeconomics, and guidelines and methodologies were identified for presentation during the MSEC assembly from 6-11 November 2000.
- Organized two seminars at IBSRAM for MSEC partners.
- Seven technical papers prepared for international meetings and conferences.
- Prepared and submitted the 1999 annual report and the first semester report for 2000 to ADB

C. Capacity Building and Institution Development

- Conducted training on GIS, economic valuation of environmental impacts and statistical techniques for 12 NARES partners (2 each from Laos, Indonesia, Philippines, Nepal, Thailand and Vietnam) on 24-29 April 2000 in Bangkok, Thailand.
- Conducted the meeting on socioeconomic site characterization and on-farm research for 13 participants (2 each from Indonesia, Laos, Nepal, Philippines, and Vietnam and 3 from Thailand) from the collaborating countries from 5-7 July 2000.
- Consultants have been tapped for the preparation of a publication on soil erosion and C-sequestration (Dr. Rattan Lal of the Ohio State University), soil erosion and hydrology models (Dr. Eduardo Paningbatan of the University of the Philippines Los Banos) and on DSS-SLM (Dr. Mohammad Rais). Consultants on policy and bioeconomic modelling are being explored.
- One graduate student from the University of Bayreuth is working in Thailand, 2 students from the University of the Philippines worked in the Philippines; 1 student from Asian Institute of Technology is interested to work in Indonesia and 1 from Kasetsart.is interested to work also in Thailand.

D. Governance

- Continued to link with IRD, ICRISAT, and University of Bayreuth for support in terms of strategic research.
- Conducted a meeting of the consortium steering committee from 13-15 June at IBSRAM, Bangkok. In addition to the business meeting of the committee, a technical session which presented and reviewed the progress of the project in the participating countries was conducted. Another meeting is scheduled during the MSEC assembly in November.
- Signed MOU with the Bureau of Agricultural Research (BAR) of the Department of Agriculture (DA), Philippines for Philippine support and collaboration with MSEC. The MOU provides for a Philippine contribution of $50,000.
- Finalized and executed the contract with Dr. Rattan Lal of Ohio State University for the preparation of C-sequestration book, with Dr. Eduardo Paningbatan of the University of the Philippines Los Banos for the identification, evaluation and validation of appropriate soil erosion and hydrology models for MSEC and with Dr. Mohammad Rais for the modification of the existing IBSRAM DSS-SLM.
- Conducted 7 monthly meetings of the IBSRAM-MSEC group.
- Conducted field and monitoring in visits in the participating countries. These visits provided the opportunity to address the problems encountered by the national partners like operation of the instruments, data collection, downloading, analysis and submission to IBSRAM. These also provide the chance to conduct more in-depth training for other partners in the field.

4. Publications

Penning de Vries, F.W.T., C. Niamskul, H.D. Bechstedt, A. Maglinao and A. Sajjapongse. 2000. Participatory approaches for sustainable use of sloping land in Asia. In: R.P. Toetter et al (eds.) Systems research for optimizing future land use in South and Southeast Asia. SysNet Research Paper Series No. 2 (2000). IRRI, Los Banos, Philippines. Pp. 203-215.

Drechsel, P. Gyiele, L. and Kunze, D. (in press) Relations between population density, soil nutrient depletion, and economic growth at the supra-regional scale in sub-Saharan Africa. *Ecological Economics.*

Drechsel, P., Cofie, O.O., Kunze, D. and Penning de Vries, F. (in press) Soil nutrient depletion and population growth in sub-Saharan Africa: A Malthusian nexus ? *Population and Environment.*

5. Staff and partners

1. Dr. Amado Maglinao, Coordinator, IBSRAM
2. Dr. Jean Pierre Bricquet, Hydrologist, IBSRAM
3. Dr. Gadsaraporn Wannitikul, Economist, IBSRAM
4. Mr. Jean Louis Janeau, Soil scientist, IBSRAM
5. Dr. Suraphol Chandrapatya, Training and extension specialist, IBSRAM
6. Dr. Frits Penning de Vries, Director of Research, IBSRAM
7. Ms. Wannipa Soda, Research Assistant, IBSRAM
8. Dr. H.P. Singh, National Coordinator, India
9. Dr. Ty Phommassack, National Coordinator, Laos
10. Dr. Fahmuddin Agus, National Coordinator, Indonesia
11. Dr. Dhruva Joshy, National Coordinator, Nepal
12. Mr. Rodolfo Ilao, National Coordinator, Philippines
13. Mr. Warin Jirasuktavweekul, National Coordinator, Thailand
14. Dr. Thai Phien, National Coordinator, Vietnam
15. Mr. Anolath Chanthavongsa, Project Leader, Laos
16. Mr. Sukristiyonubowo, Project Leader, Indonesia
17. Mr. Ram B. Maskey, Project Leader, Nepal
18. Dr. Conrado Duque, Project Leader, Philippines
19. Mr. Arthorn Boonsaner, Project Leader, Thailand
20. Mr. Somchai Inthasothi, Project Leader, Thailand
21. Mr. Tran Duc Toan, Project Leader, Vietnam

Institutional partners

1. Central Research Institute for Dryland Agriculture (CRIDA), India
2. Center for Soil and Agroclimate Research (CSAR), Indonesia
3. Soil Survey and Land Classification Center (SSLCC), Laos
4. Nepal Agricultural Research Council (NARC), Nepal
5. Philippine Council for Agriculture, Forestry and Natural Resources
6. Research and Development (PCARRD), Philippines
7. Royal Forest Department (RFD), Thailand
8. Land Development Department (LDD), Thailand
9. International Research for Development (IRD), France
10. International Center for Research in Agroforestry (ICRAF), Indonesia
11. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India
12. University of Bayreuth, Germany
13. Southeast Asia Center for Graduate Study in Agriculture (SEARCA), Philippines
14. International Rice Research Institute (IRRI), Philippines

6. Donors

Asian Development Bank (ADB), Philippines
Institute for Research and Development (IRD), France
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The governments of the Netherlands, Norway, Philippines

VIII (a) MSEC logframe

SUMMARY	OBJECTIVELY VERIFIABLE INDICATORS	MEANS/SOURCES OF VERIFICATION	IMPORTANT ASSUMPTIONS
OVERALL GOAL: To contribute to the long-term increases in agricultural productivity, poverty reduction, and conservation and enhancement of land and water resources	Reduction of soil erosion, nutrient losses and run-off and increase in agricultural production in benchmark sites; reduction of negative effects of erosion off-site	Community development plans and statistics; field survey	Participation of relevant stakeholders committed; policy environment supportive of natural resources management
PROJECT PURPOSE: To facilitate, enhance and sustain the adoption and use of land management systems that increase agricultural productivity and conserve soil and water resources	Number of stakeholders involved in project implementation	Progress reports; publications, field surveys	Stakeholders continue to be committed to participate; commitment of NARES to implement research and disseminate results
RESULTS/OUTPUTS:			
1. Decision support tools and guidelines for improved soil erosion management in catchments	Number of programs/models (DSS) evaluated and applied; number of guidelines prepared and published	Progress reports; technical publications; field surveys	Programs/models available for evaluation
2. Improved technologies and land management systems that will address both increased productivity and resource conservation	Number of improved technologies and land management systems evaluated and used	Technical reports; field surveys	NARES implement the research; benchmark sites established and maintained
3. Methodology for assessment of impacts of improved practices on production, and environmental conditions	Adaptation of methodology in other environments	Technical reports	Availability of expertise in the countries
4. Information and communication channels for improved dissemination and sharing of results	Number of communication channels developed and information materials produced	Technical reports; field surveys	Extension personnel participate
5. Enhanced capacity of the NARES in catchment research and subsequent dissemination of its results to farmers	Number of persons trained; quality and quantity of equipment provided; number of students assisted	Reports, list of training courses; training materials; list of equipment; thesis reports	Trained staff stay with project
6. Improved program management, monitoring and evaluation	Improved quality of outputs; less administrative problems; quality and quantity of collaboration	Progress reports	Project outputs made available; scientific committee starts to function

VIII (b) List of Activities for the Different Outputs

Output 1 Tools and Guidelines for Improved Soil Erosion Management	Output 2 Improved Technologies and Land Management Systems	Output 3 Methodology for Impact Assessment	Output 4 Information and Communication Strategies	Output 5 Enhanced Capacity of the NARES	Output 6 Improved Program Management , Monitoring and *Evaluation*
a. Adapting the methodologies for economic assessment of soil erosion and nutrient depletion b. Adaptation of the tool on the economic assessment of on-farm trials c. Evaluation of DSSAT and SQI to explore consequences of erosion and loss of nutrients and organic matter d. Exchange of approaches on catchment studies and standardization of methods, techniques and assuring quality e. Analysis of success stories of catchment management in Asia	a. Quantification and evaluation of the biophysical, environmental, and socioeconomic effects of soil erosion, both on-site and off-site b. Development and evaluation of catchment-based land management options that will be sustainable and acceptable to various users	a. Assessment of resources including indigenous technical knowledge (ITK) and needs with key stakeholders b. Analysis of impact of consortium model c. Evaluation of policy and institutions and assessment of impact	a. Presentation of technical papers in relevant seminars and conferences b. Preparation of annual reports and related documents c. Establishment of MSEC web page and data base and linked to SWNM web site d. Establishment and operation of a list server for sustainable land management	a. Conduct of relevant training programs b. Provision of needed equipment c. Provision of consultancy services d. Support for complementary researches of interested graduate students	a. Forging linkages and collaboration b. Periodic visits to the MSEC sites in the participating countries c. Conduct of monthly meetings, 2 SC meetings and 1 MSEC assembly

Theme 4: OPTIMIZING SOIL WATER USE (OSWU)

1. Introduction and Project overview

Goal, objective and expected outputs

The long-term goal of OSWU is defined as: Sustainable and profitable agricultural production in dry areas based upon the optimal use of the restricted available water at different scales.

The overall objective of the project is: to develop and promote adoption of integrated land management strategies and techniques that capture and retain rainwater with crop husbandry techniques that maximize productive transpiration and minimize evaporative and drainage losses, within water-efficient, productive and sustainable cropping systems.

Linkages with other consortia and networks

Through collaboration of the member countries in relevant topics and exchange of progress and planning reports, duplication of efforts should be avoided. Some of those linkages are real collaboration, while others are still in the drawing-board phase.

Within SWNMP, the one closest to OSWU is Combating Nutrient Depletion Consortium (CNDC) because of its rainfall and target area (i.e. the humid and sub-humid tropics of sub-Saharan Africa). It has been mentioned in various chapters of these proceedings that nutrient depletion has associated negative consequences for water use efficiency.

The Managing Soil Erosion Consortium (MREC) has its mandate preliminary in Asia (focus on Thailand, Indonesia, and the Philippines) with much higher rainfall, so that links will therefore relate mainly to methodological issues.

Links with Managing Acid Soils (MAS) Consortium will be limited, because of the much more acid nature of the soils and the eco-regional zone which is the hillside, savanna and forest margin agro-ecosystems of Latin America. However, this consortium started recently activities in Africa.

In most countries, OSWU members have links to specific projects dealing with the same problems of water management (e.g. CRISP in Mali, and PGRN in West Africa especially related to use and conservation of rainwater, selection of variety related to climatic constraints, and soil and water conservation. Results of the OSWU Consortium will also be of importance to the Convention to Combat Desertification, especially in the formulation of sustainable farming systems.

In the WANA region, links with the On-Farm Water Harvesting (OFWH) Consortium could comprise mainly water harvesting techniques and their development, dissemination, and impact.

In SSA, links seems to be also very natural with the Desert Margins Program (DMP), especially in the field of soil water conservation technologies. Currently, overlapping countries include Burkina Faso, Kenya, Mali, Niger, and South Africa.

In East and southern Africa, another potentially important link could be with the ASARECA network on Soil and Water Management (SWM-Net). Currently, overlapping countries include Kenya, Zimbabwe, and South Africa.

In West Africa, a possible link could also be established with the Consortium for Sustainable Use of Inland Valleys with OSWU focussing on the upland part of the watershed. Current overlapping countries include, Burkina Faso and Mali.

At the same spatial scale, collaboration with IWMI in sub-Saharan Africa could be useful (e.g. also on supplemental irrigation). IWMI works currently in the OSWU member countries South Africa and Kenya. If financial means permits, inviting countries who have experience with watershed management may also be an option.

So far, links with projects and consortia acting mainly in developing countries are mentioned. Linkages with Advanced Research Institutes (ARIs) in the developed world are also envisaged (e.g. Institute of Hydrology, UK). For instance, in the USA farmers too need to increase water use efficiency, as recently underscored.

The WOCAT Training Workshops in Niamey (May 1999) have revealed a great opportunity for linking OSWU to WOCAT. OSWU members from Burkina Faso and Niger, and ICRISAT participated. The OSWU convenors will, in collaboration with WOCAT resource persons, stimulate the use of the WOCAT approach within the consortium, especially to monitor implementation of developed technologies in the various countries.

In summary, OSWU is an open-structured consortium, and linkages with partners will be determined by demand and supply from the participating partners on the basis of commonly-set goals that increase alignment and research efficiency.

Project work breakdown structure (Annex: Theme 4-OSWU)

Project outputs and activities have been re-formulated and developed in the general OSWU Consortium proposal and given in Annex: OSWU to be implemented according to the funding level.

2. Highlights of progress in outputs of the SWNN logframe

The OSWU consortium activities are now based on overall discussion points by all consortium participants of SWNMP.

A large number of possible linkages have been identified. They include, for instance, another SWNMP consortium (CNDC), the Desert Margins Program (DMP) in SSA, the Water Husbandry Program in WANA OFWH, and WOCAT.

The assessment of impact of research and technologies aiming at optimized soil water use will have to play a major role in future OSWU activities. Using the WOCAT tools will facilitate impact assessments.

The importance of the SWNMP need to be further put in place by using standardized methods, global testing of products, and establishment and/or strengthening of long-term study sites. A meeting with stakeholders planned for 2000 will also help in further improving the integration of the four SWNMP consortia.

OSWU with the progress on the achievements given in the section below is a major guidelines for OSWU to build its research agenda on the basis of research approach adopted using the same numbering in Wageningen Report.

Output 1: Activity 1.4: Use of Crop simulation model has been planned and training courses has been conducted in WANA on CropSyst cropping systems simulation model developed by Washington State University of USA with close cooperation of ICARDA to calibrate for WANA region for further application of existing research results for assessment of larger areas under given soil and crop management practices. This needs a database on soil, climate and crop production with their management techniques, which is not easy to find because of the classical approaches in conducting trials targeted on yield data mostly. New approach is to work with minimum data set that new trials can be used for modeling purposes and previous data could be modified into this set as closest approximation. ICRISAT has worked jointly with the Agricultural Production Systems Research Unit (APSRU) to extend the APSIM modeling package to make it more useful in the African SAT. In addition. Pigeonpea and pearl millet growth and development modules – Developed from existing data sets collected by ICRISAT, manure module – Simulates decomposition and nutrient mineralization of manure in relation to manure quantity and quality, phosphorus module developed by APSRU with assistance from ICRISAT and weeds module integrated in APSIM for Maize are in use at ICRISAT for African SAT regions.

Output 1: Activity 1.5: Key research and development issues in the context of optimizing soil water use are soil surface management to increase infiltration and decrease run-off and evaporation, and the manipulation and adaptation of cropping systems to optimize crop water use. Ways to optimize soil water use in low-input production systems will often be different from those in high-input situations. A decision tree for the choice of optimum technologies was developed for use by researchers, extension agents and farmers as given elsewhere (van Duivenbooden and Bielders, 1999).

Output 2: Activities 2.1: Technologies for reducing the production risks in drought prone areas are frequently referred to as soil and water conservation technologies. These technologies are focussed on reducing runoff water losses, on runoff water collection or on harvesting and storage of runoff water for later use, sometimes in combination with soil fertility management practices. Such technologies include the Zaï, half-moons ("demi-lunes"), stone bunds, as well as surface management practices as tied-ridging and plowing or crop residue management. Such technologies are mostly related to appropriate soil management (including no-till options for conservation) , use of adapted crop cultivars, inorganic fertilizer, crop residue management, cropping system management, pest control, and integrated watershed management with the combination of these factors as indicated under .

Output 3: Activity 3.1: The potential impact of OSWU research was evaluated using the belief network approach. Preliminary analysis using a simple belief network shows that, if OSWU takes a multi-disciplinary approach, the impact on agricultural production could be significant in areas with a high demand for OSWU technologies and where there is significant scope for yield improvement (Batchelor et al., 1999). However, impact of improved SWNM practices is under discussion with the partners from centers and NARES. It is obvious that research is restricted to the level of fields of a few farmers only, and that a collaboration with Non-Governmental Organizations (NGOs) and development projects is indispensable to obtain impact in larger areas. Taking stock from experiences obtained elsewhere, as documented through the WOCAT (World Overview of Conservation Approaches and Technologies) program for West Africa (Bielders et al., 1999), is also essential to avoid duplication of efforts.

Output 3: Activity 3.3: Ex-ante analysis of long-term crop rotation trials in WANA has preliminarily shown that replacing fallow by food and forage legumes, cumin, oilseed crops, melon and water melon etc. in rain-fed production systems increase rain-water use efficiency to double compared with fallow-cereal system. In addition, the legumes had a positive affect on soil organic matter, which has been increased from 1.05 to 1.3% in about 8 years in a clay loam soil.

OSWU steering committee meeting was held between 24-27 October, 2000 to discuss the common approaches accepted in SWNMP Wageningen Meeting as given in Logframe and Budget sheet.

3. Progress Report on OSWU activities reported under the SWNM logframe format

Output 1:
Decision support tools for improved [more productive and resource-use efficient] SWNM developed and evaluated in different agro-ecological zones:

Activity 1.4. Improvement, evaluation, and comparison of crop/systems models and fostered application thereof

The minimum data set forms have been sent to all members for collection of the soil weather and crop data available to start for comparisons of different models. A Ph. D student is already studying at ICARDA the crop parameters development for simulation models. It is a continuous process and needs time for tangible outputs. Previous work for WANA region could be given as an example for such output as published by Pala et al. (1996). Cropsyst have been evaluated in many parts of the world, particularly in Mediterranean-type environments and continental-type climatic environments as well.

ICRISAT has worked jointly with the Agricultural Production Systems Research Unit (APSRU) to extend the APSIM modeling package to make it more useful in the African SAT. This has resulted in the development of several new modules such as:

- Pigeonpea growth and development module
- Pearl millet growth and development
- Manure module – Simulates decomposition and nutrient mineralization of manure
- Phosphorus modules now needs testing in the field
- Weeds module

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. Some testing has already been done and reported (see section 5), and more is in progress. For some applications, for example for applications involving farmers, it is deemed sufficient to do a 'sensibility' test, which could be used by doing a run of the model against last year's weather data and seeing how well the model approximated last year's data.

Activity 1.5. Decision tree for efficient rain water use

A decision tree for the choice of optimum technologies was developed for use by researchers, extension agents and farmers as reported by van Duivenbooden and Bielders (1999). In the semi-arid regions, the choice of technological options that can be used for optimizing rainfall water use will depend on the relative risk of occurrence of climatic or edaphic drought as well as on the ability of crops to make optimal use of water stored in the soil. If a high risk of climatic or edaphic drought exists, technologies must be implemented to deal with this problem first, to ensure that technologies aimed at optimizing soil water use will be profitable. This decision tree has been used by researchers working in the OSWU and it has been disseminated through researchers to extension agents and farmers within the OSWU mandate countries. However, it is a simple logical framework that could be utilized by everybody concerned after the publication is disseminated. Work suggested under 1.4 will contribute towards water use efficiency, providing data and information to OSWU.

(ICARDA/ICRISAT) will work on the definition of technologies in a more attractive format at their earliest convenience (Activity 1.5.1).

As follow up activity (1.5.2), it will be sent to the following countries for introduction to and distribution of the DSS for use and feedback from extension agents and farmers to be monitored and reported.

Output 2:

Improved technologies for increased production based on efficient use of water and nutrients adapted and applied by land users:

Activity 2.1. Develop improved practices for fragile soils at different scales e.g., crop/tree/pasture systems

2.1.1. Different Management options (Tillage, sowing date, planting pattern and weed contol) for optimizing soil water use in Morocco

a) Effect of planting pattern on yield and water use efficiency of bread wheat in semi arid regions of Morocco:

The main objective of this study is to assess how a planting pattern change through variation of seeding rate and seeding method can affect bread wheat production and water use efficiency, under semi arid conditions in Morocco. Two experiments will be carried out on bread wheat in chaouia region: one at the experiment station (Jemaa Riah- Aridoculture center) and the second at a farm level in a larger scale. Studied Factors planting methods (12-cm row spacing, 24-cm row spacing and broadcast) and seeding rates (200 and 400 kernels/m²). To evaluate the effect of planting pattern on weed infestation, all the treatments will be split in two: weedy and weed-free plots. The cropping season 1999/00 has experienced a severe drought. Total rainfall received was 184.8 mm with an irregular distribution. This amount of rain is by far less than the long term average of the region which is around 390 mm. Most of the rain was concentrated during the early season (October-January) where the total amount is 142.5 mm. Therefore, early season was favorable and allowed a good stand establishment. However, the drought that occurred starting the second decade of January and continued until April damaged all the crops grown. The 35 mm received in April came very late to make any saving for winter grown cereals and legumes. Cumulative rainfall and its distribution place the cropping season 99/00 under the lowest and the less probable year in the region of Settat. Thus no tangible outputs could be recorded. (Boutfirass, M.; M. Karrou and M. El Gharous, INRA-Settat).

b) Season displacement, tillage and weed management effects on water use and water use efficiency of hickpea
in dry-land region of Morocco: The experiment was conducted as on and off-station trial to evaluate different combination of tillage and weed management systems in terms of water use, water use efficiency, yield and yield components; to determine the potential of winter vs. spring planting season in term of productivity, the pattern of water use, water use efficiency within different conservation techniques; to evaluate weed infestation and biomass production under different combination; and to determine the production costs and returns of different strategies. Low moisture coupled to high temperature that exceeds 30° C registered from late February to April did not give any possibility for grain crop production in dryland agriculture in Morocco. (A. El Brahli and R. Dahan, INRA-Settat).

2.1.2. No- and minimum tillage as an alternative to conventional in dryland fallow / wheat and annual cropping systems in Central Anatolia, Turkey.

The research has aimed to assess the no-tillage and reduced tillage systems in terms of water economy, to compare and evaluate the tillage systems in terms of crop yields, and feasibility of the systems as to production economy, weed, pest and disease control. Conventional fallow-wheat/barley system with the application of conventional deep tillage and successive operations and chemical fallow were compared chickpea-wheat/barley cropping systems with minimum and zero-tillage applications.
Soil moisture differences at planting cannot be attributed to the treatment difference due to the first and the preliminary year of the trial. After winter, the observation on the plots indicated that there were significant crop hazard for all treatment. The pathological observation and analysis showed that the damage was result of snow molt disease. The long period (3 moths) snow cover was responsible for the disease development and intensive damage. Minimum tillage and traditional fallow systems provided statistically more yield than chemical fallow and zero tillage systems. The chickpea yield obtained from minimum tillage (1.98 t/ha) was higher than zero tillage (1.66 t/ha). But the difference was not significant according to statistical analysis. On the demonstration plots chickpea yields with the zero tillage (1.01 t/ha) was slightly over the minimum tillage (0.95 t/ha). Although it is the first year of the trial, both no-tillage and minimum tillage show promising results in terms of energy use efficiency compared with deep conventional tillage in crop production (M. Avci and agronomy team, CRIFC).

2.1.3. Mulching and in-field water harvesting techniques: the way to increase yields in water-scarce areas, the case of Jordan and South Africa

a) Jordan: Two water-harvesting techniques (Diamond and semi-circle) combined with the following treatment combinations of no mulch, straw mulch and stone mulch were tested to evaluate each water-harvesting technique on the basis of a 50% rainfall probability level, at Al-Khanasreh (860 m elevation with mean annual rainfall of 206 mm) station using Atriplex, and Al-Shoubak (1365 m elevation with mean annual rainfall of 315 mm) regional center using Pistachio. Annual rainfall was 64% and 32% of the mean in this season, respectively.

At Khanasreh site, the performance of both WH techniques used was just around 41% considering the designed crop water requirement for Atriplex (400 mm). This fact can be attributed to the low runoff coefficient per storm (except at Jan-28 due to the occurrence of little snowfall that melted quickly). However, at Shoubak site, the situation was much different. The performance of WH techniques was less than 20% considering the crop water requirement of Pistachio (650 mm). This was mainly due to both low rainfall amount and intensity during the season, coupled with drought in the previous season. (Dr. Abdel Nabi Fardous, Mohammed Ali Mudabber, Mohammed Jitan, Adel Al-Shoubaki, Mahmoud Eyadeh, Rania Khlaifat, Ahmad G. Abu-Dallu, NCARTT, and Prof. Mohammed Shatanawi, UoJ).

b) South Africa: A summer and winter study was conducted in a semi-arid part of South Africa on a sandy loam and clay soil to evaluate the effects of crop residue and stone mulches on evaporation from the soil surface and on soil temperature. All data are now being processed. Preliminary results indicate that a 50% stone mulch is as effective in inhibiting evaporative water losses and reducing undesirably high soil temperatures as a 50% organic mulch. This result has beneficial socio-economic implications for rural farmers because crop residues are important animal-feedstuff. The effects are more pronounced on the clay than on the sandy loam soil. (Mr J J Anderson, Dr D J Beukes, Mr J J Botha, Ms H M de Bruin, Mr P M Khumisi, Mr S D Thuthani, Dr L D van Rensburg, Mr P P van Staden, ISCW and Prof. A. Bennie, UOFS).

2.1.4. On-farm evaluation of water and nutrient use efficiency in a traditional land rehabilitation technique (Zaï) in Niger and Zimbabwe

a) Organic amendment decomposition, nutrient release and nutrient uptake by a millet crop in a traditional land rehabilitation technique (Zaï) in the Sahel in Niger:

The present Ph.D. research program was setup in order to address the issue of the resource use efficiency of the organic amendments (animal manure, compost, millet stover, zero input control) used in the Zaï system with characteristics of catchment area (no catchment, 25 cm diameter catchment, and 50 cm diam. catchment). The research encompasses on-station (ICRISAT-Sadore-Niger), off-season research trials as well as on-farm (Damari, 424 mm rainfall in the season of 1999/00 with 550 mm mean rainfall and Kakassi, 397 mm seasonal rainfall with 450 mm mean rainfall) rainy season experiments with the aims at understanding the interactions between water and nutrient management components of the Zaï system. Attention is focused on nutrient release from different sources of locally available organic amendments and on nutrient uptake by a millet crop grown on degraded land treated with Zaï system. In summary, the zai increased the amount of water in the soil profile as well as the plant available water, but at the end of the cropping season the water collected was either consumed or drained of.

In fact the water stock in the profile was almost the same regardless of the planting technique used. It is important to mention that the stock of water was higher in the zai treated plots during the cropping period. Therefore it may be said that the improved water availability and the nutritional status of the soil created a better condition for the plant development. These conditions favored a better root growth and the colonization of an important volume of soil. All this contributes to the improved millet yield observed in the pits. The trend of the variation in the stock of water in the soil profile during the cropping period shows that the availability of water in combination with the nutrient available are the key to the success of the zai system. A steady release of nutrient from the organic amendment in combination with the water collected in the zai favor the development of important rooting system to make a better use of this water and the nutrient, which can explain the good performance of the crop in terms of grain yield at Damari and Kakassi with the zai. (Fatondji Dougbedji, Charles Bielders, C. Martius, P.L.G. Vlek and A. Bationo, ICRISAT-Sadore, Niger).

b) On-farm experimentation in Zimbabwe:
This project is aimed at increasing the productivity and incomes of small-scale farmers in the SAT of Zimbabwe, using an on-farm participatory approach at three locations representing a transect from the better-endowed to the marginal SAT. Included are 'mother trials' (researcher-designed, replicated trials implemented by farmers) and 'baby trials' (farmer-led and implemented, unreplicated trials). Technologies tested included those aimed at more efficient use of water (modified tied ridging, seed priming, weed management) and nutrient management (manure inputs using different types and storage, small inputs of fertilizer with or without manure, legume rotations). Results of the experiments were evaluated by researchers' measurements and farmer rating. In some cases the design of the experiments was aided by using APSIM to provide an ex ante scenario analysis of promising technologies. Modified tied ridging is a less labour-intensive modification of tied ridging that conserves rainwater in the field, controls weeds, and reduces erosion. This has been implicated at three sites in 2000. There were no yield responses, which was not surprising since there was above average rainfall.
Both Farm yard manure and fertilizer N increased yield in this above average season. Seed priming, despite more rapid emergence, did not provide higher yield because of favorable season. However, farmers who evaluated the trials felt that yield differences might occur in drier years. (RJK Myers, ICRISAT and NARES).

Activity 2.2. Comparative evaluation of water and nutrient constraints to crop production (yield trend analysis) and recommendations for improved production systems by matching options to constraints

a) ICRISAT: Interest in this topic was sparked during discussion at the Wageningen meeting earlier this year of possible opportunities for cross-consortia activities. Since then there has been further discussion, but not yet agreement on how to proceed. This meeting offers an opportunity for OSWU to advance this process. To help this process, here is what ICRISAT is already doing.

In southern Africa, ICRISAT's soil fertility research is located mainly at four sites (in Zimbabwe unless stated otherwise) – Mangochi in Malawi in the better-endowed part of the SAT, Mahuto (near Masvingo) also in higher rainfall SAT traditional maize area, Tsholotsho in traditional sorghum area, and Manama (Gwanda South) in traditional pearl millet area – this represents a transect from high to low within the SAT.

On-farm research at these sites is 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, Concern Universal in Malawi). In the workshops, the group examines questions to address with 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. In the process, we have learnt a lot.

The first workshops that we ran consisted of researchers only. Then we brought in the extension specialists. Finally we are now testing whether it is productive to include farmers in this part of the process. We have learnt that researchers alone tend to pose questions that are outside the decision matrix of the farmers. However, researchers have been successful in examining small fertilizer recommendations (in contrast to current recommended rates), and combinations of fertilizer and manure. Researchers and extension specialists tend to raise questions that are more relevant to farmer decision-making. For example, they have brought about testing that compares 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.

Our taking of the modeling to the farmers has only just started, and we have yet to do an evaluation of that process. At whatever level this process was conducted, there were outputs that permitted a preliminary analysis of the performance of possible management interventions, including an estimate of the climatic risk and economic benefits. On that basis, some interventions were discarded and others were included in on-farm trials. One future outcome of this work is an appreciation of what technologies are appropriate for which agroclimatic areas (RJK Myers, ICRISAT-Zimbabwe and the team and H. Bremen, TSBF to come together for further work plan as agreed at Steering Committee meeting).

b) ICARDA work in Syria which has good environmental difference from 600 mm to 150 mm rainfall, thus on-farm crop variety testing and international yield trial results will be evaluated through the study on the genotype and environment interactions in relation to rain-water use efficiency. The effects of soil and crop management practices on crop rain-water use efficiencies across the transect of the environment will also be studied as ex-ante analysis (M. Pala, C. Studer, J. Ryan, H. Gomez, ICARDA).

ICARDA's Long-Term Cropping Systems Trial: Soil Moisture Dynamics and Crop Water-Use Efficiency: Rainfall – and consequently soil moisture – is the dominant factor controlling crop yields in the drought-prone West Asia – North Africa (WANA) region. Not only is rainfall low (200 – 600 mm yr-1), but it varies widely from year-to-year and within seasons. In one of ICARDA's major long-term, cereal-legume rotation trials designed to assess sustainable productivity, we used the neutron probe to monitor soil moisture. Patterns of seasonal recharge /discharge were identified. Depth of wetting varied with seasonal rainfall. Based on crop yields, water-use efficiency was calculated for each cropping option in relation to the durum wheat crop. The greatest limitation to growth was the supply of water and not the soil moisture storage potential. With N added to the cereal phase, system water-use efficiency increased, and was least in the continuous wheat rotation and greatest for wheat /lentil. The implications of water use for Mediterranean cropping systems are developed (H. Zhang, M. Pala, J. Ryan, and H. Harris, ICARDA).

Output 3:
Impacts of improved practices on production, the environment and socioeconomic conditions assessed:

Activity 3.1. Elaborate common approach to impact assessment for SWNM technologies
3.1.1: Development of common guidelines together with IBSRAM: OSWU will collaborate with other SWNMP consortium (IBSRAM) to develop a frame work for the assessment of impact of technologies in relation to soil water use and its interaction with other management practices on farmers' socioeconomic and biophysical environment. Then the framework will be applied in the OSWU member countries.

Activity 3.3. Determine the impact of improved SWNM practices on soil and water quality at selected sites
Impact assessment of improved SWNM practices will be made in 6 selected countries after the frame-work developed under activity 3.1.1.

Output 4:
Improved information and communication exchange framework established and materials produced for stakeholders

Activity 4.2. User friendly information on SWNM practices, strategies, and policies developed and disseminated to stakeholders

Publications (proceedings of workshop), handouts (rainwater-use decision tree) and pamphlets etc. will be published and disseminated as available. This is a continuous activity and the reports and publications are disseminated to the stakeholders already.

Output 5. Stakeholders capacity for better SWNM enhanced

Activity 5.1. Training of NARES staff on SWNM technologies and the use of DSS

5.1.1: Training in APSIM simulation model;
Training to improve the skills of our partners in the use of tools relevant to water and nutrient use efficiency is ongoing. Firstly, training workshops have been conducted during 2000 in the use of systems modeling as a tool for use by researchers and extension workers. Secondly, training of the trainers for farmer field schools has been initiated with one training implemented specifically for the semi-arid tropics (SAT).
Further training in systems modeling will be conducted in March 2001 as discussed at SC meeting. To maximize the benefits of such training, we have set up a process:

- Requests for training must be accompanied by a clear purpose statement which outlines how the modeling skills will be applied in the future, and what configuration of APSIM is necessary for that application. Inappropriate use of models is avoided. Completion of a good purpose statement is an iterative process that results in joint 'ownership', as should be the case in any true collaboration. The joint ownership implies a genuine commitment of the trainee to carry out the purpose, and of the providers of the training to provide backup after training is finished.
- An agreed workplan should be prepared that describes how the purpose is to be achieved. Access to necessary computers must be verified. A licence application for APSIM will be made.
- Adequate resources for implementing the work need to be assured.

Activity 5.2. Organize farmers' field schools for SWNM technologies: ICRISAT developed this in Zimbabwe and will be disseminated to other member countries as well. Morocco has started farmers field schools under integrated pest management project, which will be utilized to disseminate the SWNM technologies as well.

Other OSWU Related Research work funded by other sources

With the light of this, there have been follow-up of long-term trials of cooperating countries such as Egypt, Jordan and Iran for resource use efficiency, water in particular. Summary of the work is given below for each country:

Egypt
Long-term trials based on different agroecologies of Egypt as well as neighbouring farmers' fields which are under monitoring by the project have been visited for a week. The resource-management program initiated some years ago in Egypt, collaborative between ICARDA and a group of national research institutions, provides an early example of the new research paradigm in action: Program activities began with a preparatory phase, comprising inventory studies, rapid rural appraisal and multi-disciplinary surveys, and the knowledge gained was used in the planning of two closely related research activities, long-term agronomic trials (LTT) and long-term farm monitoring (LTM). The long-term trials (with such experimental variables as water quantity, water quality, nutrient input and crop rotation) have been established at sites representing the old irrigated lands, the areas newly reclaimed from desert, and the rainfed agricultural areas; and each trial is complemented by extensive long-term monitoring in villages

close to the experimental site, recording farmers' perspectives, farming practices and the condition of their soils and crops, with the aim of identifying over time sustainable and non-sustainable practices and the social and economic factors that underlie them. The complementarity of LTT and LTM activities within an integrated, multidisciplinary approach provides a new research model for the identification of sustainable, intensive production systems that has wider application in other agroenvironments.

Jordan

The Project of Tillage, Residue and Nitrogen Management in Crop Rotations conducted in collaboration with National Center Agricultural Research and Technology Transfer (NCARTT) and University of Jordan (UOJ). The project has been established to study the different systems of crop residue management under three tillage methods which are conventional deep moldboard plowing, deep chisel (modification to deep plowing) and minimum tillage by ducks-foot cultivation (conservation tillage) combined with different rates of nitrogen application on wheat crop in wheat-lentil or wheat-vetch two course rotations or wheat-lentol-melon three course rotation in different agroecological zones of Jordan and their effects on systems productivity and on soil physical and chemical properties and **crop water use efficiencies**.

The project is jointly implemented by NCARTT and University of Jordan since 1990. Three graduate students completed their MSc. degree with thesis research related to tillage, residue and nitrogen management.

The initial results of crop data showed that wheat grain yield significantly varied in each location and rotation depending on the seasonal climatic conditions. Tillage systems had significantly affected the wheat yield, however, it interacted with residue management to some extent. Chisel use before the rainfall appeared to be the worst one, but ducks-foot cultivation as a minimum tillage used after the initial rainfall seemed to be, if not better, as good as moldboard plowing which has been used before rainfall. Conservation practice by ducks-foot cultivator which is easily available for farmers has a promising future in sustainable production systems affecting soil aggregate stability positively. It was better in moisture retention than moldboard and chisel. Conservation tillage has also a lower energy requirement and reduced time for tillage. However, at some stage of crop production within a common crop rotations moldboard has to be used especially for growing summer crops such as melon.

Residue management did not show any clear effect on wheat yield for the first five year. However, yield trends showed that grazing stubble in summer and incorporating the remainder late in the season was better than the early incorporation of the stubble without grazing. However, long-term effects of residue management on soil quality parameters still the aim of the project.

Nitrogen application increased mean wheat yield significantly almost in every ecological zone as independent of tillage and residue management, but year. So, this may give an opportunity to farmers to modify nitrogen application in late winter and early spring according to seasonal conditions for sustainable production.

Iran

The dryland research program was initiated 4 years ago on the Studies on fallow replacement by legumes and oilseed crops in fallow-cereal rotation in the dry areas of Iran a) to investigate the effect of introducing annual food and feed legumes and oilseed crops into the fallow-wheat rotation on the productivity, b) to study the effect of introduction of above mentioned crops on soil organic matter and nitrogen content, eventually soil quality c) To quantify biological nitrogen fixation by legumes and determine their contribution to the nitrogen nutrition of cereals, d) To assess the profitability of crop sequences compared with fallow-cereal rotation in a farming system context in relation to **precipitation use efficiency** to increase the productivity of rain water by improved soil and crop management practices.

Initial results show that fallow replacement is feasible with other crops, legumes in particular for a more productive and sustainable system.

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5. Staff and partner list

ICARDA
Dr. Willie Erskine, AADG-Research
Dr. Mustafa Pala, Systems Agronomist, NRMP
Dr. Christoph Studer, Soil-water-plant Specialist, NRMP
Dr. John Ryan, Soil Fertility Specialist, NRMP
Dr. Theib Oweis, Water Management Specialist, NRMP
Dr. Adriana Bruggeman, Hydrologist, NRMP

ICRISAT
Dr. Robert J. Myers, Soil Fertility Specialist, Zimbabwe
Mr. D. Fatondji, Research Assistant, Niger
Mr. O. Hassane, Research Assistant, Niger

WANA-NARS
Dr. A.T.A. Moustafa

Deputy Director, Soils Water and Environment Research Institute (SWERI)
Agricultural Research Center, Egypt

Dr. E. Pazira
Research Professor & Director General
Iranian Agricultural Engineering Research Institute (IAERI) Agricultural Research, Education & Extension Organization (AREEO), Ministry of Agriculture, Iran

Dr. A. Al-Nabi Fardous
Director General, National Center for Agricultural Research and Technology Transfer (NCARTT), Jordan

Dr. M.H. Ababneh,
Director for Rainfed Agric. Research Program
National Center for Agricultural Research and Technology Transfer (NCARTT), Jordan

Mr Ali Al-Shrouf
Soil water specialist, National Center for Agricultural Research and Technology Transfer (NCARTT), Jordan

Dr. M. Boutfirass
Agronomist; Institut National de la Recherche Agronomique (INRA) CRRA, Maroc

Dr. G. Al-Tabi
Head of Land Use Section in Soils Directorate Ministry of Agriculture and Agrarian Reform,
Syrian Arab Republic

Dr. M. Avci
CerealAgronomist
Central Research Institute for Field Crops (CRIFC), Turkey

SSA-NARS
Dr. J. Itabari
NDRFC, Kenya

Dr. M. Doumbia
Soil Scientist, Institut d'Economie Rurale (IER), Mali

Dr. A. Kodio
Scientist, Team Leader SP/GRN, Institut d'Economie Rurale (IER), Mali

Dr. Z. Moussa
Agronomist/Agricultural Engineer
National Coordinator, PDR-ADM/Keita, Niger

Dr. A. Moustapha
Scientist Bioclimatologist
Institut National de Recherche Agronomique du Niger (INRAN), Niger

Dr. M. Gandah
Soil Scientist
Institut National de Recherche Agronomique du Niger (INRAN), Niger

Mr. M. Issoufou
Geographer -Land Use Specialist, Responsable CSE-SIG, PASP/GTZ, Niger

Prof. V.O. Chude
Univ-Professor: Teaching & Research, Institute for Agricultural Research (IAR)
Dept. of Soil Science, Ahmadu Bello Univ. P.M.B. 1044, Nigeria

Dr. D.J. Beukes
Research Manager, ARC-Institute for Soil, Climate & Water, South Africa

Dr. A.T.P. Bennie
Lecturer, University of The Orange Free State, South Africa

Dr. J. Mzezewa
Soil Scientist
Department of Research and Specialist Services (DRSS), Zimbabwe

Dr. B. Ouattara
Soil Scientist, Institut d'Etudes et de Recherches Agricoles (INERA), Burkina Faso
Tel: +226-319207.

6. List of donors

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Annex: OSWU:
Logframe of the OSWU consortium

Output 1: Decision support tools for improved [more productive and resource-use efficient] SWNM developed and evaluated in different agro-ecological zones:	*Milestones*	**Completion date**	*Responsible*	*Funds required*	*Observations*
Activities:					
1.1 Utilizing the field activities given below and others with the use of crop modeling combined with GIS to generalize for wider areas for more sustainable farming systems.	Map of soils and climate, production data for important crops in the systems	Pending	ICARDA, ICRISAT	30,000	Requires consultancies
1.2 Improvement, evaluation, and comparison of crop/systems models and fostered application thereof	Maps of outputs such as drought index, water and fertilizer use and their efficiencies, yield predictions	Pending	ICARDA, ICRISAT	15,000	Requires consultancies
1.3 Decision tree for efficient rain-water use	Dissemination to decision makers and extension agent and farmers	12/2000	ICRISAT, ICARDA	5,000	Requires short-term consultaies
1.4. Data base systems developed for soils and climate for decision making and use by Models to generalize the results for wider areas	Information collated and being mapped by GIS for Syria	Continue	ICARDA,	10,000	Requires support from Agro-ecological Characterization project

Output 2: Improved technologies for increased production based on efficient use of water and nutrients adapted and applied by land users:	*Milestones*	**Date of completion**	*Responsible*	*Funds required*	*Observations*
Activities:					
2.1 Mulching and in-field water harvesting techniques: the way to increase yields in water-scarce areas, the case of Jordan and South Africa	Documents for best WH techniques for improved WUE	06/2001	Jordan, South Africa, ICARDA, ICRISAT	30,000 (15,00/country for 2 years)	Partial funding from OSWU
2..2 Different Management options (Tillage, sowing date, planting pattern and weed contol) for optimizing soil water use in Morocco	Documents for best management for improved WUE	06/2001	Morocco, ICARDA	22,500 (3 years)	Partial funding from OSWU
2.3 On-farm evaluation of water and nutrient use efficiency in a traditional land rehabilitation technique (Zaï) in SSA	Ph.D. thesis on Zai technique as an on-farm assessment	09/2001	Niger (ICRISAT)	7,500 (3 years)	Partial funding from OSWU
2.4 No- and minimum tillages as an alternative to conventional in dryland fallow / wheat and annual cropping systems in Central Anatolia, Turkey.	Document on no-till and conservation tillage	08/2002	Turkey, ICARDA	30,000 (4 years)	Partially funded by OSWU
2.5 Comparative evaluation of water and nutrient constraints to crop production (yield trend analysis) and recommendations for improved production systems by matching options to constraints	Document on spatial and temporal yield trend	09/2001	ICRISAT, ICARDA and NARSs	30,000	Partially funded by OSWU
2.6. Promising systems-mycorrhizae and OSWU	Documents for the effects of mycorrhizae on WUE	2001	S. Africa, ICRISAT	10,000	Partially supported by OSWU
2.7. Applications of Systems modeling (review workshop and support)	Documents available	2001	ICRISAT, ICARDA	30,000	funded by OSWU
Output 3: Impacts of improved practices on production, the environment and socioeconomic conditions assessed:					
3.1 Elaborate common approach to impact assessment for SWNM technologies and conduct impact studies at selected sites	Adoption and impact of improved OSWU technologis documented	Pending	ICARDA, ICRISAT and NARSs	30,000 (About 5,000/country in 6 selected areas from WANA and SSA each)	Partially funded by OSWU
3.2. Determine the impact of improved SWNM practices on soil and water quality	Reports and papers	On-going	ICARDA, ICRISAT,		Funded by Centers

Output 4: Improved information and communication exchange framework established and materials produced for stakeholders	*Milestones*	**Date of completion**	*Responsible*	*Funds required*	*Observations*
Activities:					
4.1.Thematic workshops with stakeholders on priority SWNM issues	Problems identified and solutions proposed	Pending	To be defined	20,000	Requires theme identification and participants
4.2. User friendly information on SWNM practices, strategies, and policies developed and disseminated to stakeholders	Bulletines and other materials available for decision making	Pending			Information exchange with stake holders and consortium members
4.3. Training of NARS stafff from SSA on APSIM cop simulation model	Training materials available	01/2001	ICRISAT	18,000	Supported by OSWU
4.4. OSWU steering committee meeting and discussion on the work plan with respect to Wageningen meeting outputs	SC meeting minutes	10/2000	ICARDA, ICRISAT	18,000	Supported by OSWU

Capitals: Computers for needed countries: 15,000 for SSA + WANA if needed
Travel of Conveners: Included within the activities
Communication cost: Included within the activities