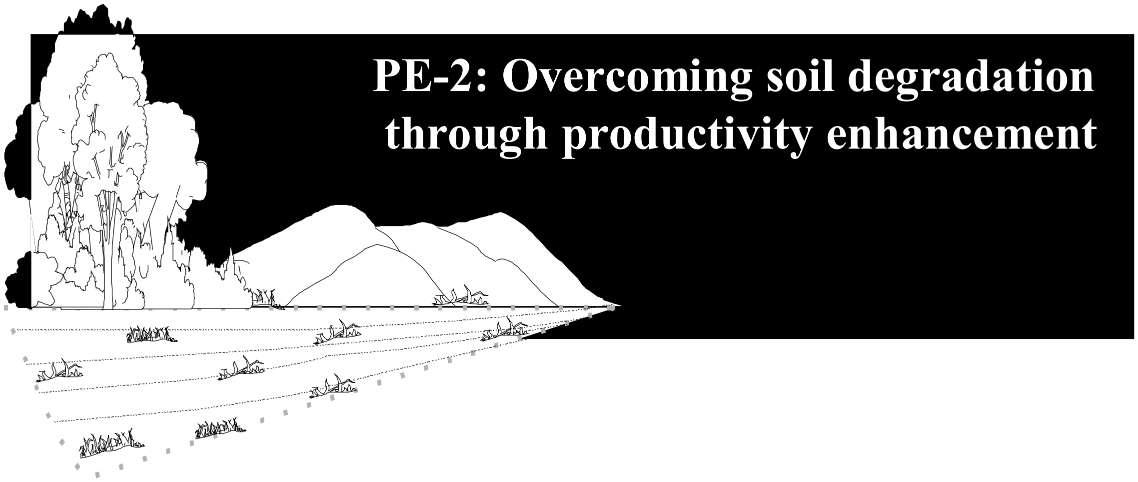

PE-2: Overcoming soil degradation through productivity enhancement

Annual Report 2001

CIAT
Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

Acknowledgement

The members of the soils research team wish to acknowledge the efforts of Dr. Richard J. Thomas in promoting soils research at CIAT as Manager of Soils Research Project and in the CGIAR through his leadership of the Soil Water and Nutrient Management Systemwide Program convened by CIAT. Richard has led and championed soils research with wide range of partners resulting in a sound body of excellent science. He has a clear vision of a balanced program of strategic and applied research that produces useful tools - developed from sound science - that help our clients to improve their livelihoods. The fruitful work of the soils research team and partners under his leadership on “Sustainable Land Management of Acid Soil Savannas” has been recently selected as the winner of the 2001 CGIAR's Excellence in Science Award in the Outstanding Partnership Award category. This award re-affirms his belief of the role of the CGIAR in being centers of excellence and a recognition of the need to reach outside the CGIAR to improve the efficiency of research. Not only the staff of the Soils Research Project of CIAT, but also all beneficiaries of CIAT’s research outputs must be indebted to Richard’s inspired leadership.

The Soils Research Team.

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PE-2: Overcoming soil degradation through productivity enhancement

PROJECT OVERVIEW

Objective: To identify strategic principles, concepts and methods for protecting and improving soil quality through the efficient and sustainable use of soil, water and nutrient resources in crop-livestock systems.

Outputs: Crop/forage components characterized for compatibility in systems and resource use efficiency in acid soils; methodologies and indicators for assessing soils quality; incorporating local knowledge; strategic principles for managing crop residues and green manures, soil biota, and soil erosion; process-oriented simulation models calibrated and validated to overcome site specificity; strategies for confronting soil degradation disseminated to NARS and NGOs (Table 1A).

Gains: Guidelines for selecting productive and resource use efficient crop/forage components and combinations; guidelines for managing nutrients, crop residues and green manures, and controlling erosion and improving soil structure; a diagnostic kit of soil quality indicators to assist farmers as well as extension and NGO personnel in assessing soil health and making resource management decisions; a decision support system for resource conservation and productivity enhancement; strengthened NARS capacity in strategic research on soil, water and nutrient management.

Milestones:

2000 Nutrient cycles and budgets and soil organic matter accumulation in crop rotation and pasture systems quantified; management guidelines for minimizing erosion and increasing productivity defined for hillsides; strategies for managing soil fauna identified; plant attributes identified for greater nutrient acquisition and use efficiency.

2001 Indicators of soil fertility, biological health, and physical quality identified for hillside and savanna agroecosystems; demonstrated benefits of crop rotations and pasture systems on soil quality and productivity; guidelines for maintaining soil structure produced.

2002 List of soil quality indicators available to NAS to monitor land degradation. Decision making tools available for managing soil erosion, nutrient depletion, and maintenance of an arable layer. Erosion and nutrient depletion risk assessment maps available. Correlations established between local soil quality indicators and scientific measurements.

Users: Principally crop and livestock producers and agriculture extensionists (advisors) in acid soil agroecosystems of LAC. Relevant also to farmers on similar soils in tropical Africa and Asia.

Collaborators: NARS/NGO's: CORPOICA; EMBRAPA; CIPASLA; CETEC; CIPAV

Universities: Nacional, del Llano (Colombia), UNA (Nicaragua), UCA (Nicaragua), ENA (Honduras), E.A.P. Zamorano (Honduras), Paris, Rouen (France), Hohenheim, Freiburg, Gottingen (Germany), SLU (Sweden), AUN (Norway), Cornell, Michigan State, Montana State, Ohio State (USA), ETH (Switzerland.).
International Research Institutes: IFDC (USA); IRD, CIRAD (France); CATIE (Costa Rica), CIP (Ecuador), FAO-Lempira Sur (Honduras), IIAG-CSIC Galicia (Spain).

CG system linkages: Enhancement & breeding - 15%; Crop Production Systems - 50%; Biodiversity - 15%; Stengthening NARS- 20%; Co-convenor Systemwide Program on soil-water-nutrient management (SWNM) and lead institute for the Integrated Soil Management (MIS) consortium.

CIAT Project linkages: Diversity in systems of rhizobia and mycorrhizae populations (SB-1), acid soil adapted components received and adaptive attributes identified for compatibility in systems (IP-1 to IP-5), simultaneous evaluation of multipurpose legume to improve soil and feed quality (IP-5), combination of Integrated Soil Fertility Management and Integrated Pest Management research approaches (IP-1), strategies to mitigate soil degradation (PE-3 to PE-5), to make soil conserving systems profitable (SN-1) and to strengthen NARS via participation (SN-2).

Financing plan: 60% unrestricted core, 40% restricted core .

Table 1A. Project work breakdown structure

Project title: Overcoming soil degradation through productivity enhancement

Purpose
To identify strategic principles, concepts and methods for protecting and improving soil quality through the efficient and sustainable use of soil, water and nutrient resources in crop-livestock systems

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Output 1 Soil, water and nutrient management constraints assessed and plant components characterized for improved production and resource conservation	**Output 2** Strategies developed to protect and improve soil quality	**Output 3** Improved decision making for combating soil degradation and greater agricultural productivity	**Output 4** Institutional capacity for SWNM enhanced through the dissemination of concepts, methods, tools and training
1.1 Determine and characterize edaphic and climatic constraints. 1.2 Survey native plants and their potential use as biofertilizers. 1.3 Survey land users for soil and crop management knowledge 1.4 Characterize plant components for production potential, nutrient use efficiency (phosphorus and nitrogen) and improvement of soil physical conditions. 1.5 Determine rooting strategies of crop, forage and improved fallow components 1.6 Test compatibility of plant components in different systems (including farmer participation)	2.1 Develop a concept of, and strategies for, the establishment and maintenance of an "arable layer" for sustainable production. 2.2 Develop strategies for nutrient acquisition and replenishment via efficient nutrient cycling and integrated nutrient management. 2.3 Develop appropriate and diverse strategies for controlling soil erosion. 2.4 Develop strategies to maximize C sequestration in soils and minimize emissions of green house gases. 2.5 Characterize soil biodiversity and develop strategies to manage beneficial soil biological processes.	3.1 Identify dynamic soil properties and test their suitability as soil quality indicators 3.2 Develop and test a soil quality monitoring system (including indigenous knowledge) for use by farmers and extensionists in hillsides and savannas. 3.3 Compile data bases to feed into simulation models and decision support systems 3.4 Develop decision support tools for improved soil, water and crop management. 3.5 Develop and test a decision support system for organic materials. 3.6 Develop soil degradation risk assessment maps.	4.1 Organize and coordinate field days and workshops 4.2 Prepare guidelines/pamphlets on soil, water and nutrient Management concepts 4.3 Promote and participate in specialized training courses, prepare training materials 4.4 Publish research results in refereed journals and other publications 4.5 Supervise postdoctoral research, graduate and undergraduate theses 4.6 Foster research linkages with institutions in the region and advanced research organizations

Table 1B. Project: PE-2 - Logframe 2001

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
Goal Overcoming soil degradation through productivity enhancement and resource conservation	• Yields in farmers fields increased. • Land degradation halted/reduced. • Yields per unit area and input increased. • Land use changed	• Farmers surveys. • Regional/national production statistics. • Land use surveys (satellite imagery, rapid rrural appraisal) .	• Land survey data available • Farmers adopt new technologies Socioeconomic conditions are favorable for achieving impact

Purpose
 	
Strategic principles, concepts and methods for protecting and improving soil quality through the efficient and sustainable use of soil, water and nutrient resources in crop-livestock systems, developed and disseminated to clients.
	• Technologies for soil improvement/ management developed.
	• Limiting soil-plant-water processes identified.
	  • Compatible plant components identified for low fertile soils in crop-livestock systems.
	  • Guidelines, manuals and training materials for soil management produced.
		• Scientific publications
		• Soil and crop management guidelines published
		• Decision support systems developed
		• Annual reports
			• Economic analysis of options available
			• Effective linkages within CIAT and partners in the region
			• Socio-economic inputs available from other projects (e.g., PE-3, BP-1)
			• Field sites accessible

Outputs 1. Soil, water and nutrient management constraints assessed and plant components characterized for improved production and resource conservation.	• Soil and water management constraints identified with farmer and NARS participation. • Questionnaire produced and farmers interviewed in at least two agroecosystems. • Plant components identified and matched to edaphic/climatic constraints.	• Annual Report • Reviews published • Document of synthesized results • Detailed tables published in Annual Report.	• Literature available • Farmers continue to participate. • Projects SN-2, PE-3 and PE-5 actively participate. • Collaboration of Project PE-4 and NARS. • At least one assistant is assigned to the activity in Honduras/Nicaragua • SN-3 (IPRA) plans work with EB (BID poverty project).
2. Strategies developed to protect and improve soil quality.	• Recommendations of soil and crop management practices for efficient nutrient use and erosion control in systems. • Soil properties, management practices and plant components that affect N capture and fluxes identified. • Strategy identified for minimizing global warming potential in the savannas • Strategy identified for establishing and maintaining beneficial soil macrofauna populations in savannas.	• Project reports/ publications. • Management guidelines published • Document of synthesized results	• Sufficient operational funds available for chemical analyses. • Continuity of long-term experiments. • Modeling expertise available from partners e.g. Michigan State Univ. USA, IFPRI,CSIRO • Soil biology expertise from ORSTOM/Univ. of Paris available.

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
3. Improved decision making for combating soil degradation and greater agricultural productivity.	• List of Soil Quality indicators prepared and available to monitor degradation in reference sites. • Tools designed for estimating soil erosion and training manual written. • Decision-making tool for soil and water management produced. • Map of risk assessment of soil degradation (erosion, soil nutrients) for hillsides and savannas produced. • Decision making tools for use of organic materials produced. • Decision tree to create/maintain an arable layer produced. • Correlations established between local soil quality indicators and objective measurements. • Improved crop and soil models developed and validated	• Annual Reports/ publications. • Training manual for use with tools • Kit available to farmers and NARS. • Maps published. • Pamphlet published detailing decision tree.	• Collaboration from partners. • Information from questionnaires synthesized comparisons made with available PE-3 results. • Collaboration with PE-3 on soil erosion in CA. • Collaboration with SN-2, PE-4, PE-3, TSBF and SWNM Program. • Collaboration with MW (UNEP) on land quality indicators at reference sites. • Collaboration with PE-4.
4. Institutional capacity for SWNM enhanced through the dissemination of concepts, methods, tools and training.	• At least 9 undergraduate, 3 Master's and 2 Ph.D. theses submitted. • Workshop held on soil physics. • Workshop on C sequestration held. • At least three projects with partners submitted to donors. • ELABS initiated • At least 10 field days and four training workshops held on local soil quality indicators	• Theses available in library. • Reprints available. • ELAFIS workshop report • Workshop report on C sequestration. • Project documents	• Continuing interest/participation of NARS and ARO partners. • Continued support for collaborative activities e.g. systemwide SWNM program.

EXECUTIVE SUMMARY

The objective of the Soils Project (PE-2) continues to be the identification of strategic principles, concepts and methods for protecting and improving soil quality through the efficient and sustainable use of soil, water and nutrient resources in crop-livestock systems. To achieve this objective, we emphasize assessment of soil, water and nutrient management constraints; characterization of plant components for improved production and resource characterization; development of concepts and strategies to improve soil quality and health; development of decision support systems for combating soil degradation and greater agricultural productivity; and dissemination of concepts methods, tools and training to enhance institutional capacity for soil, water and nutrient management.

This year the responsibility of Project Management was transferred from Dr. R.J.Thomas to Dr. E. Barrios.

This year we have increased our efforts in Central American Hillsides in close collaboration with PE-3, IP-5 and PE-4 projects of CIAT. We have also faced problems of restricted access to our field sites in Colombia. We have addressed this problem, in part, with an approach to decentralize our research effort by out-posting three research staff to Nicaragua. Out-posted staff include one shared (PE-2, IP-5, PE-3) post-doctoral fellow as well as two research assistants carrying out their PhD and MSc theses in collaboration with IRD and CATIE respectively. We have also increased our team efforts to synthesize the work on the long-term experiments in the Colombian Llanos. This will result in a publication with partners on land use options and soil management recommendations for the Altillanura region of the Llanos of Colombia.

We also made special efforts to increase integration with other CIAT projects – PE-3 (hillsides), IP-5 (forages) and PE-4 (land management) – combining soils and production systems research at the plot, farm and landscape scales, developing better soil and crop management options and decision support tools for savanna and hillside farmers. This integration has been catalyzed by additional shared activities and positions.

Increased efforts in Africa are expected as we progressively move towards more integrated activities with the Tropical Soil Biology and Fertility Programme based in Nairobi, Kenya. This strategic alliance will also complement new joint activities with IP-1 (beans) on the application of molecular tools to study soil microbial biodiversity in our efforts to combine Integrated Soil Fertility Management (ISFM) and Integrated Pest Management (IPM) research approaches.

Main highlights of research progress in 2001

Output 1. Soil, water and nutrient management constraints assessed and plant components characterized for improved production and resource conservation

- Showed that the supply of both N and P limit corn yields at Central America reference sites.
- Showed that: (i) excessive application of chicken manure as an organic fertilizer on Andean volcanic ash soils leads to soil crusting and sealing by physical/chemical dispersion mechanisms and the interaction of physical and chemical characteristics; and ii) improper land use and fertilization practices can markedly reduce cassava root yields.
- Developed a method to predict precipitation (including intermittent drought) for seven consecutive days for soils of different texture.

- Surveyed land users in Colombia and Honduras for local knowledge about soils and their management and identified native plants as important indicators of soil quality related to modifiable soil properties.
- Showed that deep-rooted tropical pastures can enhance soil quality by improving the size and stability of soil aggregates when compared with soils under monocropping.
- Developed methodology to determine root distribution and abundance for stony soils predominant at Nicaraguan reference site.
- Showed that rooting depth and grain yield of maize could be markedly improved by direct drilling rather than chisel + direct drilling on plots planted from phase I of Culticore.
- Green manure evaluation sites established in 8 communities at the Nicaragua reference site. Communitity field days carried out and key informants identified. Participatory learning process initiated.

Output 2: Strategies developed to protect and improve soil quality

- Showed that the maize and green manure cropping systems were better than the grass alone pasture system at separating the effect of increased number of disc harrow passes on soil physical and chemical characteristics.
- Showed that organic P is involved in short term P dynamics in soils with low or no P fertilization.
- Showed that earthworm surface casts represent a significant source of easily available P to plant roots.

- Observed diet preference by *M. carimaguensis* for seeds from the soil seed bank and found considerable loss of viability of seeds in earthworm casts.
- Showed that biogenic physical structures produced by soil macrofauna on the soil surface can be related to their ecological function in the soil.

Output 3: Improved decision making for combating soil degradation and greater agricultural productivity

- Showed that oxalate extracted P or the combined pools of resin + bicarbonate-P of the Hedley fractionation scheme may be better suited to determine soil P availability in oxisols that receive strategic application of lower amounts of fertilizer P.
- Showed that differences in plant quality attributes could be more important than sample preparation in determining the extent and rate of decomposition of plant material in the soil and rumen.
- Developed a methodological guide, through a participatory approach, to identify and classify local indicators of soil quality related to permanent and modifiable soil properties. This guide is being used in Latin America/Caribbean (Colombia, Honduras, Nicaragua, Peru, Venezuela, Dominican Republic) and Africa (Uganda, Tanzania).
- Showed that distribution and abundance of soil macrofauna appears to be related to local land classification units.
- Created a database for past and present field experiments in savannas and hillsides agroecosystems to facilitate further analysis and use by PE-2 and other CIAT projects.
- Developed soil maps for the municipality of Puerto Lopez, Colombia, using a geo-referenced soil data bank (GEOSOIL), to facilitate land-use planning and site-specific soil management recommendations.

Output 4. Institutional capacity for SWNM enhanced through the determination of concepts, methods, tools and training

- 9 field days organized, one training course held in Africa, and a workshop held in Colombia.
- 36 students are associated with the project (10 Ph.D. theses).
- Active collaboration is maintained with 87 partner institutions ranging from NARS, NGO's, Universities and other IARC's.
- The project has access to funds from 7 special projects
- 28 articles for refereed journals have been published or are in press, 90% of which are co-authored with other institutional partners.

Progress towards achieving output milestones of the project logframe 2001

Output 1: Soil, water and nutrient management constraints assessed and system components characterized for improved production and resource conservation

- **Soil and water management constraints identified with farmer and NARS participation**

Soils at our Central America reference sites in Honduras and Nicaragua appeared to be both N and P limited thus responding best to the combined application of N and P. One Post-Doctoral Fellow will start studies in Nicaragua on "farm resource and nutrient flows" in the Wibuse watershed at the San Dionisio Reference Site in Nicaragua.

In Cauca region of Colombia, we have made progress in identification of some biophysical mechanisms that are related to crust formation. We found that excessive application of chicken manure as an organic fertilizer on Andean volcanic ash soils leads to soil crusting and sealing due to physical dispersion, chemical dispersion, and the interaction of soil physical and chemical characteristics. We also demonstrated that improper land use and fertilization practices can markedly diminish cassava root yields.

For the Llanos of Colombia, we have succeeded in applying a method to predict precipitation (including intermittent droughts) for seven consecutive days for soils of different texture for the Altillanura region of the Orinoco river basin based on the behavior of rainfall data of Carimagua and La Libertad. This methodology can be used in other tropical regions and will permit a better planning of agricultural land use and farm operations.

- ***Questionnaire produced and farmers interviewed in at least two agroecosystems***

The increasing attention paid to local soil knowledge in recent years is the result of a greater recognition that the knowledge of people who have been interacting with their soils for long time can offer many insights about sustainable management of tropical soils. Case studies show that there is a consistent rational basis to the use of local indicators of soil quality. Biological indicators (native flora and soil fauna) were shown to be important local indicators of soil quality related to soil management. Although benefits of local knowledge include high local relevance and potential sensitivity to complex environmental interactions, without scientific input local definitions can sometimes be inaccurate to cope with environmental change. It is argued that a joint local/scientific approach, capitalizing on complementarities and synergies, would permit overcoming the limitations of site specificity and empirical nature and allow knowledge extrapolation through space and time.

- ***Plant components identified and matched to edaphic/climatic conditions***

Field studies conducted at Carimagua and Matazul (Savannas) contributed to define lime and nutrient requirements for acid soil tolerant varieties of rice, maize, cowpea and soybeans in rotational production systems on heavy-textured Oxisols. Field and glasshouse studies on crop and forage components indicated that forage legumes are more efficient in acquiring P per unit root length. Comparative studies of a forage grass (*Brachiaria dictyoneura* CIAT 6133) and a legume (*Arachis pintoi* CIAT 17434) demonstrated that the legume could acquire P from relatively less available P forms from oxisols of Colombia.

Field research carried out at Carimagua showed that both native savanna and introduced pastures develop deep root systems compared to field crops such as maize. Studies on root distribution of maize showed that most of the roots are in top 20 cm of soil depth. Application of higher amounts of lime did not improve subsoil-rooting ability of maize but contributed to greater nutrient acquisition. Cultivation with disc harrow (8 passes) markedly improved maize growth and nutrient acquisition. We made progress in demonstrating the importance of deep-rooted tropical pastures to enhance soil quality by improving the size and stability of soil aggregates when compared with soils under monocropping. The concepts and strategies developed from this work are relevant to different areas of the Llanos for improving soil quality and agricultural productivity.

Field studies in Cauca (Hillsides) on root and shoot attributes of crop and forage components has identified elephant grass as an effective fodder grass for sloping lands which can minimize soil loss and also could acquire greater amounts of N, P and K from low fertility acid soil due to its abundant fine root production. Studies on rooting strategies of naturalized and introduced pastures indicated that naturalized pasture is adapted to low soil fertility conditions due to its ability to produce finer root system. Inter-cropping of Cassava with cover legumes reduced soil loss and improved nutrient acquisition by cassava. The impact of improved fallow species on subsequent maize cropping is being evaluated.

Output 2: Strategies developed to protect and improve soil quality

- ***Recommendations of soil and crop management practices for efficient nutrient use and erosion control in systems***

Agricultural land-use systems replacing native savanna on oxisols affect the partitioning of P among inorganic and organic P fractions. Indicators of organic P mineralization suggest that organic P is more important for delivering available P in improved grass-legume pastures than in continuously cropped soils. In cultivated soils, much higher P fertilizer doses significantly increase available inorganic P contents with lesser impact on organic P pool sizes. Studies indicated that the amount and turnover of P that is held in the soil microbial biomass could increase when native savanna is replaced by improved pasture while it could diminish when soils are cultivated and cropped continuously.

The important activity of the earthworm species *Martiodrilus carimaguensis* in natural and introduced pastures involving incorporation of P from organic sources into soil P pools, increasing labile P pools, and improving P cycling was demonstrated in short-term studies conducted in the Llanos. The ecological significance of earthworms in P cycling in the native savanna and the introduced pasture was related to superior quality of litter from improved pasture. Enhancement of biological activity in pastures was reflected by larger population sizes of *M. carimaguensis* as well as higher microbial biomass P.

Therefore, strategic application of lower amounts of P fertilizer to crops and planting of grass-legume pastures are recommended to promote P cycling and efficient use of P inputs in low P oxisols of tropical savannas.

Studies on the impact of improved fallows in Cauca (Hillsides) indicated that *Tithonia diversifolia* improves soil P availability in P-fixing soils of tropical hillsides.

- ***Soil properties, management practices and plant components that affect N capture and fluxes identified***

We found that use of disc harrow could improve N uptake by maize and green manure crops but not grass alone pasture system. This year, our efforts to evaluate the impact of no-till systems on plots of Culticore phase I, resulted in demonstrating that direct drilling or chisel + direct drilling treatments are better suited to plots that were under crop-pasture rotation than under monocropping or cereal-legume rotation. We also found that the rooting depth and grain yield of maize could be improved markedly by direct drilling rather than chisel + direct drilling on plots planted from phase I of Culticore. Data on the impact of no-till systems on N capture and fluxes are being analyzed.

- ***Strategy identified for minimizing global warming potential in the savannas***

Three papers from the two Ph.D. theses reported last year have been submitted for publication.

- ***Strategy identified for establishing and maintaining beneficial soil macrofauna populations in savannas***

We have achieved substantial progress toward this milestone and it is summarized in a book entitled "Nature's Plow: Soil Macroinvertebrate Communities in the Neotropical Savannas of Colombia". This book includes 24 refereed research publications. It is already published in English and the Spanish edition is in press. This year we observed diet preference by *M. carimaguensis* for seeds from the soil seed bank and found considerable loss of viability of seeds in earthworm casts. We also showed that biogenic physical structures produced by soil macrofauna could be related to their ecological function in the soil. These structures can modulate the availability or accessibility of one or more resources used by other soil organisms.

Output 3: Improved decision making for combating soil degradation and greater agricultural productivity

- ***List of soil quality indicators prepared and available to monitor degradation in reference sites***

Field studies were conducted to quantify the residual effectiveness of P fertilizer inputs in cereal-grain legume rotations (Maize-soybean or rice-cowpea) in terms of both crop growth response and labile P pool sizes in an oxisol in the Llanos of Colombia. The results showed that soluble P applications to oxisols of Colombia remain available for periods of time which are much longer than expected for "high P-fixing"soils, such as the oxisols of Brazilian Cerrados. These studies also showed that Bray-II could be a useful method to estimate P availability in Colombian savanna Oxisols. Recent work indicated that microorganisms can take up, within a few days, high quantities of phosphate from the soil solution; and an increase in microbially bound phosphorus could be an indicator of improved soil fertility for a low P Colombian Oxisol. Lists of soil quality indicators have been published and are being incorporated into guides for use by stakeholders with PE-3.

- ***Tools designed for estimating soil erosion and training manual written***

A student thesis on the use of a newly designed mini-rainfall simulator was completed this year. A training manual (on the application of the universal soil loss equation) is being prepared for soils of the Andean region based on research carried out in Cauca (Mondomo and S. Quilichao), Colombia.

- ***Decision-making tool for soil and water management produced***

A decision support tool for soil use and management (based on soil slope, texture and depth) has been developed for use in the Colombian Llanos. The NuMaSS (nutrient management decision support system) was successfully tested with data from the long-term experiments in the Llanos. Application of this decision support tool 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. An alternative strategy to cropping low P Oxisols was developed that involves strategic application of lower amounts of P fertilizer to crops and planting of grass-legume pastures to promote P cycling and efficient use of P inputs.

- ***Map of risk assessment of soil degradation (erosion, soil nutrients) for hillsides and savannas produced.***

This year we made progress in using a georeferenced soil data bank (GEOSOIL) to develop maps based on specific properties of soils. These maps are useful for planning of land use and for developing site-specific recommendations for soil management for the municipality of Puerto Lopez in the Altillanura of Colombia.

- ***Decision making tools for use of organic materials produced.***

The decision tool prepared by a collaborating institute (TSBF in Africa) was tested in 2000 and details reported in project SW-2.

- ***Decision tree to create/maintain an arable layer produced***

A brochure on the strategies to develop an arable layer is in preparation.

- ***Correlations established between local soil quality indicators and objective measurements.***

Efforts on this milestone have resulted in a guide for soil quality indicators and a training module that brings technical and local knowledge of soil quality together. One publication is *in press* in **Geoderma** special issue on ethnopedology. A second training course was held in Africa and the Methodological Guide 'Local Indicators of Soil Quality. East Africa Edition' was published (with PE-3, SW-2).

- ***Improved crop and soil models developed and validated***

Data from long-term experiments in the Colombian Llanos on plant and soil phosphorus have been used by modellers working with the CERES, NuMaSS, PDSS2 and APSIM models.

Output 4: Institutional capacity for SWNM enhanced through the dissemination of concepts, methods, tools and training

- ***At least 9 undergraduate, three Master's and 2 Ph.D. theses submitted***

Three Ph.D. theses were successfully defended at University of Norway, ETH, Switzerland, and University of Paris I, respectively. Two M.Sc. theses were successfully defended at Universidad Nacional de Colombia and obtaining the 'meritorious' qualification. Six undergraduate theses were completed and one of them was recognized as 'meritorious' by the University of the Llanos. This year one of our Laboratory Technicians (Jesús H. Galvis) was chosen for the award of 'outstanding student' by the University of Santiago de Cali for his academic excellence.

- ***Workshop held on soil physics.***

A workshop was held in 1999 and was attended by 50 researchers and technicians from Latin America.

- ***Workshop on C sequestration held.***

A workshop was held in Brazil in October 2000 and the final project is pending.

- ***At least three projects with partners submitted to donors.***

Three new projects (BMZ-GTZ, EC, PRONATTA) received funding in 2001 and one concept note was submitted to BMZ.

- ***ELABS initiated***

Lack of funding has prevented advances in this area.

- ***At least 10 field days and four training workshops held on local soil quality indicators***

9 field days and one training workshop on soil quality indicators were held. Restrictions on staff travel and lack of personnel for training continues to hinder the progress in this area.