TropSoils

Extension Proposal & Program Plan

1987-1992

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About the Cover

Two Peruvian women—one poking her planting stick into the soil, the other dropping her seed in the hole. Like people in developing nations everywhere, these women depend on soil resources every day of their lives. TropSoils conducts its research with the needs of farmers and their families in mind. We recognize that, in developing nations around the world, the lives and livelihoods of each generation will depend on the careful and sustained management of our soil resources. *Photo and design by Neil Caudle, Department of Agricultural Communications, North Carolina State University.*

About this Document

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Program Extension Proposal

Problem

The availability of food in adequate amounts, on a reliable basis, and at affordable prices continues to be a primary problem facing developing countries in the world. In many areas, increasing population coupled with flat to declining production of agricultural commodities has resulted in a net decrease in per capita food production. Efforts to correct this situation have focused on raising the level of productivity on land already in use and diverting lands from other uses to agriculture. All too often, these actions do not bring about the desired increase in food production but rather contribute further to soil degradation and environmental deterioration.

It is a false hope that world populations can be sustained by reliance on traditional farming practices. Improvements in technology are essential, and some minimum inputs will be required. However, it is also apparent that providing the technology to increase food production does not ensure the elimination of hunger or the prevention of famine. Thus, issues related to poverty, sustainability of an agricultural practice, enhancement of the natural resource base, and improvements in the quality of the environment are critical. These are all factored into the Trop-Soils program and are given due attention in its detailed actions.

Challenge

Few of the tropical lands available for increasing food production possess the most favorable characteristics to achieve this objective. The humid tropics and acid savannas, which for the most part have favorable rainfall and temperature regimes, have soils whose chemical properties constrain plant growth. The semiarid tropics and steeplands have many of the same kinds of soil-related problems, plus population pressures and limitations imposed by climate.

The areas eligible for agricultural development have been identified as some of the world's most fragile ecosystems. Thus, it will be difficult to both farm these lands and at the same time preserve the natural resource base—the soil. Already, badly managed fields have been abandoned, and valuable forests are being cut and cleared to replace them. Numerous studies have concluded that soil erosion and declining soil fertility constitute a major threat to agricultural development and sustainable natural resource management in the developing world.

Since soils play a critical role in the success or failure of farming systems in the tropics, it is not enough to focus only on the crop or commodity. Alternative soil-management technologies are required that will enable users to address diverse circumstances and to provide the flexibility to meet ever-changing needs and opportunities.

Historical Reference

TropSoils was initiated after an extensive and comprehensive planning process which recommended, and was approved by AID and BIFAD, an approach built around agroecological zones with each having a primary research site representative of the respective zone. As a collaborative program, input into the selection of specific research topics and support in carrying out the research was provided by the local AID mission, the host country, and the participating U.S. university.

The program has proceeded without significant deviation from the basic plan. Major research activities have been established within the three agroecological zones for which funding was provided. The assistance and support by the AID missions has been constructive, host-country institution inputs have been consistent with the resources available, and U.S. university leadership has enabled the program to make remarkable progress. Currently research is in progress at the primary centers in Niger, Indonesia, Peru, Brazil and Mali. Major emphasis is being given to extrapolation and adaptation of the results to a wider clientele through a network approach. One network is already functional, and on-site studies are in progress in Guatemala, Honduras, Costa Rica, Panama, Bolivia, Peru and Brazil. Emphasis is placed on host-country personnel for leadership in selecting the topics, planning and conducting the research, and interpreting the data. The role of TropSoils is one of technical support.

Projects are being modified as rapidly as practical to reflect the expanding information base, changing priorities and financial constraints. It is crucial to recognize, however, that the purposes for which TropSoils was established and the kinds of problems it is committed to solving cannot be achieved by hop-scotching around the tropics with a collection of short-duration tests. Sustained efforts on carefully analyzed priority topics offer the best hope for making an impact on increased food production while enhancing the natural resource base. Studies by the External Evaluation Panel and by Hogan, Ratchie and Robins conclude that the organization, operations, and commitment by the program participants, and the flexibility to make modification as needed provide a sound basis for continued support for TropSoils and are reasons to be optimistic that measurable progress will be made in the future.

Current Status

During the six years in which TropSoils has been functional, our knowledge on soil constraints to plant growth has been expanded and methods for ameliorating these problems have been identified. Due to the relatively short life of the program, the information has been obtained under a limited set of crop and weather conditions. Minimum consideration has been given to the economic aspects and to other important factors relevant to on-farm application of the technology. The absence of well-defined predictable relationships among the soil-plant-atmosphere continuum imposes further limitations on the extent that the technology can be transferred to site-specific situations.

While there are no quick fixes to these problems, we will be able to make further progress in narrowing the technology gap. This document, and the accompanying research project documents, provide justification for such an effort, details on how it would be undertaken, and a projection of expected results.

Goal

The goal of TropSoils is to develop and adapt improved soil-management technology that is agronomically, ecologically and economically sound for developing countries in the tropics.

Objectives

1. To conduct a collaborative soil-management research program that will contribute to a sustainable agriculture, improve the natural resource base, and minimize environmental degradation.
2. To select topics for research that are relevant to priority problems identified in consultation with user groups.
3. To communicate the information to diversified user groups.
4. To provide advanced training in the principles of soil management to developing country personnel through participation in the research program.

Global Plan

TropSoils has operated, since its inception in 1982, under the basic plan devised by the Planning Entity and approved by AID and BIFAD. This plan has proven to be an effective approach to the design and management of the program and, with some updating to reflect progress made and changing financial conditions, is proposed as the guide for the future.

TropSoils' global plan is:

1. To conduct user-oriented research based on established principles of soil science, along with principle-oriented research as needed, to overcome soil constraints to sustained agriculture, and to enhance the natural resource base for developing nations in the tropics.
2. To conduct these studies in collaboration with partner nations and international research centers so as to make the best use of available knowledge and resources, to ensure that the research is adapted to both user and setting, and to link people and institutions into active soil-management networks.
3. To deploy the research efforts according to agroecological zones, which are groupings of tropical regions that share many soil and climatic characteristics, so as to focus the programs and facilitate the extrapolation of results from one area to another.
4. To establish and sustain long-term research at primary sites in each zone and to develop secondary sites as needed to adapt new technologies to achieve the efficiency and continuity necessary for sound soil-management programs.
5. To coordinate work at each of these primary sites under the leadership of a U.S. land grant university with proven expertise in its respective zone, so that projects draw on all the resources and experience of the university, both in the field and on the campus.
6. To team these programs, and their respective networks, into a single, unified program, global in scope, assisted and guided by the Technical Committee, the Board of Directors, the External Evaluation Panel, the Management Entity and the primary funding agency, AID.
7. To encourage the broadest exchange among all components of this unified program through publications, site visits, technical conferences and other regular communications.

Strategy

Agroecological Zones

While developing nations in the tropics share in common such soil constraints as soil acidity, nutrient deficiencies, water stresses and erosion, these constraints manifest themselves in varying ways and degrees from region to region. The strategy employed is to structure the attack along agroecological zones. While a given zone is not a homogeneous unit, the constraints are sufficiently common to provide a focus for the research. The zones and their basic features are as follows:

1. Humid tropics. This is the portion of the tropics where there is no more than a three-month dry season and temperature is not a limiting factor to plant growth. The native vegetation is tropical rainforest. Soil acidity and nutrient deficiencies are common chemical constraints to crop production.
2. Semiarid tropics. This zone is characterized by a protracted dry season of six to nine months duration. Erratic precipitation, wind and water erosion, desertification, soil acidity and nutrient deficiency are major constraints to crop production.
3. Acid savannas. This portion of the tropics is characterized by a strong dry season of four to six months, savanna vegetation and predominantly acid soils with inherently low nutrient levels but generally good physical conditions. Temperature is not a limiting factor to plant growth.
4. Steeplands. This category includes the densely populated regions of the tropics where soil erosion is a major concern. Soil properties, moisture and temperature regimes vary.

Research Locations

A second component of the strategy is to utilize selected research sites within an agroecological zone. This feature enables the research to be concentrated in a manner that will maximize the output from limited resources and promote the continuity that is essential for long-term research. The countries where research is being conducted are:

Humid tropics—Peru, Indonesia and Brazil
Semiarid tropics—Niger and Mali
Acid savannas—Brazil

This approach has proven to be a useful means of focusing the research in a cost-effective manner. However, with the reduction in current and projected funding, some revision in concept of research location may be necessary. One option is to maintain a location where the primary developmental research would be conducted, referred to as a "research center," and to select other locations where adaptive and promotional work would be conducted, referred to as a "research site."

Lead University

A third component of the strategy is that research leadership is provided by a U.S. university that has experience with the predominant soil constraints in a given agroecological zone. This approach provides a means to utilize the scientific expertise in specialized subjects and to provide a focal point for overall program management. The TropSoils plan provides for the following lead university arrangement:

Humid tropics (Peru)—North Carolina State University
Humid tropics (Indonesia)—University of Hawaii

Semiarid tropics (Niger)—Texas A&M University
Acid savannas (Brazil)—Cornell University

Collaboration

The fourth component of the strategy is inherent to the CRSP concept—collaboration. The primary participants are AID, the U.S. universities, and the collaborating country agricultural research organization. Currently these are:

Peru—Instituto Nacional de Investigación Agraria Agroindustrial (INIAA)
Indonesia—Center for Soils Research (CSR)
Niger—Institut National de Recherches Agronomiques du Niger (INRAN)
Brazil—Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA)

Experimental Approach

The role of soil management in the food production is to rectify mismatches between soil characteristics and plant requirements. Several basic concepts undergird the TropSoils experimental approach and serve as a reference base for determining if a project is likely to contribute to the program's goal. These concepts are:

1. The research establishes cause-and-effect relationships between soil properties and plant growth, as influenced by climate.
2. The approach uses established principles of soil and crop science. When necessary, basic research is conducted to clarify existing principles or to explore new ones.
3. The technologies developed maximize the utilization of the inherent properties of the soil, while making modifications as needed to enhance this important natural resource base.
4. The technology packages address soil constraints across landscape positions in a manner that minimizes environmental degradation.
5. The technology packages are flexible enough to accommodate both the economic status of the user and the natural characteristics of the resource.
6. The transfer of soil-management technology from the research sites to other locations will be through network schemes, thus making the program truly global in scope and application.

Continuity

Research to provide soil-management technology for developing countries is dynamic and, thus, must be sustained. Research needs change as users of the resource change. Recognizing this, the TropSoils plan uses a collaborative approach to establish a soil-management research infrastructure within each partner nation. This collaborative approach develops in the partner nation a pool of trained scientists and leaders who can direct their own research and technology-exchange programs. Furthermore, it links people and institutions into a network that will serve to keep attention directed on ways to most effectively use and conserve the important natural resource—the soil.

Communications

To improve soil management in developing nations and gain support for its programs, TropSoils must ensure that its expertise is recognized and its research results are disseminated in a useful, highly visible form. Two broad goals have been

set forth for TropSoils' program-wide communications effort. The first is to help focus diverse information gleaned from individual projects and bring it to bear on the practical solution of soil-management problems of global significance. The second is to convey, to a non-technical audience of public officials and policy-makers, TropSoils' objectives and accomplishments.

TropSoils has performed a commendable job in communicating the results of its work to, primarily, a technical audience. This fact is evidenced by the large number of publications in scientific journals and similar publications, as documented in "TropSoils Administrative Report, 1981-1987." However, we have been less effective in disseminating the information to AID and to users in the host countries. This situation is evidenced by studies which show that TropSoils has good support in those countries where it has personnel on-site and studies in progress. In other areas, it has very little following, and the information from its programs is not being adequately employed to solve local problems.

A first step in achieving this goal is the recognition that communicating with the target audience will require techniques and persons with skills that are different from those for communicating with scientific peers. Thus, upon recommendation of the Management Entity and with the approval of the Board of Directors, a discrete communications program has been established which takes its place along the side of the four technical programs as a contributing element to achieving the overall TropSoils goal. This program is described in detail in the Communications Plan of Work and is outlined as follows:

The primary objectives of the communications program are:

1. To apply the best available soil-management information to problems of global or regional import.
2. To convey achievements to public officials, university administrators and other decision-makers concerned with the subjects of TropSoils research.
3. To assist and improve internal TropSoils communication.

The target audiences are:

1. Those who conduct agricultural research and extension programs in developing nations in the tropics.
2. Those who set or influence agricultural policy or assist development in developing nations in the tropics.
3. Research and teaching faculty working in soils, agronomy and international programs at overseas sites and in the U.S.
4. The staff of other foreign-assistance projects; environmental groups.
5. All others with a vested interest in managing tropical soils, improving this natural resource base, and avoiding environmental degradation.

Impact

TropSoils is a research program. Its goal is to develop soil-management technology and adapt it for user groups. However, we recognize that for the technology to have an impact on natural resource preservation and food production, and to minimize environmental degradation, it must be applied. While technology transfer is not a designated TropSoils goal, we have a vital interest in the ultimate outcome of the technology developed. Therefore, we will seek opportunities to interface with technology-transfer programs, to provide constructive inputs, and to use the results of these interactions in assessing and prioritizing our research goals.

Relationship of the TropSoils Program to AID Priorities

Agricultural Program Focus

The focus of AID's agricultural program is "to increase the income of the poor majority and expand the availability and consumption of food, while maintaining and enhancing the natural resource base." The TropSoils program will make a direct contribution to this focus because (a) it is directed toward improving net income of the agricultural sector, which contains a substantial portion of the poor; (b) it will provide technologies that keep purchased inputs to a minimum, while increasing the production of food products; (c) it will provide feasible alternatives to opening up new lands, thus reducing deforestation; and (d) it promotes soil-management practices that will reduce erosion on lands in cultivation.

Sustainability of Agricultural Program

A guiding principle in all of the TropSoils' programs is to develop practices that will be applicable to a range of economic, social and environmental conditions. The method employed is to develop alternative practices which are adaptable to the specific landscape position, social structure of the society, financial resources of the farmer, and changing needs of the public.

Forestall Environmental Degradation

World population is growing at a rate of over 80 million per year and is expected to increase to more than ten billion in the next century. Such rapid growth necessarily places severe stress on the natural resource base. This stress and its concomitant degradation of the environment increases as destructive practices are employed on existing lands and more marginal lands are brought into production. Experience shows that maximizing the efficiency in commodity production reduces the stress on the natural resource base.

Environmental considerations have always been in the forefront of TropSoils orientation and planning. For example, declining agricultural productivity is recognized as a fundamental cause of environmental degradation. Practices which increase productivity on lands already in cultivation will reduce the need to open up new lands, and thus reduce wind and water erosion. For example, improved pastures not only produce more food products but also reduce erosion, increase nutrient cycling, and increase organic matter in the soil.

Expanded Programs in Africa

The emphasis given by AID to Africa's urgent need to develop a sustainable agriculture, to enhance its natural resource base, and to reduce environmental degradation has been given high priority in the TropSoils program goal, objectives and strategy. Most of our efforts in Africa to date have focused on the severe problems of the Sahel. From the beginning, however, we have designed the research conducted in Latin America and Asia to be relevant to Africa as well. For example, techniques developed in the acid savannas of Brazil and the humid tropics of Peru and Indonesia are ready for transfer to Africa. Aggressive efforts are being made to locate collaborators in Africa with whom we can work to adapt these practices to local situations. As rapidly as we can develop collaborative relationships, we will shift programs and resources to capitalize on the opportunities. In the interim we will continue to serve Africa's needs in a cost-effective manner by maintaining our

work in those countries where we currently have productive working relationships and where the information is applicable to the problems of Africa.

Plan of Work

Development Procedure

Each Program Coordinator consulted with the collaborating country administration and research personnel to identify topics of high priority for both country programs and for the agroecological zone. Discussions were then held with the field- and campus-based faculty to develop research outlines, personnel requirements and budgets to accomplish the stated objectives. The resulting proposals were presented at a meeting at Atlanta, Georgia, December 4 and 5, 1987, attended by representatives of all the research programs, the Board of Directors and the External Evaluation Panel.

Proposed budgets for each component were developed by the Management Office and submitted to the Board of Directors for review and approval. The Program Coordinators were later advised of the approved budgets and revisions were made in the Plan of Work to adjust project activities to anticipated funding. The resulting Plan of Work for each technical program, the communication program and the management office are included with this proposal.

Problems Addressed

The types of soil constraints that are addressed by these programs may be categorized into the following themes: infertility, toxicity, droughtiness, compaction, crusting, degradation, erosivity, salinity, and variability.

Mechanisms to Solve or Overcome Problems

From the research proposed we expect that the problems identified can be ameliorated through use of one more of the following: soil-acidity management, fertilizer management, agroforestry, low-input farming, conservation-effective farming, geostatistics, expert systems and decision support systems.

Budget and Staffing

Data on budget by components, budget by objects and staffing are given in the following tables. These are reported in more detail in the Plan of Work for each component.

The total budgets for 1987-1988 and 1988-1989 are based on actual and projected funding for the respective periods. Budgets for the remaining three years represent a six percent increase over the budget for the preceding year. This modest increase is necessary to meet normal adjustments imposed by inflation, personnel salary increases and changes in overhead rates.

The funding requested is the absolute minimum necessary to conduct the programs described. Funding at a lower level will require downward adjustments in the research conducted.

Staffing Pattern. Soil Management CRSP

Category	Year 1987-1988	1988-1989	1989-1990	1990-1991	1991-1992	Total CRSP Funded	Total Other
				FTE			
Campus-based Scientist	6.62	6.52	6.62	6.62	6.62	1.70	31.30
Field-based Scientist	7.00	7.00	6.00	6.00	6.00	32.00	0
Graduate Student	19.25	19.50	20.75	20.25	19.75	55.85	43.65
Other	50.00	49.70	50.00	50.00	50.00	59.70	190.00
Total	82.87	82.72	83.37	82.87	82.37	149.25	264.95

Projected Budget for Components. Soil Management CRSP

Object	Year 1987-1988	1988-1989	1989-1990	1990-1991	1991-1992	Total
				x $100		
Cornell University	3516	3186	3377	3580	3795	17454
University of Hawaii	3540	3040	3222	3416	3621	16839
N.C. State University	5224	5140	5449	5776	6120	27709
Texas A&M University	4335	4765	5051	5354	5675	25180
Communication	940	1500	1589	1684	1786	7499
Management Office	3055	2919	3093	3280	3477	15824
Contingency	240	300	320	340	360	1560
Total	20850	20850	22101	23430	24834	112065

Projected Budget for Objects. Soil Management CRSP

Object	Year 1987-1988	1988-1989	1989-1990	1990-1991	1991-1992	Total
			x $100			
Salaries	7850	7911	8384	8888	9422	42455
Benefits	1577	1547	1640	1739	1844	8347
Allowances	1641	1544	1637	1735	1840	8397
Travel	1781	1909	2024	2146	2273	10133
Supplies	1165	1157	1226	1299	1378	6225
Equipment	406	117	124	130	139	916
Other Direct Costs	1885	1945	2061	2185	2315	10391
Indirect Costs	4545	4720	5005	5308	5623	25201
Total	20850	20850	22101	23430	24834	112065

Acid Savannas

Department of Agronomy
Cornell University

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CU-110 Plant-Microbial Competition for Nutrients 25

CU-111 Nutrient Balance for Cropping Systems Based on Legume Green Manures in Oxisols and Ultisols 27

Research Topic: Soil Constraints to Management of Acid Savanna Soils

CU-108 Characterization of Structure Stability and Root-Restricting Pans in Cerrado Soils 30

Research Topic: Management of Water & Nitrogen in Acid Soils of the Tropics

CU-104 Understanding Water and Nitrogen Dynamics in Cropped Acid Soils of the Tropics for Improved Management 34

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Introduction: Acid Savannas Research Program Proposal

The overall TropSoils program goal is to develop stable food production systems on an agronomically, economically, and ecologically sound basis in the developing countries of the tropics. The major thrust of our ongoing research program is to relieve soil constraints to crop production on the Oxisols and Ultisols of the acid savannas in the humid tropics.

The acid savanna regions of the tropics are dominated by the soil orders Ultisols and Oxisols. At least 500 million hectares of acid savannas are found worldwide with major portions in South America. There are nearly 200 million hectares in Brazil alone. In addition, large areas occur in Africa and Southeast Asia. These areas are characterized by a wet-dry cycle with sufficient precipitation for at least one crop per year. Many of the acid savannas are rapidly being developed without a sound soil management base resulting in low productivity and widespread erosion.

The soils of these areas are deep, well drained, highly permeable, and have favorable physical conditions so that their potential for food crop production is high. The principal factor limiting their productivity is their low fertility. With increasing availability of high-yielding varieties of food crops the potential of these areas is higher than ever before. Thus, the low natural fertility of these soils is an even more crucial limitation than previously. To achieve this potential, however, it is necessary to determine the most effective and economic amounts and methods of application of liming materials, nitrogen, phosphorus, potassium, and micronutrients in relation to cropping systems and management practices.

Earlier work carried out on the highly weathered, well-drained Oxisols of the acid savannas of Brazil has demonstrated that with proper application of lime and fertilizer phosphorus and nitrogen, improved yields of many food crops can be achieved. Without these inputs crop failure is the result. Water, however, may be a limiting factor in extensive areas of the acid savannas even during the rainy season, especially where subsoil acidity restricts root growth. A short period without rain during the growing season can nullify the beneficial effects of the other inputs. Likewise, liming may be necessary to provide sufficient calcium and magnesium for adequate plant nutrition. Work at CPAC has resulted in management practices for lime and fertilizer phosphorus and nitrogen that are used widely in the Cerrado region of Brazil, as well as being adapted for use on similar soils in other parts of the world.

The overall goal of the research program is to develop soil management strategies for sustained crop production and conservation of natural resources based on a comprehensive understanding of the physical, chemical, and biological processes

that affect the fate of water and ions in cropped soils of the acid savannas and the humid tropics. Within the framework of the agreements with the Management Entity of the Soil Management CRSP and EMBRAPA, three major research topics were selected for the collaborative research program:

1. Nitrogen management in acid savanna/humid tropic soils.
2. Soil constraints to management of acid savanna soils.
3. Management of water and nitrogen in acid soils of the tropics.

The goals of the nitrogen management work are to find effective ways to manage crop residues, biologically fixed nitrogen, and fertilizer nitrogen for sustained crop production and maintenance of soil fertility. With increased cost of energy and, thus, increased cost of fertilizer nitrogen, the thrust is to improve the utilization of biologically fixed nitrogen. We wish to learn how much nitrogen can be fixed, how much can be utilized by the succeeding crop, and how to incorporate legume green manures and crop residues into viable cropping systems. Management of organic nitrogen sources is complicated and may require both special cropping systems and/or special management. The role of biomass nitrogen and microbial turnover will be assessed for its effect on competition for nitrogen by higher plants and the availability and ultimate fate of fertilizer and green manure nitrogen. The addition of large quantities of nitrogen from green manure legumes likely will result in increased nitrate leaching. The nitrate leached will be accompanied by equivalent amounts of cations so that cropping sequences will be required that minimize losses of nitrate and the accompanying cations.

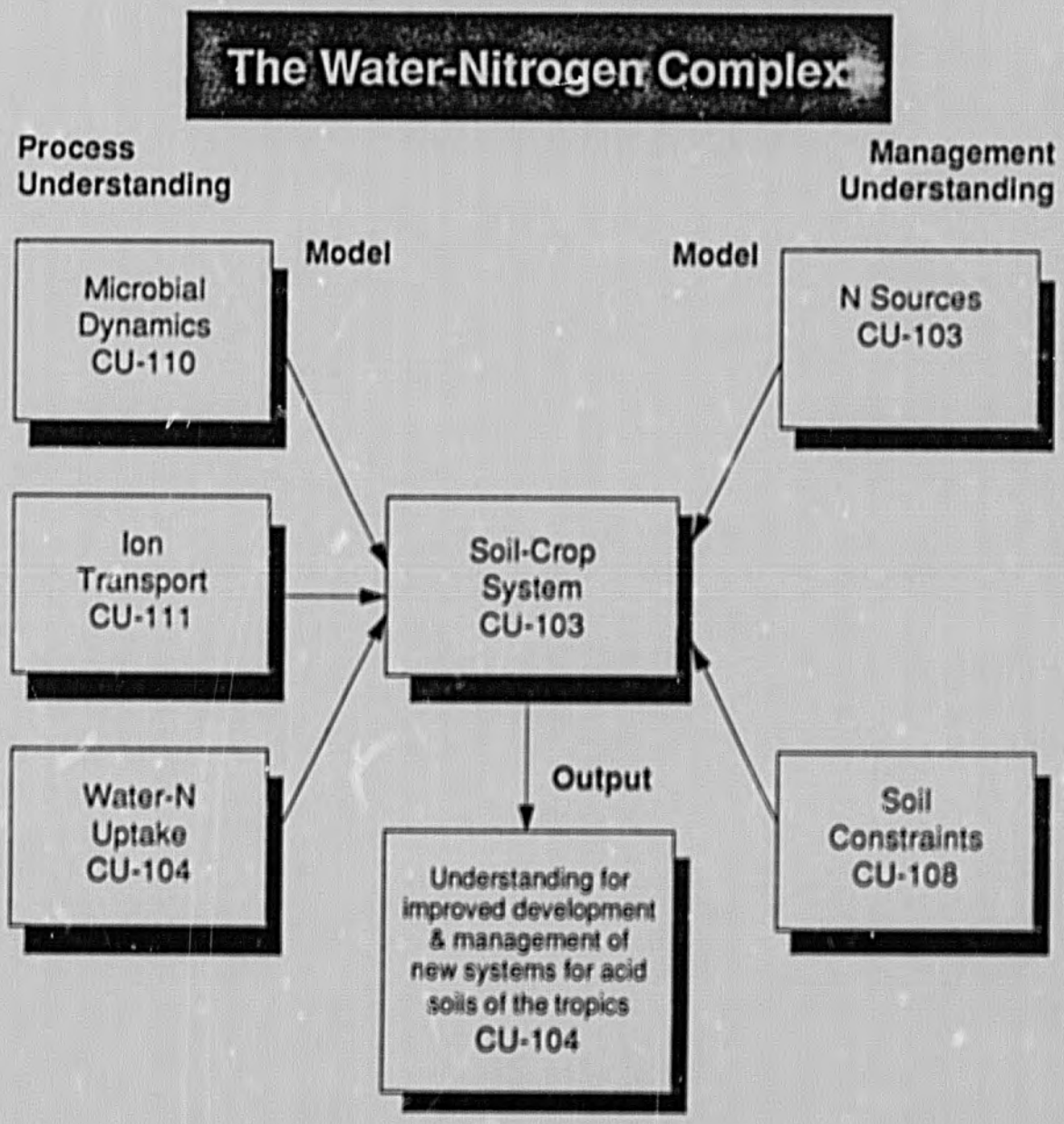
The second research topic, soil constraints to management of acid savanna soils, has as its goals the identification of chemical and physical factors of significance to use and management, to understand the genesis of these properties, and to inventory these properties for use in management of the acid savanna soils. One project to determine the relationships between soil color patterns and natural drainage characteristics, and to develop means of identifying those Oxisols with restricted drainage has been completed. Further work to evaluate the role of iron in soil genesis is under way. Work to establish the potential for tillage pan formation on these soils as well as the influence of various chemical additions on the stability of soil structure is necessary so that management practices can be developed to avoid or minimize physical constraints to crop production.

The third major topic, management of water and nitrogen in acid soils of the tropics, has as its goals the development of a quantitative understanding of water and the fate of soil amendments in the acid savanna soils. Experiments are being carried out to achieve these goals with the objectives of developing predictive models for use in describing nitrogen and other ion movement and distribution in the Cerrado soils. Models relating water use to crop yield will be constructed to be useful in extending experimental results to other locations. It is expected that data collected from the other two research topics as well as that developed as part of this topic will be combined into models to help develop improved crop management systems. These models also will be used as predictive tools to extend these management systems to other locations.

These three research topics can also be viewed as a soil-nitrogen complex where the overall output is understanding for improved development and management of new systems for acid soils of the tropics. This output will be accomplished by research on the soil-crop system. Work on understanding the process contributing

to the soil-crop system will be done by research on microbial dynamics, ion transport, and water-nitrogen uptake. Likewise, management understanding will be increased through research on nitrogen sources for improved crop production, and on minimizing soil constraints, mainly physical, to production.

All of these research topics and associated research projects have been developed in collaboration with Brazilian counterpart scientists at the CPAC. The projects supplement and complement their ongoing research program on the acid savanna soils. In addition, these projects contribute to the research program of the Agronomy Department at Cornell.



Research Topic

Nitrogen Management in Acid Savanna/Humid Tropic Soils

Project Number

CU-103

Project Title

Soil- and Crop-Management Systems for Acid Savanna/Humid Tropic Soils Using Green Manures and Crop Residues as Nitrogen Sources

Project Leaders

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Collaborators

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Problem Statement

The collaborative research program between EMBRAPA, Cornell University, and North Carolina State University has demonstrated that corn production is significantly increased by the application of nitrogen to Oxisol soils in both the acid savannas and humid tropics of Brazil. To evaluate nitrogen as a constraint to production, the following modification of the framework for N recommendations in New York is used as follows:

$$Np = Ns + Nr + KfNf$$

where:

Np = N uptake of the crop required to achieve the yield goal
Ns = N supplied from soil mineralization
Nr = N supplied from organic residues and green manures
Nf = N supplied as fertilizer
Kf = fraction of fertilizer N taken up by the plant.

The relationship between yield and nitrogen content of the aboveground dry matter of a crop provides a good estimate of the amount of nitrogen that must be accumulated by the crop. Each component of this model must be evaluated, and in this work we are interested in developing cropping systems to maximize the contribution of Nr to the nitrogen needs of the non-legume food crop.

Farmers in New York make extensive use of manure and legumes as sources of nitrogen and, in fact, these sources of nitrogen are far more important than fertilizer nitrogen on many dairy farms. In the research program in New York we have evaluated manure, crop residues, and previous legume crops by assigning a specific value to the amount of mineral nitrogen which each source is expected to furnish to a succeeding non-legume crop. The values we assign are based on a

fairly extensive set of field experiments performed over many years. In the acid savanna and humid tropic regions of the tropics we must develop sources of organic nitrogen and cropping sequences to match the nitrogen needs of the cropping system with the nitrogen release by the organic nitrogen source.

Corn response studies in limited areas of the acid savannas and humid tropics have shown that leguminous green manures and crop residues may supply all or part of the nitrogen needed for maximum production. Few farmers, however, avail themselves of this seemingly inexpensive, inexhaustible source of nitrogen. One important reason why farmers do not make better use of biological sources of nitrogen is the ease with which fertilizer nitrogen can be managed. More important is the lack of knowledge of how to manage organic sources of nitrogen to obtain consistent results from their use. A recent survey conducted by the agricultural extension service in one state of Brazil showed that almost all farmers listed management of leguminous green manures high on their lists of perceived knowledge needs. Management of organic nitrogen sources is more complicated than management of fertilizer N sources. Their use requires special cropping sequences and special management. Until the specific input-output relationship can be developed, the role of biological nitrogen relative to fertilizer nitrogen cannot be determined.

Objectives

1. Develop planting sequences and cropping systems to most effectively use legumes and plant residues to supply the nitrogen requirements of non-legume crops.
2. Evaluate the role of legumes and crop residues in nitrogen cycling and soil organic matter maintenance.
3. Determine the effects of legumes and crop residues on long-term soil productivity and recycling of nutrients in acid savanna/humid tropic soils.

Operational Plan

Field experiments will be carried out to develop practical means to utilize green manures and organic residues as sources of nitrogen in cropping sequences. These will be long-term experiments in which green manures and organic residues will be incorporated at various stages into the cropping systems, and their rate of mineralization will be measured. In a trial already begun in the acid savannas, a large number of legumes are being tested for dry season survival with the objective of identifying legumes that could be grown as green manures between wet season crops. The potential of these materials to supply nitrogen to the non-legume crop component will be evaluated and input-output relationships necessary to develop practical management systems using biologically fixed nitrogen will be developed. Measurements of crop yields, plant nitrogen uptake, soil nitrogen, green manure and plant residue nitrogen will be made. Site characterization will be made.

Field experiments to be carried out include measuring the potential of several legumes to supply nitrogen for succeeding nonlegume crops, response of corn to N supplied by leguminous green manures as well as fertilizer N, the ability of green manure legumes to recycle cations, and the response of green manure legumes to fertilizer P.

Detailed field experiments will initially be conducted at the CPAC, Planaltina, Brazil, and the UEPAE, Manaus, Brazil. The necessary analytical work will be

carried out at these respective centers. As this work develops, experiments derived from these results should be extended to sites with other soils and environmental conditions in Latin America and Africa. In addition, the results may be tested in farmer fields to test the validity of the results under farmer practice.

Assessing Accomplishments

Evidence already at hand shows that green manure legumes can supply most, if not all, of the nitrogen required by nonlegume crops in a cropping system. The ultimate goal is to develop cropping systems utilizing green manure legume nitrogen which consistently supply adequate nitrogen for non-legume crops in farmers fields. Economically feasible and sustainable cropping systems which use plant nutrients efficiently should be the result.

Research Topic

Nitrogen Management in Acid Savanna/Humid Tropic Soils

Project Number

CU-110

Project Title

Plant-Microbial Competition for Nutrients

Project Leader

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Collaborators

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Problem Statement

Crop recovery of applied fertilizer N is generally in the range of 30% to 50% and about 60% is the best usually achieved in research plots. The tremendous amount of research carried out on fertilizer management practices and N-loss processes has improved fertilizer N use to the present level; but it is unlikely that further work in these areas will lead to substantial gains in N-use efficiency.

The question of what is limiting fertilizer N efficiency is not easy to answer as there may be many contributing factors. We hypothesize, however, that the nature and timing of microbially mediated N transformations in soil have an important impact on fertilizer N availability and on its recovery by plants. Growth of heterotrophic microorganisms in soil is generally limited by the availability of carbon sources. A base-level population is maintained by the native soil organic matter, but the microbial population would be expected to expand in size in response to inputs of carbon during crop growth, and consequently N is immobilized. The N-immobilization phase will ultimately be followed by a mineralization phase when the carbon inputs cease and the microbial population declines in size back to a base level.

The dynamics of soil microbial populations have been little studied, and the additional N and other nutrients immobilized as crop yields are increased by fertilizer inputs are unknown. Lynch and Panting found that microbial biomass carbon increased by 300 kg C/ha in the top 5 cm of soil during growth of a winter wheat crop in England. If it is assumed that this increase also occurred to a soil depth of 20 cm and that the overall C:N ratio of the microbial biomass is 8:1, the amount of N immobilized by the expanding microbial biomass would be 150 kg N/ha. This simple calculation suggests that the amount of N temporarily immobilized may be high. The ultimate fate of this immobilized N will depend upon the timing of its release, environmental conditions at the time of release, and whether or not other sinks for it exist.

The dynamics of microbial populations and the timing of N-mineralization-immobilization processes will be altered when green manures are used as N

sources. In this case, the green manure is itself a source of carbon for microbial growth, and a portion of the green manure N is presumably converted to microbial biomass N before there is substantial crop growth and carbon input from/through roots. The additional input of carbon in green manure-based cropping systems may result in higher microbial populations and higher amounts of N immobilization compared to fertilizer-based cropping systems.

Objectives

1. To assess the effect of crop growth on microbial growth and competition for nutrients, especially N.
2. To determine how temporal variation in microbial mineralization-immobilization processes influences the availability and ultimate fate of fertilizer and green manure N.

Operational Plan

The general approach in this project will be to follow, in selected cropping systems, the dynamics of the soil microbial population with reference to its nutrient content and the timing of immobilization-mineralization phases.

The most widely accepted method for measuring microbial biomass C is the chloroform fumigation method of Jenkinson and Powlson. Procedures for measurement of microbial biomass N also involve a fumigation treatment. They include mineralization of N following chloroform fumigation of soils and extraction of N immediately following chloroform fumigation. In our opinion, these methods are not entirely satisfactory. A new procedure based on equilibration of microbial biomass N-14 with added N-15, developed by Duxbury and Lauren (unpublished data), appears promising. Some initial laboratory work will be done to determine the best method for measuring N in the biomass of Cerrado soils.

In studies with green manures, more information can be gained by using both N-14- (natural abundance N-15) and N-15-labelled plant materials in separate experiments. Both microbial biomass P and S have been measured by extraction following fumigation, and these elements could also be determined if time and resources permit.

Assessing Accomplishments

The proposed study addresses a fundamental question relating to the efficiency of fertilizer N sources, and should identify what needs to be done in order to improve crop recovery of N from both inorganic and organic N fertilizers. It relates directly to the various green manure projects being carried out by Reid, Bouldin, and Bowen, to the ion movement modelling project (Riha), and to the proposed green manure/base movement project (Bouldin).

This study will complement a similar effort by J. Duxbury and D. Bouldin on the interpretation of experiments with N-15 and the fate of green manure N in rice-based cropping systems in India. The work in Brazil will be with upland crops.

Research Topic

Nitrogen Management in Acid Savanna/Humid Tropic Soils

Project Number

CU-111

Project Title

Nutrient Balance for Cropping Systems Based on Legume Green Manures in Oxisols and Ultisols

Project Leaders

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Collaborator

Manoel S. Cravo, UEPAE-Manaus, EMBRAPA

Problem Statement

The use of legume green manures in cropping systems will eliminate the need for N fertilizer. However, cropping for an extended time period will require inputs of other nutrients such as P, Ca, Mg and K. The reasons for this are the following: a) The removal of crop products will inevitably deplete the soil supply; recycling is seldom complete and the inputs of N will likely increase the yields and hence accentuate the losses of other nutrients. b) The increased N supply will likely lead to increased NO_3 leaching; the leached NO_3 will be accompanied by an equivalent amount of cations. c) In order to grow the legumes and increase the yield potential of the non-legume crop so that it can take advantage of the increased N supply, amendments such as lime and P will usually be required.

The Ultisols and Oxisols contain no primary minerals and the exchangeable pool is the only source of Ca, Mg, and K. This is a relatively small pool which can be easily depleted by anything which accelerates losses. Because there are no primary minerals, once this pool is depleted, it can only be restored by soil amendments. Although the data are relatively sparse, the behavior of different legumes during the dry season at CPAC suggests that the rooting depth differs greatly among legumes. If this is true then the different legumes would be expected to differ in their ability to recover cations from the lower portions of the profile and hence recover them before they are leached beyond the rooting depth of any crop. Thus the possibility exists that by combining a deep-rooting legume green manure with an appropriate non-legume crop the leaching of nutrients beyond the root zone can be largely eliminated. This is not only prudent in an economic sense but it is also essential in an environmental sense.

Another advantage of the legume green manures is reduction of erosion. The legumes furnish ground cover which protects the soil from the impact of the rain, and this helps to maintain the infiltration capacity of the surface soil. This ensures that most of the rain is soaked up by the soil, thereby increasing available water and reducing erosion by decreasing surface runoff. The increased organic matter additions from the green manure crops also improve soil structure.

Objectives

1. To develop cropping sequences based on legume green manures which keep losses of Ca, Mg, K and NO_3 to economically and environmentally sound levels.
2. To develop models which will describe the losses of Ca, Mg, K and NO_3 under different soil and climatic regimes and to define the input data required for these models.

Operational Plan

The first requirement is a large area of reasonably uniform soil which has not received differential treatments recently. The individual plots should be large enough so that the lateral movement of water between plots does not interfere with the nutrient balance measurements and which will lend themselves to splits at a later date should there be a reason to impose additional treatments. As a first approximation, perhaps 15 by 20 m is a minimum size with perhaps 20 by 30 m being maximum. Probably five replications is a minimum. Initially four main plot treatments will be tested with two subplots per main plot.

The proposed main plot treatments are as follows:

Treatment 1. This treatment will be aimed at a pH of about 5.1 in the surface 25 cm and a pH of about 5 to a depth of about 1 m. The Mg/Ca ratio will be about 0.1 and the K/Ca ratio will be about 0.1.

Treatment 2. The pH will be about the same as in 1. The Mg/Ca ratio will be about 0.4 and the K/Ca ratio will be about 0.1.

Treatment 3. The pH will be about 6.0 in the surface 25 cm and perhaps 5.0 or higher in the remainder of the profile to a depth of about 1 m. The Mg/Ca ratio will be about 0.25 and the K/Ca ratio about 0.2.

Treatment 4. The pH and Mg/Ca ratio will be about the same as in 3. The K/Ca ratio will be about 0.05.

The subplots will be devoted to two or three different legume green manures in a cropping sequence of green manure-corn or green manure-cassava.

Initially, soil samples will be taken to a depth of 1.5 to 2 m on a 10-m grid from areas which will be in the borders between plots, and the following characteristics will be determined: pH in water and KCl, exchangeable ions, total N and C, mineralogical analysis, bulk density and particle size analysis. The holes will be back filled with bulk soil from the same depth taken from outside the experimental area. Bulk samples will be stored in sealed glass containers for subsequent analyses.

At approximately one to two year intervals plots will be sampled to a depth of about 1 m and analyzed for selected parameters. Samples for NO_3 analysis will be taken periodically (one to two month intervals) from the surface and perhaps subsurface layers. Tensiometers and gypsum blocks will be used to monitor the soil water content to depth of about 1 m. The appropriate plant uptake parameters for use in the models will be determined in nutrient culture experiments. The initial hypothesis is that the NO_3 level will be high enough so that except in treatment 1 plots the Mg/Ca ratio and in treatment 4 the K/Ca ratio will be determined by the plant uptake parameters and not the soil ratios.

Additional experiments will be run in adjacent areas for one or two year intervals to investigate specific objectives. An example of such an experiment would be detailed studies of root distribution which would destroy the plots for further use if

they were done in the main experiment.

Current work is developing a method for describing uptake and leaching of NO_3. Another model has been developed which describes the uptake of Ca, Mg, K, and NO_3 for individual roots. The resulting models will be combined and expanded to describe the uptake and leaching of the listed ions.

The Oxisols and Ultisols furnish superior experimental soils for developing cropping systems with acceptable losses of Ca, Mg and K. The total of these elements can be easily measured. Usually the total in the soil profile is small enough that any appreciable loss can be measured over a period of a very few years.

The soil and climatic regime at Manaus is nearly ideal for the proposed study. The climatic regime is favorable for continuous crop production. The precipitation is in excess of ET and hence the leaching potential is high but not excessive. The soil structure is favorable for deep rooting provided the chemical limitations are ameliorated by liming. The erosion potential is appreciable but not excessive. For all of these reasons, if an acceptable cropping sequence can be developed at Manaus, then likely an acceptable sequence can be found for drier regimes where Oxisols and Ultisols are found.

Assessing Accomplishments

As the experiment proceeds the models will be developed concurrently with availability of input data and parameters. The assessment of the results will be made in terms of the amount of input data required to extrapolate the results to other sites and the availability of such data, or the reliability of the model outputs using what data is available.

Research Topic

Soil Constraints to Management of Acid Savanna Soils

Project Number

CU-108

Project Title

Characterization of Structure Stability and Root-Restricting Pans in Cerrado Soils

Project Leaders

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Collaborators

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Problem Statement

Physical characteristics of medium- and fine-textured Cerrado Oxisols have generally been considered excellent for mechanized agriculture because of the very stable but weakly coherent micro-aggregate structure. However, evidence is beginning to mount that deleterious physical situations are developing in areas subjected to continuous annual cropping. In some fields in the Sao Gotardo region of Minas Gerais state, a decade of intensive cultivation has resulted in the formation of an extremely hard compacted layer 10 to 15 cm deep. Shallow rooting of the predominant crop in this region, soybeans, has been attributed to increased soil strength, reduced macroporosity, and poor aeration rather than aluminum toxicity or low nutrient status of the subsoil.

As a consequence of the shallow rooting of annual crops, the relatively costly investments in lime and fertilizer in Cerrado soils may not be utilized to maximum extent. Nitrogen which is mineralized in the surface soil and applied fertilizer N may be carried quickly out of shallow rooting zones with excessive amounts of percolated water where root-restricting pans occur. Nitrogen losses can also occur from denitrification when water perches on compacted layers.

The presence of tillage pans reduces water capture from the frequently brief, intense storms thus limiting replenishment of subsoil moisture. Even the available subsoil moisture which should be utilized by plants during short dry spells (*veranicos*) is not accessible because of root restriction in the surface horizon. The occurrence of severe plant moisture stress during rainless periods may be the most serious consequence of soil compaction for rainfed agriculture in the Cerrados.

Soil erosion, which has not been held to be a concern in these deep, gently sloping, highly permeable soils, is becoming increasingly evident in Cerrado soils. It is common to observe areas of total removal of surface soil down to the characteris-

tic marks of the harrowsole in cultivated fields. Deep gully formation where runoff water is channeled along contour ridges or discharged at field edge is a serous problem on soils where slope lengths may reach several kilometers. Reduced infiltration and increased runoff associated with subsoil compaction increase the severity of erosion under these circumstances.

Several factors are suspected to contribute to the formation of compacted layers in Cerrado soils. Normal farm traffic with heavy tractors and harvestors contributes to wheel track packing, while the traditional practice in the Cerrado region of soil tillage almost exclusively with heavy disk harrows is almost certainly a major aggravating factor. Once compacted, Cerrado soils may have no natural correction mechanisms since both shrink/swell and freeze/thaw cycles are absent. The presence of tree roots in cleared Cerrado land has discouraged any form of deep tillage in the initial years of cultivation. The lack of crop rotation in what frequently are cash grain operations without the presence of cattle raising to justify grass-legume leys is another critical factor.

Soil conditions in root-restricting pans should be characterized so that possible chemical or physical barriers to root growth can be identified. Once the nature of the barrier is determined, an attempt should be made to identify the natural factors or induced mechanical and chemical processes that result in the formation of root-restricting pans. This should furnish keys to management practices for avoidance of the problem before it starts.

The clay fraction of these Oxisols consists mainly of kaolinite, gibbsite, and hematite; and, typical surface areas of these Oxisols are 40 to 50 m^2/g. Clearly, stable aggregation of these clay particles must confer the excellent physical characteristics to these soils. The nature of this aggregation and the degree to which it is affected by agricultural management is not clear at present. Al oxide-kaolinite interactions have been experimentally observed to aggregate kaolinite and similar processes may stabilize these soils.

Zero points of charge (ZPC) of these Oxisols range from just below pH 4.0 to above pH 5.0, with the surface horizons typically having lower ZPC values than the lower horizons. Since the unamended soils commonly have pHs in the range of 4.5 to 5.0, it is apparent that the soils maintain a pH which is not greatly different from the ZPC value, although the surface horizons, in particular, have pH values which are somewhat higher than the ZPC values. Since charge development on clay particles with ionizable surface groups depends upon the degree to which the pH is adjusted away from the ZPC, as shown below,

$$> M\text{-}O|^{-} \underset{-H^{+}}{\overset{<-->}{<-->}} > M\text{-}OH|^{0} \underset{<-->}{\overset{+H^{+}}{<-->}} >M\text{-}OH_2|^{+}$$

a low density of charge is expected on the mineral particles of the Cerrado soils. Low charge density is conducive to the agglomeration of particles, according to the theory of colloidal aggregation, so that mineral suspensions adjusted to pH values near their ZPC have a tendency to flocculate. Thus, the very low surface charge reported for Cerrado soils accounts for these soils' aggregated behavior.

Conversely, soil treatments which generate surface charge may destabilize and even disperse the aggregated colloids. Phosphate adsorption on soil oxides is widely known to generate negative charge on these minerals, and sulfate also generates negative charge to a lesser degree. In addition, liming, by raising the soil's pH substantially from its very acidic natural value, has the potential to increase the negative charge of the soil colloids several-fold. We have preliminary evidence, based on the tendency of clays from the surface horizons of Cerrado soils to form more stable dispersions upon physical agitation than the subsurface horizons, that chemical properties may be influencing physical stability. As stated earlier, the surface soils tend to have pH values somewhat above their ZPC values, and this may account for their tendency to disperse.

In this phase of the project, possible relationships between colloidal dispersibility, which has the potential to adversely affect soil structure and agricultural productivity, and the soil amendments which are necessary to maintain soil fertility will be established.

Objectives

1. Diagnose soil conditions associated with root-restricting pans in Cerrado soils subjected to continuous annual cropping.
2. Identify the natural factors or induced mechanical and chemical processes that result in formation of root-restricting pans.
3. Determine which mechanisms are primarily responsible for limiting root development in Oxisol tillage pans (critical bulk density exceeded, inadequate aeration, soil pores too small, high soil strength, toxicity, etc.).
4. Determine the effects that soil amendment practices have on the physical stability of the clay and organic fractions in Cerrado soils.

Operational Plan

Paired sampling sites of adjacent cultivated and virgin soils will be chosen in several Cerrado areas where preliminary evidence of tillage pan formation has been found. Pits for sampling will be dug during the rainy season and measurements will be made of bulk density, mechanical impedance, moisture content, organic matter content, particle size distribution, and Fe, Al, and Si.

Where possible, at sites that are more readily accessible to EMBRAPA/CPAC, crop root development will be observed during periods of moisture stress on compacted soils. A more thorough diagnosis of soil conditions will be made at these locations.

Soil treatments, including liming and addition of phosphate and sulfate fertilizers, will be evaluated for their effects on clay dispersibility. It is expected that dispersibility will be measured by light-scattering techniques employing a standard UV-visible spectrophotometer. Detailed investigation of the differential dispersibility of soil minerals may be necessary if it becomes apparent that certain minerals are responding quite differently to the soil treatments. In this case, it will be necessary to identify clay minerals quantitatively or semi-quantitatively by techniques such as infrared spectroscopy and x-ray diffraction. The results may be used to establish empirical and theoretical relationships between surface properties and aggregate stability.

Assessing Accomplishments

Production systems utilizing legume green manure crops are likely to help alleviate some of the effects of mechanical impedance for succeeding crops. An integral part of any system for sustained crop production and maintenance of soil productivity will likewise need to be the adoption of management techniques for avoidance of serious soil compaction. Characterization of the tendency for soil compaction in Cerrado soils should help identify those management techniques that are most advisable.

Research at CPAC has established the importance of large phosphate fertilizer inputs to Cerrado soil productivity. In addition, gypsum additions to the soil are recommended to counteract Al toxicity to roots in the subsoil, and our research has shown that this practice will increase the cation exchange capacity of the soil. Yet none of this work has attempted to establish any relationship between the chemical modification of the soil and potential physical alteration, either beneficial or deleterious. This study will provide this missing aspect by attempting to link chemical and physical behavior of Cerrado soils.

Research Topic

Management of Water and Nitrogen in Acid Soils of the Tropics

Project Number

CU-104

Project Title

Understanding Water and Nitrogen Dynamics in Cropped Acid Soils of the Tropics for Improved Management

Project Leader

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Collaborators

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Problem Statement

There is a need for water and nitrogen management strategies based upon a comprehensive understanding of the physical, chemical, and biological processes that affect water and nitrogen fate in cropped acid soils of the tropics. A great many field experiments in temperate regions have addressed these issues, and a substantial data base has been assembled. It remains to generalize these studies into a broadly based set of water and nitrogen management guidelines useful in acid soils of the tropics. One method of achieving this goal is to summarize water and nitrogen transport and nitrogen transformational processes into a dynamic simulation model of water and nitrogen fate in cropped systems.

On a scientific level, such models can provide a conceptual framework, integrate knowledge obtained from many experiments, and pinpoint areas of ignorance. On a research management level, simulation models can provide support to research programs and can establish a basis for collaborative research. More specifically, a research-type water and nitrogen simulation model can guide in the interpretation and design of field experiments, predict crop and soil responses in a range of soil, crop, and climatic conditions and suggest new management strategies. Several models useful in such applications have been developed and applied to field cases. However, existing models have been tested primarily on studies conducted in soils of the temperate climates of the Northern Hemisphere. Although the basic formulation of these models provides a starting point for description of water and nitrogen dynamics, their ability to adequately describe water and nitrogen fate in cropped acid soils of the tropics needs to be established.

Agricultural researchers working in the tropics have accumulated a substantial amount of knowledge through experience in managing water and nitrogen in a range of agricultural settings. However, such knowledge is often difficult to retrieve, and data from experiments and regions are incomplete to use in the creating or testing of dynamic simulation models. Clearly, this knowledge needs to be retrieved and structured in a manner applicable to systems and problems other than those

for which it was acquired. We propose to develop a partitioning-type model for use in making nitrogen management recommendations when only a limited amount of quantitative information is available, but where a qualitative understanding of climate regimes, soil properties and crop responses may exist. This simpler model can be used for agroeconomic analysis, technology delivery and education.

Objectives

1. Develop a comprehensive description in simulation model form of water and nitrogen movement and nitrogen transformation in cropped soils of the natively acid soil regions of the tropics.
   a. Quantify the effects of soil physical properties upon water availability and soil-water movement and their impact upon crop yield, evapotranspiration, and transient soil-water regimes in a manner useful to irrigation and crop production programs.
   b. Quantify the effects of soil chemical and biological properties on nitrogen transformation and transport, crop residue properties on nitrogen mineralization, and nitrate movement on base cation transport.
2. Use the model of 1) as a guide in interpreting previous studies and in designing further field experiments to increase understanding of water and nitrogen fate in these soil-crop systems.
3. Develop a simplified model of water and nitrogen fate in these soil-crop systems that will be useful in guiding nitrogen management programs, in agroeconomic analysis and in technology delivery.

Operational Plan

As part of the previous project, a software package of simulation models of water movement in the soil-plant-atmosphere was developed. Data from experiments conducted with irrigated wheat at the CPAC, Planaltina, are being used to evaluate and modify a number of different modeling approaches for estimating water flow and crop water requirements. In the future, data from research concerning the effects of management on soil physical properties and restricted rooting will be incorporated into this model (Project 108). The model can be used to suggest future decrease in yield due to poor physical conditions in the soil. The crop water requirement model will be used to predict crop water requirements in other regions of the Cerrados and Manaus and to guide in determining soil physical data and climatic data to be collected (Project 111).

Nitrogen transport, transformation, and uptake subroutines will be added to the water simulation model and evaluated using a large data set already collected from a variable line source sprinkler experiment conducted as part of this project. In addition, data from current and future projects (Projects 103, 110) studying nitrogen transformations and uptake from crop residues will be used for model building and testing.

In conjunction with developing and testing linked water and nitrogen simulation models appropriate for the acid soil regions of the tropics, a simpler model will be developed to use more qualitative information for management recommendations. This will be a coefficient or partitioning-type model with some coefficients equivalent to those discussed in Project 103. This partitioning model will be interfaced with the user through an expert system.

Assessing Accomplishments

Performance will be evaluated in several ways. First, models will be developed that are scientifically acceptable as determined by publications in peer-reviewed journals. In addition, these models will be critiqued by users: researchers in the case of the simulation models and extension agents in the case of the management model. Also, we consider that use of the models by others is an important criterion to evaluate performances. If feasible, we plan to link with an existing user's network, such as the ARS Systems Research Resource. This would allow us to assist in the use of these models, as well as discern who is using them.

Secondly, the simulation models are meant to provide a basis for integrating research in the Cornell TropSoils Program and the general TropSoils program. The models should be used as tools for interpreting, integrating, and suggesting future research for other program scientists and country scientists. The extent that this occurs will indicate the effectiveness of not just the models themselves, but the project investigators' abilities to effectively communicate the usefulness of this approach to fellow researchers. The simulation models should serve as a tool for agricultural researchers in developing countries in creating meaningful and integrated agricultural research programs of their own device and choosing. If successful, this would result in the very important transfer of not a specific technology but agricultural research technology.

Thirdly, the management model should be useful to agricultural advisors and students and in testing agroeconomic models. It should be able to be used by people who do not have advanced training in agriculture. It should be effective in devising reasonable nitrogen management recommendations in agricultural systems for which little quantitative data are available. We plan to use the Amazon region of Brazil and a region in Africa as test cases.

Research Topic

Program
Management of Acid Soils of the Tropics

Project Number
CU-109

Project Title
Program Backstopping

Project Leaders
Douglas J. Lathwell, Cornell University
Eric R. Stoner, Cornell University
W. T. Bowen, Cornell University

Problem Statement
Efficient operations require broad-based assistance by those knowledgeable with overall working arrangements and constraints to those concerned with narrowly defined projects. Such assistance includes: processing purchases of equipment, obtaining clearances for travel, assisting in obtaining field sites at CPAC, employing labor, purchasing supplies, etc. Without this support, inexperienced persons consume substantial time in obtaining the necessary actions, which detracts from the scientific endeavors.

Objective
1. To provide technical support and administrative assistance to faculty researchers and graduate students in the operational aspects of both field- and campus-based projects.

Staffing Pattern. Cornell University

Category	Year 1987-1988	1988-1989	1989-1990	1990-1991	1991-1992	Total CRSP-Funded	Other
				FTE			
Campus-based Scientist	0.90	0.90	0.90	0.90	0.90	0.00	4.50
Field-based Scientist	2.00	2.00	1.00	1.00	1.00	7.00	0.00
Graduate Student	2.50	2.25	3.00	3.00	3.00	11.75	2.00
Other	0	0	0	0	0	0	0
Total	5.40	5.15	4.90	4.90	4.90	18.75	6.50

Projected Budget for Projects. Cornell University

Project Short Title	Year 1987-1988	1988-1989	1989-1990	1990-1991	1991-1992	Total
			x $100			
Soil & Crop Management	1110	1131	1199	1271	1347	6058
Soil & Crop Modeling	372	286	303	321	340	1622
Soil Phy. Prop.	819	698	740	784	831	3872
N. Mineralization	332	158	168	178	189	1025
Cation Movement	325	311	330	350	371	1687
Backstopping	558	602	637	676	717	3190
Total	3516	3186	3377	3580	3795	17454

Projected Budget for Objects. Cornell University

Object	Year 1987-1988	1988-1989	1989-1990	1990-1991	1991-1992	Total
			x $100			
Salaries	1200	1139	1207	1279	1356	6181
Benefits	190	203	215	228	242	1078
Allowances	562	481	510	541	574	2668
Travel	255	195	207	219	232	1108
Supplies	130	80	85	90	95	480
Equipment	40	0	0	0	0	40
Other Direct Costs	401	282	299	317	336	1635
Indirect Costs	738	806	854	906	960	4264
Total	3516	3186	3377	3580	3795	17454

Humid Tropics

Department of Agronomy and Soil Science
University of Hawaii

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Soil-Management Research for Improving Whole Farm Systems In Upland Acid Soils Of Indonesia and the Humid Tropics

TropSoils is a collaborative research program whose goal is to develop and adapt improved soil-management technology that is agronomically, ecologically and economically sound for developing nations in the tropics. Primary funding is provided by the U.S. Agency for International Development, in support of Title XII, "Famine Prevention and Freedom from Hunger" of the Foreign Assistance Act. To accomplish its goal, TropSoils employs a global plan first articulated by its Planning Entity, and endorsed by USAID. The plan's strategy is to bring the expertise of U.S. land grant universities to bear on soil-related constraints to food production in developing nations in the tropics. On the basis of their experience in tropical research, collaborating universities were chosen to lead programs in several key sectors of the tropical environment. These sectors are called agro-ecological zones. While no zone is a homogeneous unit, the soil constraints are similar enough to provide a focus for the research program. Within the zones, the universities develop primary research sites in order to maximize resources and establish the necessary continuity.

The Center for Soil Research (CSR), the Central Research Institute for Food Crops (CRIFC), Sukarami Agricultural Research Institute for Food Crops (SARIF) of the Agency for Agricultural Research and Development (AARD) and the University of Hawaii (UH) are the collaborating institutions for the Humid Tropics (Indonesia) Project.

Goal of the TropSoils Program in Indonesia

Increase farmer income and employment, foster self-reliance, enhance quality of life, and conserve natural resources.

Objectives of the TropSoils Program in Indonesia

1. Produce economically feasible, farmer acceptable, and environmentally safe soil-management packages that contribute to stable, productive, sustainable and equitable farming systems.

2. Test and validate rules and procedures that will enable soil-management packages to be transferable to other farming systems in other locations in Indonesia and the humid tropics.
3. Produce rules and procedures for soil resource management that can be used for decision making by policy makers and land use planners, as well as decision making at the farm level.

Research Outputs/Products and Related Activities

The project is designed to produce results which can be readily packaged for use in making soil-management recommendations by extension agents and government planners. To achieve this aim, the information generated by research will be organized and stored as rules and procedures for decision making in a computerized expert system. An expert system is a computer program that offers solutions to complex problems by mimicking human reasoning processes and employing a knowledge base of information obtained through research. This knowledge base, permanently captured on diskettes, can be reproduced in large numbers and transferred to any location in Indonesia for use by extension agents and government planners, thus maximizing the potential utilization of applicable research outputs to optimize farm productivity.

The research outputs of this project are rules and procedures for diagnosing problems and for prescribing optimal strategies to control outcomes of soil-management practices. Verifiable scientific hypotheses underlie each of the planned outputs and associated activities.

The research product will be an expert system that utilizes the research outputs to help land users, extension agents, and government planners manage soil resources.

Project Number

UH-1

Project Title

Diagnosing and Correcting Soil Acidity and Infertility

Project Leaders

L. Arya, University of Hawaii
N. Hue, University of Hawaii

Collaborators

R. Guyton, University of Hawaii
Social Scientist (to be employed), University of Hawaii
S. Itoga, University of Hawaii
J. Li, University of Hawaii
C. Tang, University of Hawaii
R. Yost, University of Hawaii
Sholeh, CSR
I Putu Gedger, CSR
M. Oka, SARIF
Kasli, Padjajaran University
B. Rusman, Padjajaran University

Problem Statement

For the resource-poor farmers, lime is expensive and difficult to incorporate into the subsoil where it is needed to detoxify aluminum. Without lime, only a limited number of acid-tolerant crops of low nutritional value can be grown. With lime, farmers can choose from a wider variety of marketable crops, minimize yield losses from drought, obtain higher use efficiency of N, P and K fertilizers and pest control measures, produce the desired quantity of commodities on a smaller area, and extend the length of the growing season by increasing water-use efficiency.

The precise cost-effectiveness of lime application is not known because (1) the residual effect and therefore the amortization of costs over several years cannot be quantified for sound economic analysis, (2) the optimum depth of lime incorporation which depends on amount and distribution of rainfall cannot yet be readily determined, (3) the rate of leaching of lime is not yet predictable, and (4) the role of organic matter as a substitute for lime is not known. These knowledge gaps prevent the large knowledge base on liming from being used to assess the economic feasibility of liming and fertilizer use.

The primary purpose of this research plan is to test the following hypotheses:

1. The optimum (economic) rates for lime, fertilizer (phosphorus) and organic matter application depend as much on their long-term residual effect as on their impact on the first crop.
2. In regions with high subsoil acidity, fertilizer-use efficiency can be doubled by shifting from shallow (0-5 cm) to deep (15-30 cm) incorporation of lime.
3. In soils with variable charge clays, leaching losses of lime can be minimized by lowering the zero point of charge of the soil colloid by addition of organic matter and lime.

Objectives

1. Measure the long term residual effect of lime, phosphorus, and organic matter on crop performance and the economics of production.
2. Identify the optimum depth of lime and organic matter incorporation with different water-retention characteristics under dry and wet season farming.
3. Collect lime-leaching data to develop transport equations that will predict movement of lime in the rhizosphere.

The expected outputs are rules and procedures which can be employed in a forward-chaining computerized reasoning process to diagnose and prescribe corrective measures for soil acidity and infertility. Forward chaining is a terminology of artificial intelligence which refers to problem solving by starting from the data given and working forward to a solution which is consistent with it. The developmental relevance of these outputs is that they will be organized in a way that will permit extension agents and less-experienced personnel to make expert recommendations about liming and soil fertility.

Operational Plan

The operational plan is to preserve and monitor the old lime plots for movement of lime, phosphorus level and organic matter. A subhypothesis of this project is that organic matter decomposition will be accelerated in the high lime plots.

Lime will be incorporated to four depths including one to a depth of one meter. Crop growth will be monitored in both the rainy season and dry season to measure the interaction between lime depth and rainfall amount and distribution. The Ritchie water balance model will be used to simulate runoff, consumptive use and deep drainage of water. The model will be used to define the optimum liming depth at project's end.

The data on lime movement will be used to estimate transport coefficients for calcium. Calcium sulfate will be one of the calcium sources. The effect of phosphorus and organic carbon levels on calcium movement will also be measured. Another subhypothesis is that calcium movement will be retarded by applications of phosphorus and organic matter.

The strategy is to establish a close working relationship between researchers and knowledge engineers to utilize research results for incorporation into an expert system as rules for diagnosing and prescribing measures to correct soil acidity and infertility. The research results to close informational gaps will be incorporated into an expert system on a continuing basis. Through an iterative feedback mechanism from extension agents and other users to researchers and knowledge engineers, the expert system will be used to redefine research direction and priorities.

Assessing Accomplishments

An expert system for both technical and non-technical users that can provide reliable information with which to make decisions about the economic outcomes of liming and fertilization using a range of locally available products will serve as the verifiable indicator of project accomplishment. Progressive improvements in the expert system will be monitored by validation of rules and procedures with research results obtained.

Project Number

UH-2

Project Title

Integration and Utilization of Agroforestry and Other Organic Resources in Sustainable, Low-Input Farming Systems

Project Leaders

R. Guyton, University of Hawaii
J. Fownes, University of Hawaii

Collaborators

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J. Brewbaker, University of Hawaii
N. Hue, University of Hawaii
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R. Yost, University of Hawaii
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S. Adiningsih, CSR
Iswandi, SARIF
Kasli, Padjajaran University

Problem Statement

Inexpensive, locally available agroforestry and other organic resources constitute alternatives to lime and chemical fertilizers. Fast-growing, acid-tolerant, nitrogen-fixing trees and ground cover, and other organic residues serve as sources of nitrogen-rich green manures, fuelwood, fodder, substitutes for lime, windbreaks, and soil erosion control measures. Although a relatively large knowledge base on agroforestry and organic residue management exists, the designing of an overall structure to organize the knowledge base for efficient decision making and problem solving has not been undertaken. This situation stems from (1) the newness of information technology that now allows knowledge to be organized and represented in efficient, user-friendly form for decision making and problem solving and (2) knowledge gaps on (a) the effect of soil temperature, moisture and microbiology on the nitrogen dynamics associated with residue decomposition, (b) the role of nutrient cycling by acid-tolerant, deep-rooted plants in managed agroecosystems (as opposed to unmanaged forests), (c) the complexing strength of decomposition products of organic residue for aluminum ions, and (d) the means to put the knowledge into rules and encode them into computer language.

The purpose of this research is to test the following hypotheses:

1. Green manures from nitrogen-fixing trees and cover crops represent more reliable and cheaper sources of nitrogen than urea in subsistence farming situations.
2. Deep-rooted, nitrogen-fixing trees employed in alley-cropping intercept nutrients which leach to great depths and recycle them in significant amounts for use by subsequent crops.
3. There is a high variance in the aluminum detoxification capacity of organic compounds synthesized by different trees and cover crops.

Objectives

1. Quantify the nitrogen-supplying capacity of nitrogen-fixing trees and cover legumes relative to a standard nitrogen source (e.g., urea).
2. Evaluate the role of nutrient recycling of trees in low-input, sustainable farming systems.
3. Identify organic compounds responsible for detoxifying aluminum and develop procedures for estimating "lime" equivalence of green manures.

The expected product of this work is problem-solving strategies written as rules and encoded into computer language. The developmental relevance is that these problem-solving strategies will become available to a large audience of users.

Operational Plan

The operational plan is to add known types and quantities of green manures from selected species of nitrogen-fixing trees and ground cover and follow their fate over time. The nitrogen dynamics model described by Godwin and Vleck of the International Fertilizer Development Center will be employed to simulate processes in the soil and nitrogen uptake by plants. The experimental data will be used to upgrade and calibrate nitrogen dynamic models.

The role of trees in nutrient cycling will be monitored with nitrogen-fixing trees already growing in alley-cropping experiments. Other promising species will be added, including *Acacia mangium* which seems to withstand high aluminum concentrations. The decomposition products from the green manuring experiments will be shipped to Hawaii and analyzed for their composition and chelating capacity for aluminum ions. The assumption is that organic matter from different species will differ in their capacity to detoxify aluminum ions.

The strategy is to ensure that the researchers understand how the information generated from each of the activities will be encoded into computer language and used in an expert system to aid in decision making and problem solving. The mechanism to achieve this plan is to test the outcomes of the prototype expert system against known cases and to refine the rules through validation research.

Assessing Accomplishments

An expert system that can provide reliable information with which to make decisions about utilizing various agroforestry and organic residue management practices in an economically feasible way will be the verifiable measure of accomplishment. Various stages of achievements will be monitored and evaluated by progress reports of each objective.

Project Number

UH-3

Project Title

Incorporating Farmer Goals and Constraints into Soil-Management Research

Project Leaders

Social Scientist (to be employed), University of Hawaii
R. Yost, University of Hawaii

Collaborators

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S. Sukmana, CSR
J. Swandi, SARIF
M. Oka, SARIF
B. Rusman, Padjajaran University

Problem Statement

The purpose of soil-management research is to produce results which will help planning agencies and users of land resources make reliable decisions about attaining desired goals. To achieve this purpose, it is necessary to know users' constraints, priorities and goals. But most researchers do not have the time or training to learn about user problems and conditions, and therefore sometimes do research of limited value to users.

To ensure that the TropSoils project produces user-oriented results, the project will solicit the help of users of soil-management research results to identify problems and informational gaps. As it now stands, researchers employ personal judgements to identify research priorities and informational gaps. The Indonesia TropSoils Project is also designed to use expert systems to identify knowledge gaps. There is in addition a large information gap about farmer goals and constraints which needs to be captured in expert systems. For example, before an expert system can make economic analyses for liming, it must have information not only about the milliequivalents of aluminum in the soil and the type of liming material and crop to be grown, but about the mode of transporting the lime from the local store to the farm, the implements which will be used to incorporate lime into the soil, and a host of other factors that users consider in decision making. It matters

whether lime is transported by bullock, bicycle or truck. It also matters whether lime is incorporated into the soil by hoe, animal-drawn plow or tractor. An expert system can deal with a large number of alternatives; but it must be provided with the alternatives if it is to make expert recommendations.

But how will such informational gaps affect research direction? If the hoe is the only tool used to mix lime into soil, and it is not likely to be replaced by another implement, would it pay to redirect research in a way that will enable farmers to get lime down to the desired soil depth quickly? Will the redirected research compel scientists to return to basic research on ion transport?

The hypothesis being tested is that farmers experience management problems associated with new technology which are not foreseen by researchers, and that inclusion of farmer experience, goals and objectives will render soil-management research results more user-oriented.

Objectives

1. Incorporate farmer constraints, priorities and goals into expert system and research design.
2. Use local extension service to test the expert system to observe whether it can diagnose problems and prescribe solutions for them.
3. Use feedback from extension agents to improve reliability to expert system and/or redefine research direction and priorities.

The development relevance of this research is that it will fill informational gaps needed to make sound economic analysis about soil management, and this in turn will be the basis for redefining and reprioritizing research. The product will be an expert system which employs farmer constraints and goals in its decision-making processes.

Operational Plan

This project will be initiated only if USAID/Jakarta provides funds for this effort. The individual hired for this project will be a social scientist with training in extension. This individual will serve as liaison among farmer groups, the extension service and TropSoils researchers. Extension agents will be trained in the use of the expert system and will use it to diagnose problems and prescribe solutions. A computer will be maintained at the local extension office where the extension agents can use the data base and diagnostic capability of the expert system. The TropSoils social scientist will offer assistance to see that the expert system is properly used.

Assessing Accomplishments

A prototype expert system that takes into account farmer constraints, priorities and goals that can provide extension agents with reliable information with which to make economically sound recommendations about liming will serve as the verifiable indicator of project accomplishment. This same expert system will be employed to guide research direction.

Project Number

UH-4

Project Title

An Expert System for Diagnosing and Recommending Economically Feasible, Farmer-Acceptable and Environmentally Safe Soil-Management Practices

Project Leaders

L. Arya, University of Hawaii
R. Yost, University of Hawaii

Collaborators

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Iswandi, SARIF
Amril, SARIF
Zaini, SARIF

Problem Statement

The knowledge base on soil management is large. The knowledge we add to this base from TropSoils research is small in comparison. This is not so much a problem as an opportunity to organize existing knowledge in a way that young, inexperienced, junior personnel can use like an expert would. This can be achieved if the promise of expert systems is real.

If the promise of expert systems is still uncertain, why not continue to depend on human experts? The fact is that experts aren't always available. They retire and take their expertise with them. Experts are also very expensive so that resource-poor farmers are the last to be served by human experts.

It is not so much the lack of knowledge, as the scarcity of human experts, that holds up development.

The gap is not so much informational as it is organizational. Unless existing knowledge is organized in a way that enables many users to diagnose and solve problems, the critical informational gaps will be identified more by chance than by design.

The hypothesis of this project is that most soil-management problems require a knowledge-base approach and cannot be handled effectively by a conventional computational approach or by dependence on human memory.

Objectives

1. Translate existing ACID4 soil acidity expert system into Prolog with extensions of improved user interface, multiple-objective consultation, and preliminary natural language.
2. Test ACID4 expert system for performance and integrity relative to requirements and expectations.
3. Expand soil data base interface with the expert system by increasing the soil information accessible to the expert system.
4. Incorporate learning capability into Prolog version of the expert system.
5. Add output from TropSoils research into expert system and provide feedback to researchers on critical informational gaps.

The developmental relevance of these objectives is that the shortage of human experts which now holds back development and farm profits can be overcome by knowledge-based or rule-based expert systems.

Operational Plan

The strategy is to bring to bear on this project the expertise of University of Hawaii faculty who are following advances in and contributing to the development of fifth-generation logic-based languages. The TropSoils project needs advice and assistance from faculty from the Information Science Department, and they in turn need real world examples to test their ideas. The synergism which emerges from this mutual need has already benefitted TropSoils greatly.

The mechanism to bring this about is already in place and involves agreement between data generators (field staff in Sitiung) and software developers (University of Hawaii campus faculty) to work towards a common research approach, which is to organize all relevant knowledge, both existing and newly acquired, into a form that can be used to diagnose and solve problems.

Assessing Accomplishments

The verifiable indicator of accomplishment will be an expert system that can use soil-management information for decision support as well as, or better than, a human expert in specialized areas of expertise.

Project Number

UH-6

Project Title

Project Management— Backstopping

Project Leader

G. Uehara, University of Hawaii

Collaborators

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S. El-Swaify, University of Hawaii
R. Melton, University of Hawaii
N. Murabayashi, University of Hawaii
S. Sakumoto, University of Hawaii
G. Tsuji, University of Hawaii
I Putu Gedger, CSR
Administrative Assistant (to be employed), University of Hawaii
Communications Specialist (to be employed), SARIF

Problem Statement

Management and coordination of research activities by on-site and on-campus personnel requires close coordination to ensure that both parties work towards the common goal of generating information to fill knowledge gaps that are critical for decision making by planners and users of soil resources. The isolation of the research site hampers communication and will likely be a problem for some time to come.

Objectives

1. Provide logistical support of on-site activities by both on-site and on-campus CRSP personnel and additional staff supported by USAID and the GOI.
2. Provide coordination of on-campus backstopping in administration and research in support of on-site activities in Indonesia by UH faculty/administration and CRSP-supported staff.

Operational Plan

The UH team leader and CSR country coordinator will be jointly responsible for the management of research activities and manpower resources necessary to carry out the plan of work. On-campus research activities will be coordinated among the principal investigators of each output/product, the program coordinator, project manager and department chairperson. Implementation of on-campus research with on-site activities will require coordination with the team leader and country coordinator.

Site visitation for multiple purposes at least every six months or more frequently by campus-based personnel is necessary to properly manage project activities both technically and administratively.

On-campus administrative support will include the following:

1. participation in meetings of the Board of Directors and of the Program Coordinators;
2. personnel management of on-campus faculty/staff and on-site scientists;
3. fiscal accounting of on-site expenditures;
4. procurement of equipment and supply items unavailable on site;
5. preparation of annual progress reports, technical reports, management reports as required by the Management Entity;
6. preparation of slides and graphics; and
7. compilation of project amendments and proposals.

Assessing Accomplishments

User acceptance of project outputs and products implies achievement of activities in the plan of work. Levels of progressive achievements will be a function of management of technical and fiscal resources.

Staffing Pattern. University of Hawaii

Category	Year 1987-1988	1988-1989	1989-1990	1990-1991	1991-1992	Total CRSP-Funded	Total Other
				FTE			
Campus-based Scientist	1.67	1.67	1.67	1.67	1.67	0.50	7.85
Field-based Scientist	2.00	2.00	2.00	2.00	2.00	10.00	0
Graduate Student	1.75	1.75	1.75	1.75	1.75	4.60	4.15
Other	1.00	1.00	1.00	1.00	1.00	5.00	0
Total	6.42	6.42	6.42	6.42	6.42	20.10	12.00

Projected Budget for Projects. University of Hawaii

Project Short Title	Year 1987-1988	1988-1989	1989-1990	1990-1991	1991-1992	Total
				x $100		
Soil Acidity and Infertility	920	790	837	837	940	4374
Agroforestry	1130	970	1028	1090	1155	5373
Farmer Constraints						
(Contingent on Supplemental Funding)						
Expert Systems	960	820	869	921	976	4546
Backstopping	530	460	488	518	550	2546
Total	3540	3040	3222	3416	3621	16839

Projected Budget for Objects. University of Hawaii

Object	Year 1987-1988	1988-1989	1989-1990	1990-1991	1991-1992	Total
			x $100			
Salaries	1370	1180	1251	1326	1406	6533
Benefits	440	380	403	427	453	2103
Allowances	410	340	360	382	405	1897
Travel	200	170	180	191	202	943
Supplies	370	320	339	359	381	1769
Equipment	0	0	0	0	0	0
Other Direct Costs	60	50	53	56	59	278
Indirect Costs	690	600	636	675	715	3316
Total	3540	3040	3222	3416	3621	16839

Humid Tropics

Department of Soil Science
North Carolina State University

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Introduction: Program Strategy

The focus of the U.S. Agency for International Development on agriculture is to increase the income of the poor majority and expand the availability and consumption of food, while maintaining and enhancing the natural resource base. North Carolina State University's component of TropSoils addresses this mandate in its entirety for one of the world's key endangered regions, the tropical rainforests. This plan is the product of a series of working group sessions held in Peru, Brazil and Raleigh since July 1987. Faculty and graduate students from North Carolina State University (NCSU), and scientists from our collaborating national institutions, the Instituto Nacional de Investigación Agraria y Agroindustrial of Peru (INIAA) and the Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA) have participated fully in its development.

Problem Statement

Systematic research in the humid tropics has resulted in the development and testing of five main soil-management options for this ecosystem: continuous cropping, low-input cropping, legume-based pastures, agroforestry and steeplands management. Research on soil characterization, physics, chemistry, fertility, and biology, watershed hydrology, germplasm selection, crop management, and soil-plant-animal relationships have provided the building blocks for these options. Three problems impede the widespread adoption of these options: 1) practices that will ensure their sustainability, 2) transfer of the known technology to users, and 3) current socio-political constraints and inadequate infrastructure. This five-year plan focuses on the first two problems.

Sustainability

The five management options are highly promising, but practices that ensure their sustainability need to be developed further. Sustainability can be defined as a low coefficient of variability in adequate levels of production per year through a period of years. Sustainability may also be identified in space, that is whether the management options are productive across a range of soil conditions in the humid tropics, with modifications in degree but not in kind. Determining this range is possible by utilizing both the sandy Ultisols at Yurimaguas at one extreme, and the clayey Oxisols of Manaus at the other. Three main factors have been identified as constraints to sustainability across the five management options:

Low nutrient-use efficiency. The problem is to synchronize plant growth demand with nutrient release rates, to utilize acid-tolerant germplasm, to promote the

maximum nutrient use and re-use by recycling techniques such as crop residue return, root turnover, green manures and managed fallows in order to minimize purchased input use. We are seeking innovative, yet simple, ways to make the most efficient use of nutrients that need to be added as ash, lime, inorganic and organic inputs.

Weed encroachment. A major factor responsible for the agronomic or economic collapse of most management options is weed population shifts to increasingly aggressive and tenacious species that outcompete crops. Many of the weeds can be controlled by readily available commercial herbicides, but subsequent generations can only be controlled by prohibitively costly herbicides. We propose to focus on management alternatives that can reduce weed encroachment without resorting to high-cost herbicides. Examples of such management practices include green manures in continuous cropping systems, managed fallows in low-input systems, shifting from pastures to crop production in grazed systems, cover crops, mulches, and tree successions in agroforestry systems.

Minimizing soil and nutrient losses. All management options appear to be soil-conserving. The extent of actual runoff and erosion losses varies among them but has not been quantified. Little is known about how to maximize soil-water use during the critical drought periods common to the humid tropics as well as how to eliminate excess moisture during periods of highest rainfall. We have found that even primary forests are losing nutrients from their watersheds. Although nutrient pollution is not yet a major concern in the humid tropics, we must assure that the recommended management options are soil-, water- and nutrient-conserving. Research on conservation tillage for continuous cropping, effects of grazing on soil physical properties, and watershed hydrology is proposed to quantify the soil- and water-loss processes and devise practical means of attenuating them.

An implicit sixth management option is to let the land stay as is, in primary or secondary forests. Recommendations to apply this sixth management option are seldom based on adequately quantified soils data. For example, we suspect that areas with unusually high or low plant genetic diversity have unusual soil properties. Decisions made on which land resources to preserve should be based on reliable soil data bases as are decisions about which agricultural practice to establish.

Technology Transfer

In spite of the need for additional information on sustainability, many of the technology components are ready to be transferred to national institutions for adoption to local conditions and promotion for farmer use. The two main tools of technology transfer are soil characterization and its interpretation, and research networks. Much needs to be learned about the characteristics of soils from important but hitherto unknown areas likely to be cleared. Much work is also needed to fully adapt the Fertility Capability Classification system to the various management options and to test it under a wide variety of soils and landscapes of the tropics.

Soil-management research networks are at an incipient stage of development in the humid tropics. Networking has proved to be one of the most effective ways of technology transfer in the Third World. TropSoils/NCSU is in a unique position to train network collaborators and support field activities in the 37 countries of Africa, Asia and Latin America with which we have some collaborative relationships.

Overall Program Objectives

1. To determine the factors responsible for sustainable production in the principal soil-management options for the humid tropics.
2. To validate, modify and transfer available technologies for the humid tropics through soil characterization-interpretation and support to research networks.
3. To determine the lower threshold values below which the five aforementioned management options are environmentally or economically impractical.

Overall Hypotheses

1. The five selected soil-management options can be made sustainable through overcoming constraints related to 1) nutrient-cycling efficiency, 2) weed encroachment, and 3) soil and water losses.
2. The available soil-management technologies can be successfully transferred to national institutions through soil characterization and support to regional networks.

Program Approach

The program approach is illustrated in Figure 1. The program is organized into nine projects. The first five projects tackle nutrient efficiency, weeds and soil-water relationships in continuous cropping, low-input systems, legume-based pastures, agroforestry systems and steepland management (NC-1 to NC-5). The sixth project compares different management options in terms of physical, chemical and biological properties indicative of sustainability (NC-6). The seventh and eighth projects address the technology transfer objectives through soil characterization and interpretation (NC-7) and research networks (NC-8). The final project (NC-9) provides technical and logistical backstopping for the entire program. The overall scheme is presented in Figure 1, showing the relationship between individual proposals and the flow of information from technology generation to technology transfer. A detailed description of each project is presented in the chapters that follow.

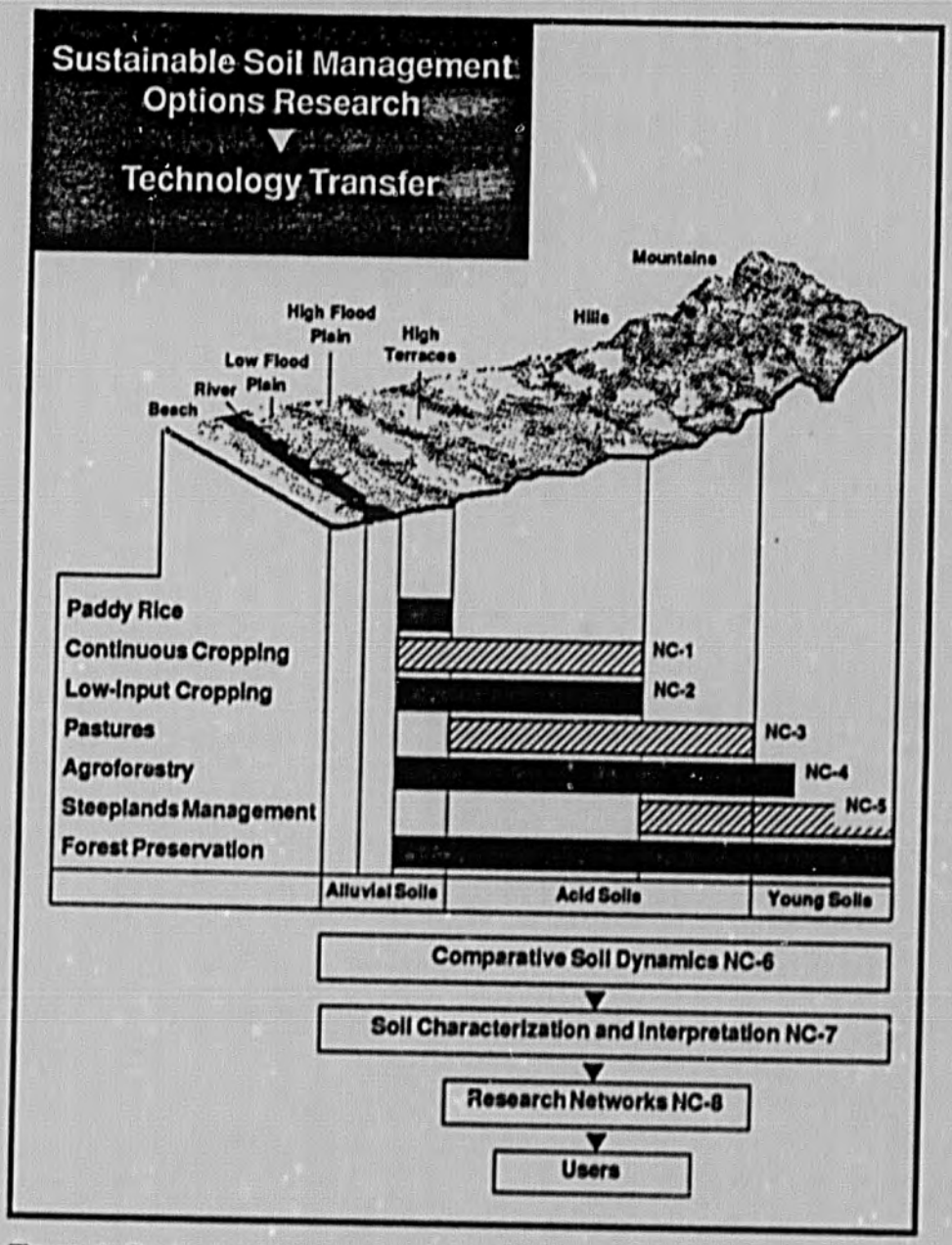

Figure 1. Conceptual framework of the TropSoils/NCSU Program proposal and individual projects.

Project Number

NC-1

Project Title

Continuous Cropping: Fertility and Tillage Management

Project Leaders

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Problem Statement

Third World demographic trends show continued population growth and more urban areas in humid tropical areas with acid, infertile soils. Relative to the majority of rural areas in this ecosystem, these cities provide a favorable marketing infrastructure for fertilizer-based, sustainable and continuous food crop production. Continuous production would avoid further deforestation by shifting cultivation and would ensure a continuous food supply to urban areas. Fertilizers, lime and farm machinery, although expensive, are increasingly available in urban centers in the humid tropics. When chemical inputs as well as mechanization are introduced to new areas, they are often used excessively and inefficiently. Well-managed continuous cropping systems would avoid excessive and inefficient use of chemical and energy inputs, as well as the resulting nitrate and pesticide pollution in rivers. As urban centers grow in the humid tropics, the continuous cropping option gains in importance.

Sustained crop yields have been achieved with continuous cropping studies in Ultisols at Yurimaguas (35 crops in 15 years) and the near-ustic Oxisols at Manaus (13 crops in six years). Soil chemical properties at both sites have improved with continuous cultivation, provided vigorous crop growth is ensured by adequate liming, fertilization, and mechanization. Despite these accomplishments, the problems of nutrient-use efficiency, weed control and the maintenance of soil physical properties need more attention.

We plan to address those problems through component research. In the past,

components have included crop selection and rotation, fertility management, and tillage practices. Species with cultivars tolerant to high levels of aluminum-saturation (60-80%) have been removed from this cropping system and placed in the low-input management option. With upland rice, this decision was also supported by the finding that this species is poorly competitive with weeds. Evaluations of recently acquired corn, peanut and soybean germplasm have indicated potential tolerance to moderate aluminum saturation levels (40-50%) that was not available in materials tested during previous years. As crop cultivar tolerance to acidity increases, fertility requirements may change from previously established levels, and soil test interpretations will have to be modified accordingly.

Studies on crop rooting depth, root biomass production, and nutrient carryover from preceding crops in rotation have strengthened the nutrient-recycling component directed towards optimizing nutrient-use efficiency. Potassium management studies in Ultisols have suggested that preferential absorption by small quantities of 2:1 subsoil clays improves the conservation and recycling mechanism of this readily soluble nutrient.

Because farmers using this technology are not likely to depend exclusively on hand labor, land preparation studies are ongoing in both conventional and conservation tillage. Conventional tillage in sandy Ultisols has resulted in poor plant anchorage during wet periods. Conservation tillage is considered to be any form of tillage that conserves natural resources such as soil, water, and energy. Imposition of various conservation tillage systems using tractor-drawn equipment is known to alter both chemical and physical soil properties. A key question is: Can timely conservation tillage practices by tractor-drawn machinery be attained in the humid tropics under high rainfall conditions?

Considerable progress has been made in defining land preparation practices entailing a minimal number of tractor passes. Experiences with mechanization have identified the need for further modifications related to interactions between weed control, tillage operations, and nutrient-use efficiency. The inability to perform mechanized land preparations during the peak of the rainy season has led to reductions in annual cropping frequency and, thus, increased opportunities for weed encroachment, surface runoff and erosion. Weed populations also have changed in response to chemical weed control practices. Conservation tillage will be a success only if planting can be done in a timely manner and if weed control can be maintained.

Preliminary studies on the use of forage legumes as green manures and mulches indicate that this management component could serve multiple purposes in mechanized cropping systems. Green manures are not only an alternative source of fertilizer N but also a potential management tool to (1) synchronize planting dates with weather patterns by serving as short fallows during the rainiest periods, (2) alleviate weed encroachment, (3) complex toxic aluminum and (4) improve fertilizer-use efficiency by concentrating nutrients in the crop root zone.

The project's hypotheses are as follows:

H-1. Crop rotations with corn, soybean and peanut cultivars with tolerance to 50% Al saturation at a soil pH of 4.8 to 5.0 are feasible and will require different fertility management from previous experience.

H-2. Green manures during the wetter part of the year will decrease weed infestation, help synchronize planting dates with favorable weather patterns, and improve nutrient recycling.

H-3. A combination of physical and biological practices will provide modified conservation tillage systems, with improved water balance and diminished soil and nutrient losses.

Objectives

The goal of this project is to develop soil-management practices for fertilizer-based mechanized cropping systems that will sustain long-term productivity while conserving natural resources in humid tropical areas with favorable infrastructure development. Specific objectives, as related to the three problem areas include:

1. Optimize the efficiency of fertilizer and lime use by high value food crop rotations, and determine more precisely the residual effects of lime and fertilizer applications.
2. Evaluate the multipurpose functions of green manures and mulches as related to tillage practices, weed control, soil and water conservation, nutrient-use efficiency and aluminum complexing.
3. Develop tillage practices that maintain desirable soil physical properties, are compatible with fertilization and weed control practices, minimize energy consumption and conserve soil and water.
4. Evaluate water balance and associated solute transport for selected tillage practices.

Operational Plan

The project's operational plan is illustrated in Figure 2, starting from the problems, continuing with component research and their interactions, and integrating the results into continuous cropping systems for sandy Ultisols and clayey Oxisols, which can be passed on to the network project (NC-8). Rounded boxes represent TropSoils-sponsored research. Experiment codes used by the program are indicated in the text as appropriate.

This project will use both primary sites at Yurimaguas and Manaus to provide a range of soil and climatic conditions. Involvement in Manaus is subject to the availability of funds. Several experiments initiated during the last quinquennium are being continued, due to either their long-term nature or the timing of their initiation. Examples of the former are the germplasm screening trials for aluminum tolerance (Y-120), the central continuous cropping study in Ultisols (Y-101), and the nutrient dynamics study in clayey Oxisols (M-901). Examples of the latter are the conventional (Y-104) and conservation tillage (Y-113) studies and studies on potassium fertilizer efficiency (Y-103).

The majority of the experiments are planted to cereal-grain legume rotations with field layouts, such that the identity of plots are preserved for several years under mechanical tillage practices. Plots are sampled periodically for chemical, physical and biological parameters in both the surface and subsoil layers, according to individual experiment objectives. Grain yields are measured and, where appropriate, additional measurements are taken for above- and below-ground plant growth and nutrition. Changes in hydraulic conductivity, moisture balance, and solute leaching under several of these systems will be evaluated. Soil trafficability variation when the soil moisture regime is altered will also be evaluated in experiment Y-111.

During the upcoming five years, multidisciplinary efforts will seek to identify and

evaluate the potential benefits of integrating forage legume green manures and mulches and incorporate these plants into existing mechanized cropping system practices. Component research will focus on a systematic classification of forage legumes as to their nutrient requirements and their potential use for weed control, biological nitrogen fixation, aluminum complexing, erosion and runoff control, and nutrient cycling. Forage legume data from the pastures project (NC-3) and data from Cornell University's green manure research in acid savannas will be used whenever possible. Legume species will be grown in replicated plots with two fertilization treatments representative of the range of fertility levels used in this management option.

Measurements during the course of legume growth will entail the quantification of desirable attributes either by changes in soil properties or by specific plant characteristics. Weed biomass and populations will be used to evaluate weed control properties. Evaluations of ground cover establishment and soil-water sorptivity will be indicative of water runoff and erosion control. Nutrient-cycling capability will entail estimates of rooting depth, nutrient accumulation, nutrient-release rates, and expected nutrient uptake by subsequent crops.

The interactive effects that green manures have on lime and fertilizer requirements for crops will be further evaluated by growing promising species in rotation with crops on the residual lime, P and K studies. Subsequent studies will be designed to evaluate the performance of selected legumes when grown in rotation with row crops in both conventional and conservation tillage systems. Based on experiences gained, these studies will address questions relating to mechanized practices for planting and eradicating forage legumes and their carryover effects into subsequent grain crops. The nature of conventional versus conservation tillage imposes a distinction between green manures and mulches (incorporation versus surface application) which requires a selection of forage legumes with different characteristics.

Assessing Accomplishments

In targeting this project for humid tropical areas with favorable infrastructure development, the soil-management practices should be both agronomically and economically feasible. Management practices should also conserve natural resources by increasing the time span for sustainable productivity while maintaining and/or improving physical and chemical soil properties and optimizing the efficiency of fertilizer and lime use through either a reduction in inputs or increased production per unit of input.

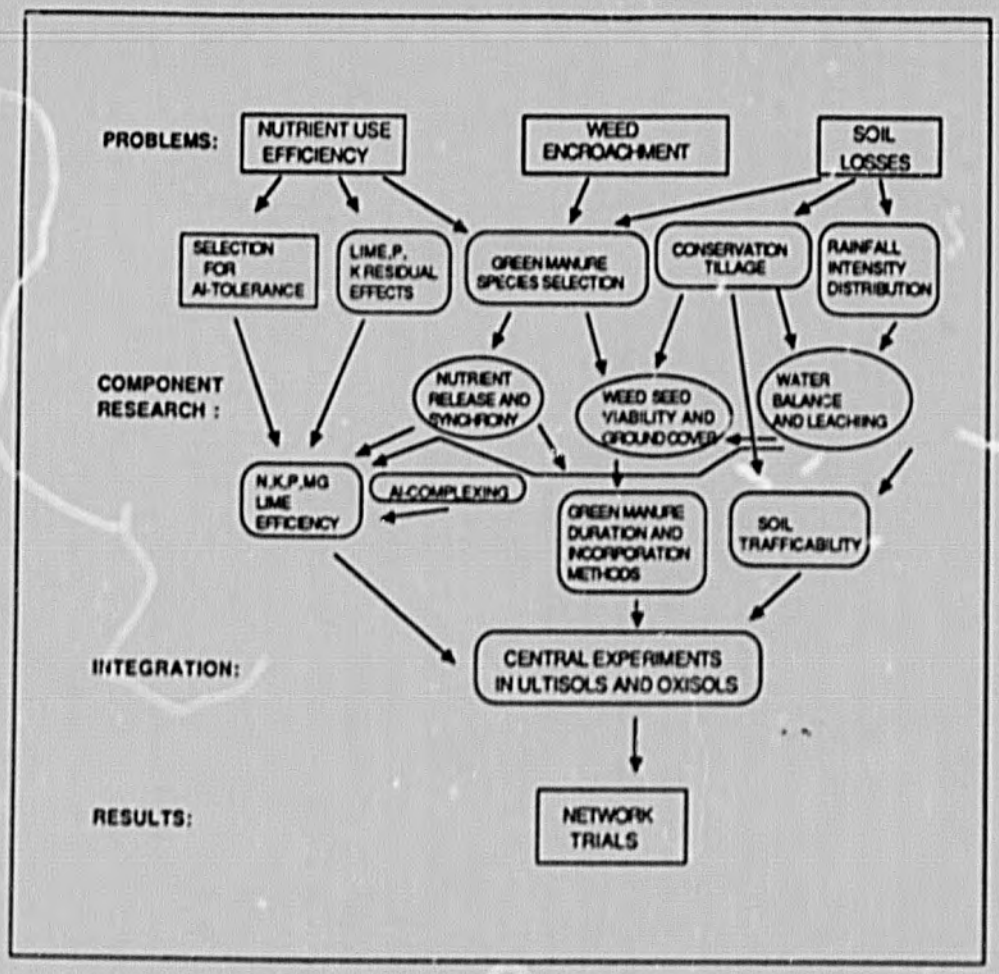

Figure 2. Continuous cultivation project flow (NC-1). Rounded boxes represent proposed TropSoils-sponsored research.

Project Number

NC-2

Project Title

Low-Input Cropping Systems for Acid Soils of the Humid Tropics

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Problem Statement

Present Status

Significant progress has been made during the last five years in this project. A low-input cropping system has been developed in Yurimaguas to serve as a transition technology between shifting and continuous cultivation for acid soils of the humid tropics. Its principal features are: 1) traditional slash-and-burn clearing of forest fallow; 2) rotation of acid-tolerant rice and cowpea cultivars with removal of only the grain to maximize nutrient cycling; 3) no use of fertilizers, lime or organic inputs brought from outside the field; 4) use of locally available herbicides and insecticides; 5) termination of cropping after two to three years due to increasing weed pressure and deficiency of phosphorus and potassium; 6) planting a kudzu fallow to smother weeds, and slash and burn it after one year; 7) subsequent options: establish grass-legume pastures, agroforestry, or intensively fertilized continuous cropping.

Five crops of upland rice and two of cowpeas were produced during a three year period on soil with pH 4.5 under this low-input system. More than half of the biomass, N and Mg, about 90% of the K and Ca, but only 37% of the P accumulated by the crops was recycled back to the soil. Herbicide accounted of 8% of total production costs. The system was highly profitable when compared with traditional shifting cultivation. These results have aroused considerable interest by network cooperators and AID.

Problems

The questions now arising are those of sustainability. How can the system, which is presently considered transitional, be transformed into a sustainable, hi-

tech version of shifting cultivation? Instead of one year of crops and 12 years of fallow, this system may produce two to three years of crops with only one year of fallow. The constraints to that possibility are clearly two: nutrient depletion and weed encroachment (Figure 3). There are no major soil-loss considerations because there is no tillage, and the soil surface is always protected by a crop canopy, mulch or crop residues.

The problem is one of how the cropping and fallow periods can be made more efficient in terms of nutrient use and weed control, while the system still serves its original purpose: a transition from shifting cultivation to continuous cropping, pastures or agroforestry.

Information Gaps

Little is known about the precise pattern of nutrient depletion beyond the fact that phosphorus and potassium became deficient in Yurimaguas. Other fields with lower topsoil clay content have lasted less than three years at the same location. The nutrient depletion pattern is also expected to be different in clayey Oxisols of Manaus, where the only information available is with acid-sensitive crops in high-input systems.

Our germplasm base for the low-input system remains very narrow: one upland rice variety with poor grain quality and two cowpea varieties. A major effort is needed to find acid-tolerant rice varieties with good grain quality, to broaden the germplasm base of cowpea cultivars, and to search for high Al-tolerance in other crops, particularly grain sorghum and sweet potatoes. The germplasm base for our managed fallow is even narrower: kudzu. Other species that have shown promise in Yurimaguas and Manaus must be tested for growth pattern, weed suppression, rooting depth and nutrient-release characteristics under acid soil conditions.

Questions also arise whether weed encroachment can be decreased by altering the present cropping sequence rice-rice-cowpea to rice-cowpea-cowpea because rice competes with weeds. Also, plant density alterations need to be investigated in order to estimate the trade-offs between possibly lower yields but improved weed competition. The relationship between weed population shifts and declining soil fertility needs to be understood, preferably at the weed species level.

The success of the low-input system so far is based upon fairly efficient nutrient cycling during the cropping period, except for phosphorus. Little is known about the dynamics and importance of organic P in acid tropical soils. Little is known about the magnitude of nitrogen losses in this system and nitrogen transformations in general. Changes in crop species, timing and planting density will affect nutrient-release patterns of above-ground residues and of roots.

Fallows are currently eradicated by burning. A significant loss of nitrogen, phosphorus and sulfur undoubtedly takes place in the process of burning. Can we conserve more of these nutrients without burning? However, weeds might not be controlled as effectively.

Finally, we need to know which are the appropriate crop: fallow ratios in low-input systems, in both frequency and time. Is the present 3:1 ratio (on a year basis) the best, or can the system's sustainability also be maintained through greater frequency of short fallows (three to five months)?

Hypotheses

The low-input system project carries the following main hypotheses:

H-1. The low-input system can extend its time span of sustainability with appropriate manipulation of highly acid-tolerant crops and fallow species, and their crop fallow ratios.

H-2. Nutrient depletion patterns will differ substantially between clayey Oxisols and sandy Ultisols.

H-3. Nutrient-cycling efficiency can be enhanced by improved knowledge of the processes involved.

Objectives

1. Develop the technology for the low-input system to become sustainable.
2. Broaden the germplasm base of crops and managed fallows for low-input systems, including the planting sequences, density and crop:fallow ratios.
3. Quantify the processes affecting nutrient cycling with special attention to carbon, nitrogen, phosphorus and potassium.

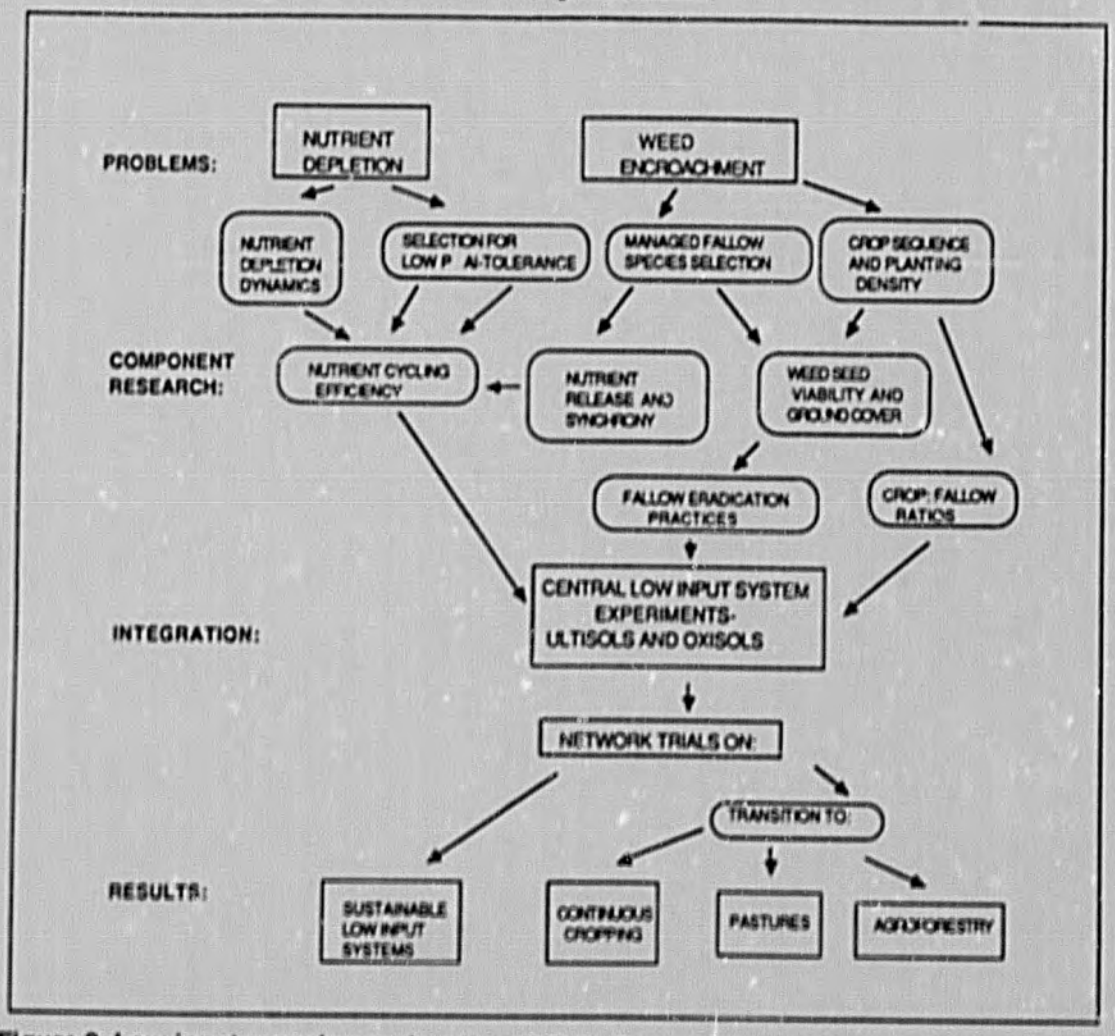

Figure 3. Low-input cropping project flow (NC-2). Rounded boxes represent proposed TropSoils-sponsored research.

Developmental Relevance

A major contribution to tropical agriculture will be made if the low-input system becomes sustainable, replacing in effect slash-and-burn in areas where market infrastructure is deficient. A tighter transition technology to other systems with a broader germplasm base, slower nutrient depletion and slower weed encroachment would also represent a major contribution for the emerging commercial farmers in the humid tropics.

Expected Products

New information on interactions between acid-tolerant germplasm, nutrient cycling and weed encroachment in clayey Oxisols and sandy Ultisols will be gained, and will be transferred to network cooperators involved in Project NC-8.

Operational Plan

The project's operational plan is shown in Figure 3, flowing from the problems to component research, to integrative research and to the results. Actual experiments are identified by rounded boxes in Figure 3 and by their code numbers in this discussion. Nutrient-depletion dynamics will be measured in the chronologic low-input experiment presently in its second year at Yurimaguas (Y-215), and in a new one to be installed in Manaus (M-914). Selection for 60-80% Al saturation of sorghum, rice, cowpeas and sweet potatoes will be conducted at Yurimaguas (Y-203) by INIAA scientists, while selection for joint tolerance to high Al and low available P will be initiated by EMBRAPA scientists in Manaus (M-913) where extremely low levels of phosphorus are found. Managed fallows species selection will be conducted in Yurimaguas (Y-222) including accessions of the genera *Mucuna, Pueraria, Centrosema, Canavalia, Desmodium, Stylosanthes* and *Calopogonium*. These accessions will be characterized in terms of decomposition rate indicators such as the percentage of N ligning and polyphenolics, rooting patterns, mycorrhizal infection, weed suppression, and nutrient accumulation in tops and roots. Changes in these properties with age of fallow, along with phenological data will determine the optimum length of fallows. The competitive ability of weed species will be studied by comparing their uptake efficiency to that of crop species. This will be studied under laboratory conditions on campus (Y-224).

Fallow eradication practices as compared to burning will be studied with the most promising species (Y-223). Crop:fallow ratios will be studied to determine the different alternatives (Y-221).

The above information will be integrated in the ongoing central low-input experiment at Yurimaguas (Y-210). The results will be transferred to the network sites under Project NC-8.

Assessing Accomplishments

Increased knowledge of nutrient-weed interactions in low-input systems and improved sustainability estimates from the central experiments and network trials can be used to assess progress.

Project Number
NC-3

Project Title
Legume-Based Pastures for the Humid Tropics

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Problem Statement
Present Status

Dual-purpose (beef-milk) production in pastures is one of the most widespread management options in the humid tropics and one with a bad reputation as an ecosystem degrader. This reputation is well earned in cases where grasses requiring high fertility are planted and no legumes or fertilizers are used. When this happens, grazing pressure increases as pasture productivity declines, leading to economic collapse and ecological damage. CIAT's Tropical Pastures Program has collected a large number of grass and legume ecotypes adapted to acid soil conditions. We put together the most promising CIAT selections in a grazing trial established in Yurimaguas in 1980 and continue to acquire improved material on a routine basis.

The central grazing experiment (Y-302) is the longest-running replicated grass-legume grazing trial based on low-input concepts in the humid tropics. While some mixtures have remained persistent and have been responsible for large gains in animal weight, others have become unstable after five years of grazing. Even under controlled experimental conditions, we have observed that animal weight loss probably resulted from lack of legume persistence and subsequent low pasture quality. Other studies in this project have provided substantial information on the nitrogen contribution of legumes in mixed pastures, potassium dynamics, and the reclamation of different types of degraded pastures. It is relevant to emphasize that the TropSoils pasture reclamation research has been successful under a wide variety of circumstances and is now at the extrapolation stage by INIAA and CIAT.

Problems

We are now facing a problem of reduced pasture persistence after a few years of grazing. The problems of sustainability at early stages have been resolved, but the key problems are low pasture quality (not quantity) and insufficient knowledge of

nutrient recycling under grazing (Figure 4). Potential soil-loss problems and weed encroachment are not considered a major problem because their occurrence is usually a consequence of overgrazing, poor pasture quality or limiting nutrients.

Information Gaps

There is very little knowledge about how nutrient cycles operate in pastures and which fluxes involved. Pastures behave very differently from crops in their interactions with soils. The acid-tolerant species we use are highly productive, deep-rooted perennials, subject to an accelerated root-recycling process caused by frequent defoliation and trampling. Estimates from experiment Y-302 show that approximately 80% of the P and over 90% of the K and Ca added as maintenance fertilization is cycled back to the soil. The phosphorus level contrasts sharply with the 37% recycling obtained with low-input cropping. We have recently discovered that much of the soil fertility changes occur in the 0-5 cm layer, and that by sampling from 0-15 cm we have been diluting these effects. All we know about nitrogen transformations is that either mineralization and nitrification rates are extremely low or denitrification rates are high, and that some legumes apparently contribute the equivalent of 150 kg N ha/yr of fertilizer N to the associated grass.

The grazing animal is the driving force in nutrient recycling. Grazing pressure (animal liveweight units per unit of forage on offer) and resting periods are the main management tools. High grazing pressures result in more trampling, more animal excreta, possibly faster root turnover because of defoliation, but less litter accumulation than lower grazing pressures.

Longer rest periods alter the grass:legume balance, build up the litter layer, and perhaps slow root turnover. Differential palatability of the grasses and legumes will alter the amount consumed by animals and hence the composition of the litter layer. There is no quantitative assessment of the processes in improved, acid-tolerant pastures in the humid tropics. There are some indications that soil organic matter and nitrogen contents are improving with time in grazed pastures. This needs to be quantified.

Severe pasture quality problems have occurred with one mixture, *Brachiaria decumbens/Desmodium ovalifolium*, during the fifth year of grazing, and similar symptoms are beginning to appear in *Brachiaria humidicola/Desmodium ovalifolium*. Animals have lost weight, eaten most of the unpalatable legume, and avoided large quantities of available grass. Some animals developed photosensitization lesions, indicative of severe nutritional disorders. The causal factors need to be identified. In sharp contrast, a pure *Centrosema pubescens* pasture continues to produce the highest and most sustained liveweight gains during seven years of grazing. Such productivity and persistence of a pure legume pasture is unheard of, suggesting that legume-dominated pastures need to be studied in detail. A further area of ignorance is the transition from crops to pastures and from pastures to crops. Much needs to be learned about this subject.

Hypotheses

The pasture project encompasses the following main hypotheses:

H-1. Declining animal productivity under good pasture management is related to the disappearance of the legume component.

H-2. Legume-dominated pastures are as productive as grass/legume pastures and are an alternative to managed fallows.

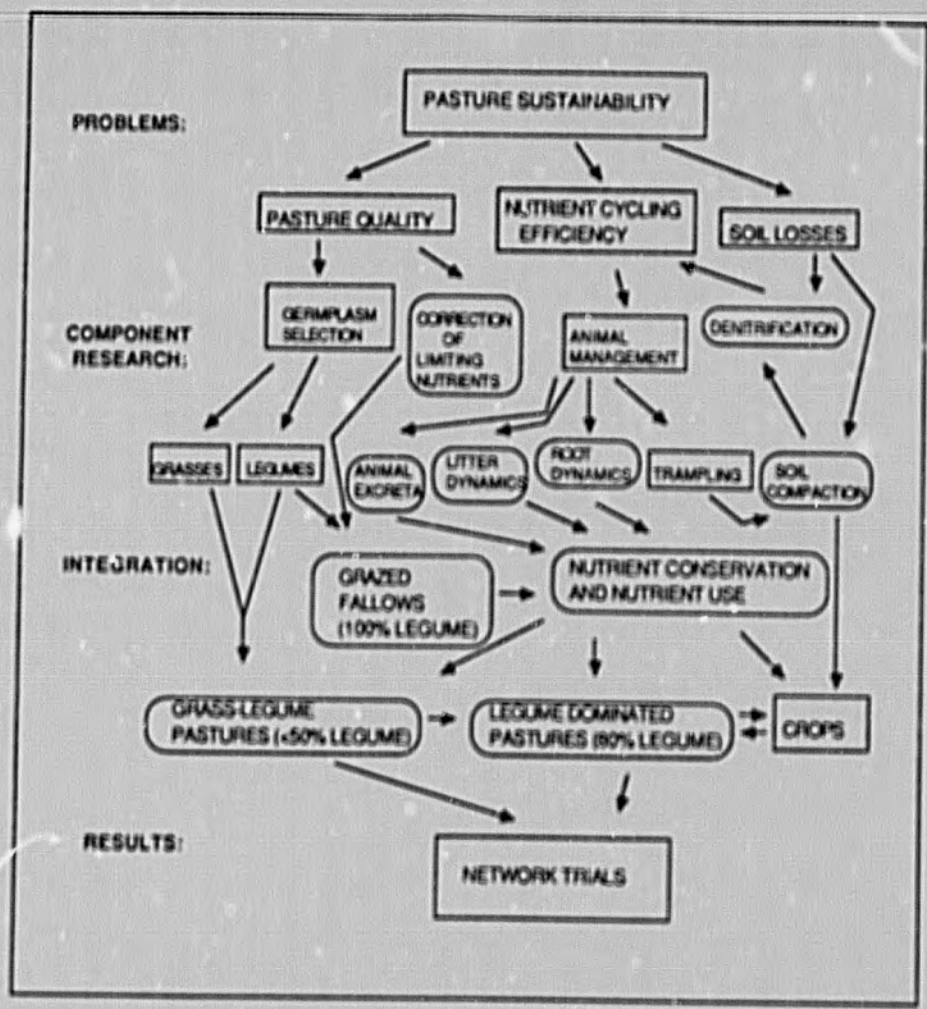

Figure 4. Legume-based pastures project flow (NC-3). Rounded boxes represent proposed TropSoils-sponsored research.

H-3. Nitrogen transfer from legume to grasses via litter decomposition may be limited by low mineralization or high denitrification rates.

Objectives

1. To identify and correct pasture quality parameters that affect the sustainability of grass/legume mixtures.
2. To develop a solid data base on carbon, nitrogen and phosphorus cycling in acid-tolerant grass/legume mixtures under grazing.
3. To develop stable legume-dominated mixtures with less than 20% grass composition.
4. To develop the appropriate practices for the transition from pastures to crops and vice versa.

Developmental Relevance

Pasture sustainability and its limits will be quantified. If legume-dominated pastures are successful, a new picture in cattle production may emerge. This research on soil-plant-animal relationships is focused as one option for small farm operations in the humid tropics. These farmers are not likely to invest in extensive pastures for beef production only.

Expected Products

Within the next five years this project is expected to 1) quantify many carbon- and nutrient-cycling processes in grazed pastures, 2) overcome persistence problems related to pasture quality, and 3) develop innovative transition technologies.

Operational Plan

The conceptual flow is shown in Figure 4, from the problems to component research, integrative research and its transfer to network trials of Project NC-8. The actual experiments to be conducted with TropSoils support are shown in rounded boxes. Numbers in parentheses relate to experimental codes in use. Most of the research will be conducted in Yurimaguas, with possibility of new trials in Manaus as the quinquennium progresses. The pasture quality problem will be tackled through identification and correction of limiting nutrients in a small plot experiment (Y-316). Another means of overcoming poor pasture quality is to select germplasm with vigorous growth under acid soil conditions but with superior quality. Quality is usually a function of high protein and low tannin contents (Y-301). This work will be conducted by INIAA counterparts in collaboration with CIAT with no direct TropSoils support. Laboratory work relating observed animal preference in grazed plots to litter quality parameters (lignin/N ratio, polyphenolics/N ratio) will determine whether these two factors are related in a predictable way (Y-320).

Nutrient-cycling efficiency will focus on soil organic carbon (Y-312) and nitrogen transformations (Y-318), and if time and resources permit, phosphorus dynamics. Present long-term grazing plots of experiments Y-302 and Y-307 will be used as appropriate for nutrient-cycling measurements, thus avoiding the cost of establishing new grazing trials. The main compartments to be analyzed are forage, litter, roots, animal excreta, and soil. Estimates of biological N-fixation, mineralization, nitrification, denitrification, ammonia volatilization and leaching will be studied for

nitrogen. Litter decomposition, root turnover, microbial biomass, structural, slow and passive organic C and N pools will be quantified where reliable methodologies are available.

Soil losses are not likely to be of major importance in well-managed pastures, but compaction by trampling occurs, triggering denitrification losses and eventually resulting in excessive runoff. One way to overcome compaction is to till, plant crops, and eventually revert back to pastures. This practice will be studied in experiment Y-315 while the use of grazed fallows as transition to cropping will be tackled in Y-313. Several species combinations for legume-dominated pastures will be studied in a new grazing experiment (Y-317). All research will be integrated in the central experiment (Y-302). Additional data may be gathered from our former plots now taken over by CIAT in Pucallpa in collaboration with Dr. Jose Salinas. Project results will be transferred to network trials through Project NC-8 and to CIAT's Tropical Pasture Subnetwork for the Humid Tropics, as appropriate.

This operational plan is therefore narrower and more soil-process oriented than previous work. Germplasm selection is in the hands of INIAA. CIAT has recently established a presence in Pucallpa, Peru, with two senior scientists who will work on germplasm evaluation, seed production and reclamation of degraded pastures. This allows TropSoils to focus on soil-related processes while keeping ties with the CIAT Tropical Pastures Program.

Assessing Accomplishments

Expected benefits are increased knowledge of pasture quality and nutrient cycling in grazed pastures, sustainability estimates from the central experiment, and network trials.

Project Number
NC-4

Project Title
Agroforestry Systems for the Humid Tropics

Project Leaders
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Problem Statement
Present Status

Shifting cultivation is no longer a sustainable farming system in many areas of the humid tropics due to decreased fallow periods caused by increased population pressure or land-tenure systems. Many of these areas do not have sufficient infrastructure or access to markets, precluding continuous cultivation as an economically viable alternative. Under the traditional system land is in production one year for every five years in unproductive fallow. The low-input system (NC-2) provides two to three years of profitable cropping, but then declines in productivity occur due to decreasing fertility and increasing weed problems; then the system has to be abandoned to some other land use. Agroforestry offers a variety of land-use options ranging in degrees of management and inputs.

Agroforestry research in Yurimaguas started in 1983 and has focused on three areas of research: food-tree systems, alley-cropping and improved fallows.

Food-tree systems include combinations of trees or woody perennials that produce edible fruit in combination with ground cover plants. Relatively unknown, native food trees with market potential have been collected and screened for acid tolerance in Yurimaguas, Manaus, and Pichis. The principal species include peach palm *(Bactris gasipaes)*, guaraná *(Paulina cupana)*, arazá *(Eugenia stipitata)*, carambola *(Averrhoa carambola)* and achiote *(Bixa orellana)*. Various aspects of nursery management, fertilization, and management of peach palm in acid soils has been investigated, and a technological package is being developed for extrapolation work. *Alley-cropping* is a successful agroforestry system in high base status soils of the subhumid tropics. Thus far we have had limited success with alley-cropping in sandy Ultisols, but better results on more fertile alluvial soils. Information to date indicates that some *improved fallows* can indeed restore stocks of nitrogen, phosphorus and potassium and suppress weeds faster than the natural forest fallows. It

remains to be seen if these differences are reflected in higher crop yields or sustained production following clearing and burning of these improved fallows.

Problems

Current agroforestry research problems relate to the sustainability of food-tree crop systems, alley-cropping and improved fallows. Three main issues are nutrient-cycling efficiency, weed encroachment and soil losses (Figure 3). Although there is little question about the possibility of trees recycling nutrients from base-rich subsoils, the fundamental question is: How much recycling does occur in Oxisols and Ultisols, and how much organic or inorganic inputs need to be added to compensate for crop extraction? Weeds are a problem in agroforestry as they are in most other cropping systems, however shade and mulches provided by the trees may effectively control weeds.

Throughout the humid tropics farmers are encroaching on fragile slope lands, the result being excessive soil and nutrient losses. Several features associated with agroforestry can aid in stabilizing these slopes and lead to sustained production.

Information Gaps

Data needed for tree-crop systems include the role of mycorrhizae in nursery management and transplanting survival, appropriate cover crops, and fertilization during the production phase of food-tree crops. Work is just beginning on species other than peach palm and guaraná, and the research design used for investigating establishment and management of the peach palm will be followed.

In alley-cropping we need to investigate biological processes (decomposition and mineralization, as related to mulch quality, N-fixation, mycorrhizal associations, root dynamics, and tree-crop competition) in order to understand the nutrient dynamics and related crop yields. A model incorporating existing data needs to be developed for the design of efficient alley-cropping systems.

The length of the fallow period has become shortened in many areas of the tropics to a point where there is insufficient time for the site to regenerate. This regeneration appears to involve aspects of soil fertility and weed control. Efforts need to be made to manage and improve the fallows. These efforts should be aimed at both reducing the size and vigor of the weed seed pool and enriching the soil with nitrogen through the inclusion of nitrogen-fixing species in the fallow vegetation.

Hypotheses

The general hypothesis addressed by agroforestry is that when trees are included in a system, sustainability can be maintained with fewer fertilizer and herbicide inputs than systems without trees because trees provide continuous nutrient cycling and they protect the soil surface from intense rains and extreme temperature fluctuations.

Specific hypotheses are:

H-1. Food-tree systems using acid-tolerant Amazonian tree species are more sustainable than short-cycle food crop systems under the same levels of inputs.

H-2. Alley-cropping can be successful in Ultisols with the use of techniques that include adapted tree species, acid-tolerant crops, and mulch and nutrient management.

H-3. Improved fallows are more efficient than natural fallows in regenerating soil fertility and physical factors, and in suppressing weeds.

Objectives

1. To develop a technological package for the establishment and management of peach palm plantations for both fruit and heart of palm production.
2. To adapt the technology developed for peach palm to other native fruit species.
3. To adapt alley-cropping to acid, infertile soils.
4. To meet crop nutrient requirements by the efficient cycling of nutrients yielded from tree prunings in alley-cropping systems.
5. To shorten the fallow period by use of leguminous species that restore nutrients and suppress weeds faster than the natural forest fallow.
6. To develop economically productive fallows.

Developmental Relevance

Agroforestry provides an economically viable alternative to shifting cultivation that is ecologically compatible with the humid tropical ecosystem. Production is sustained over time on a given unit of land, thus reducing the need to clear new forest every year. Agroforestry is a particularly attractive alternative because it incorporates features of traditional farming practices and is therefore more readily adopted, and it can be used in a range of socio-economic and landscape conditions.

Expected Products

Integration of the basic research being conducted on the components of agroforestry will provide information necessary for the design of efficient and productive tree-food systems. An alley-cropping model for acid soils will to be produced during the time frame of this proposal.

Operational Plan

Agroforestry research began in Yurimaguas and Manaus in 1983 as joint TropSoils-INIAA and TropSoils-EMBRAPA efforts. INIAA is supported by a grant from the International Development and Research Centre of Canada (IRDC) in collaboration with the International Council for Research in Agroforestry (ICRAF). Soil-related research is funded by TropSoils, while germplasm and socio-economic research is funded by INIAA and EMBRAPA. In addition, a USDA-CSRS special pass-through grant to study rhizobia-mycorrhiza interactions has recently been awarded and fills an important gap in agroforestry. This collaborative effort is the first and most comprehensive research program on agroforestry for acid soils of the humid tropics.

Most of the experiments are long-term by nature and most are already established in the field. The flow diagram appears in Figure 5 with the rounded boxes being the projects supported by TropSoils research.

Tree germplasm selection will continue both for food-producing species (peach palm, guaraná, arazá, carambola, achiote) and legumes for alley-cropping and managed fallows. Emphasis will be on the genera *Inga*, *Erythrina*, *Cassia*, and *Gliricidia*. This work is conducted by INIAA under experiments Y-406, Y-407, Y-408. INIAA agronomists, in collaboration with the New York Botanical Garden, are establishing a collection of the genera *Bactris*, *Obygnia*, *Jessenia* and *Euterpe*. Germplasm interchange with EMBRAPA and INPA in Brazil, INIAP in Ecuador and

ICA in Colombia is done routinely via an international working group. Collected germplasm, along with nodules if present, are planted in a nursery and evaluated afterwards under acid, low-fertility field conditions for growth, tolerance to insect attacks, and phenological characteristics as appropriate. TropSoils scientists provide a support role in promoting germplasm interchange with the African and Hawaiian organizations.

Fertilization and liming trials are being conducted to determine the nutrient requirements of peach palm (Y-404) and guaraná (M-904) during the vegetative stage. Similar studies are proposed for arazá in Yurimaguas and carambola and achiote in Pichis (Y-429). A new activity proposed under this project is determination of the fertilization requirements during the fruit-bearing stage in peach palm plantations grown with legume covers at Yurimaguas (Y-402). Potassium is suspected to be the primary limiting nutrient. The potential of ground potassium feldspars will be investigated as a slow-release source. Mycorrhiza inoculation in peach palm nurseries will be studied with emphasis on transplant recovery and survival and soil temperature (Y-427). The lime requirements of guaraná will be investigated in Manaus (M-911).

Ground covers for peach palm are being studied in an experiment established in October 1986 (Y-402B). Early results suggest that intercropping low-input crops with the peach palm for one year prior to establishing the cover crop is the best option. *Mucuna cochinchinensis* appears to be the most promising cover crop. Palm growth, ground cover biomass and persistence, nitrogen, and weed dynamics will be monitored. Mature peach palm plantations with suitable legume cover will be grazed to produce silvipastoral systems (Y-428).

Alley-cropping work consists of several studies that monitor mulch quality, nutrient cycling, root dynamics, weed biomass and soil physical properties. An alley-cropping experiment on fertile alluvial soils will continue (Y-417) to provide an on-site comparison with a similar one on acid, infertile Ultisols (Y-425). Studies on mulch quality and how it relates to nutrient cycling and soil organic matter will continue (Y-405B). Since alley-cropping is particularly promising for stabilizing hillsides and much crop production occurs on such hillsides, a new experiment has been planted on a 12-15% slope; emphasis will be given to measuring the effect of alley-cropping on soil loss processes (Y-434). The interactions between alley-cropping hedgerows and food crops will continue to be studied to evaluate competition between the two. The managed fallow experiment (Y-409) is in its fourth year; the fallows will be cut and burned in mid-1988, and the effects on subsequent crop production will be measured. The forest- and soil-regeneration experiment (Y-410) will be finished in 1988. Based on the results obtained in 1988, further research will be designed during the quinquennium.

The component results will be integrated to design improved fallow systems, alley-cropping systems, food-tree production and silvipastoral systems. Such information will be transferred to network trials under Project NC-8 and to ICRAF, as appropriate.

Assessing Accomplishments

Given the long-term nature of tree-based systems and the newness of the research included in this project, progress is more difficult to predict than in the other projects of this proposal. Accomplishments will be continually assessed according to the results of the component research and finally as the component research is integrated into the various agroforestry options.

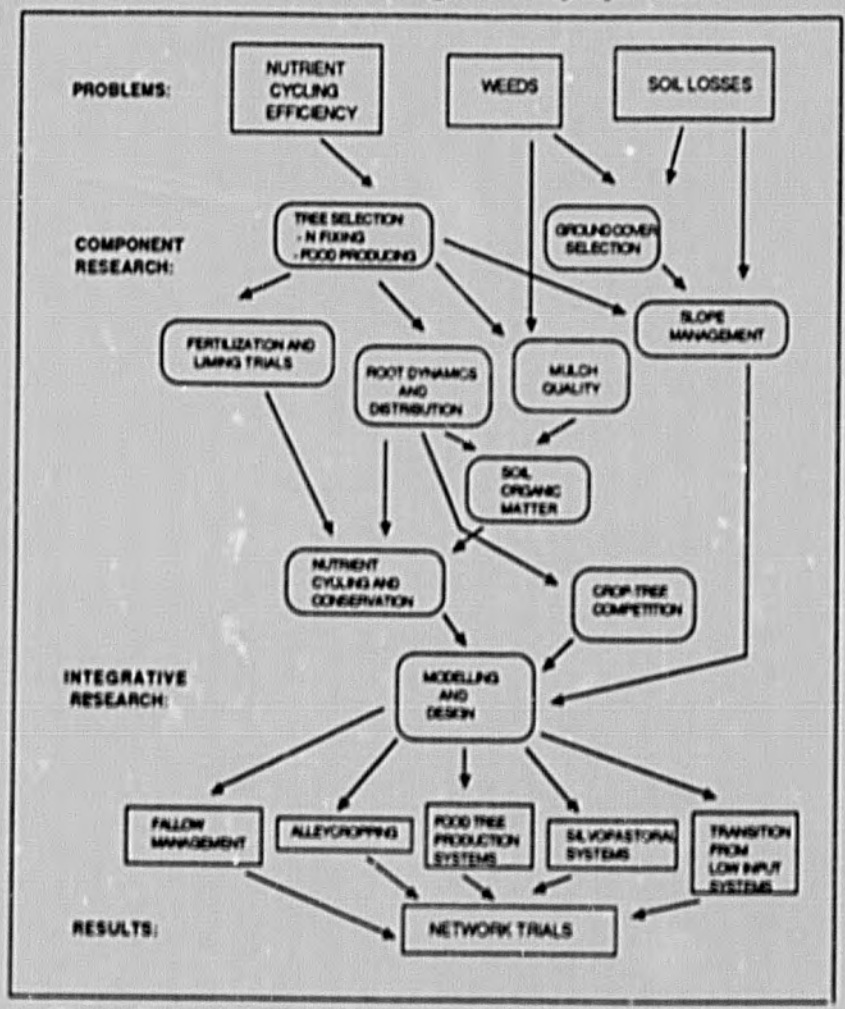

Figure 5. Agroforestry project flow (NC-4). Rounded boxes represent proposed TropSoils-sponsored research.

Project Number
NC-5

Project Title
Management of Humid Tropical Steeplands

Project Leader
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Problem Statement

The deterioration of living conditions in the Peruvian Andes due to a variety of socioeconomic factors has resulted in an unprecedented migration of mountain dwellers to the coastal cities and to the Selva. While the coast has always been favored, the government has attempted to encourage the development of the Selva to alleviate the population pressure on the already crowded metropolitan areas along the Pacific coast. The recently completed section of the Carretera Marginal and penetration roads (in the states of Ucayali, Huánuco, Pasco, Junín, Ayacucho, and Cuzco) has provided access to vast areas of primary tropical rainforest relatively close to the population centers of the Sierra (Huancayo, Cuzco). A great portion of these areas are in Selva Alta, or high jungle, which is characterized, in contrast to the Amazon lowlands, by a more pronounced relief and generally higher annual precipitation.

Concerns have been voiced about the possible negative effects of forest conversion on the environment in these areas. They range from more frequent and more severe flooding in downstream areas of the Amazon Basin due to channel aggradation as a result of higher sediment loads or due to higher surface runoff, or a combination of both. It is commonly believed that crop yields in cleared areas are not sustainable on account of soil and nutrient losses, and that the useful life span of reservoirs are shortened. These concerns are not restricted to Peru or even to the Amazon Basin, but are echoed throughout the humid tropics.

A number of investigations have been conducted in the humid tropics using artificially delimited hillslopes or small plots as experimental units. They focus on either hydrology and erosion or hydrology and nutrient movement either in undisturbed forest or under various cropping systems. Although frequently used for extrapolation purposes, data derived from plot experiments do not serve as a valid basis for true estimate of soil losses. Rarely have these processes been investigated in an integrated fashion using first-order catchments as natural experimental units. Any realistic assessment of an agroecosystem's performance and its environmental impact downstream must be based on evaluating the above-mentioned processes in the complete system under consideration, and not merely in part of it. In addition, our qualitative knowledge of hydrological, erosional, and solute proc-

esses in the humid tropics is far from complete.

It is without doubt that the introduction of inappropriate management practices following forest clearing can exceed the ecosystem's resilience and eventually lead to severe environmental degradation, the effect of which will be felt in downstream areas. The hypothesis is put foreword, however, that by introducing appropriate management options, as they have been developed in Yurimaguas for the Low Selva and tested at extrapolation sites in the High Selva, the ecosystem's resilience will not be exceeded, and its productivity will be maintained.

The project's hypotheses are as follows:

H-1. A legume-based pasture system and silvipastoral system will behave similarly to the forest ecosystem in terms of soil-loss processes.

H-2. Those two systems are superior to a traditional shifting cultivation system.

Objectives

1. To establish a base-line reference of soil- and water-loss estimates in a primary forest watershed in humid tropical steeplands.
2. To compare four different management options in terms of sediment and nutrient dynamics with primary forest.

Operational Plan

Five different systems of land use—forest, agroforestry, silvipasture, legume-based pasture, shifting cultivation—will be compared with respect to their sediment and nutrient dynamics in a quantitative fashion. The forest ecosystem data will serve as a reference frame. More specifically, the variables to be measured for each system are streamflow, sediment lead, and the concentrations of various elements (H^+ NO^-, H_2PO^-, Ca^{2+}, Mg^{2+}, K^+).

Four first-order catchments, ranging in size from about one to two hectares, in which the forest ecosystem will be converted, have been previously selected and are situated in close vicinity of the research station and the forested research catchment within the La Esperanza Forest Reserve in Pichis. Before being cleared, the four experimental catchments will be monitored, i.e., streamflow, sediment and nutrient output will be measured continuously as well as on a rainfall-event basis, for one year under forest cover to get pertinent reference data for each of them (Figure 6). During the dry season of the second year, the four experimental catchments will be cleared and the previously mentioned management options established, without interruption of the monitoring program which is to continue for another three to four years. Simultaneously, the forested research catchment will be monitored to provide supplementary data.

Assessing Accomplishments

The main basis for comparing forest vs. management option performance will be each catchment's pre- and post-clearing response to similar rainfall events. The resulting data base will serve to assess each agroecosystem's performance in terms of long term productivity and capability to minimize the environmental impact as a result of forest conversion.

Budget

This project is to be jointly funded with INIAA through a grant this institution expects to receive from the German Agency for International Cooperation (GTZ). The proposed TropSoils contribution will allow it to continue involvement in the project it initiated. This project promises to make a major contribution to tropical soil science.

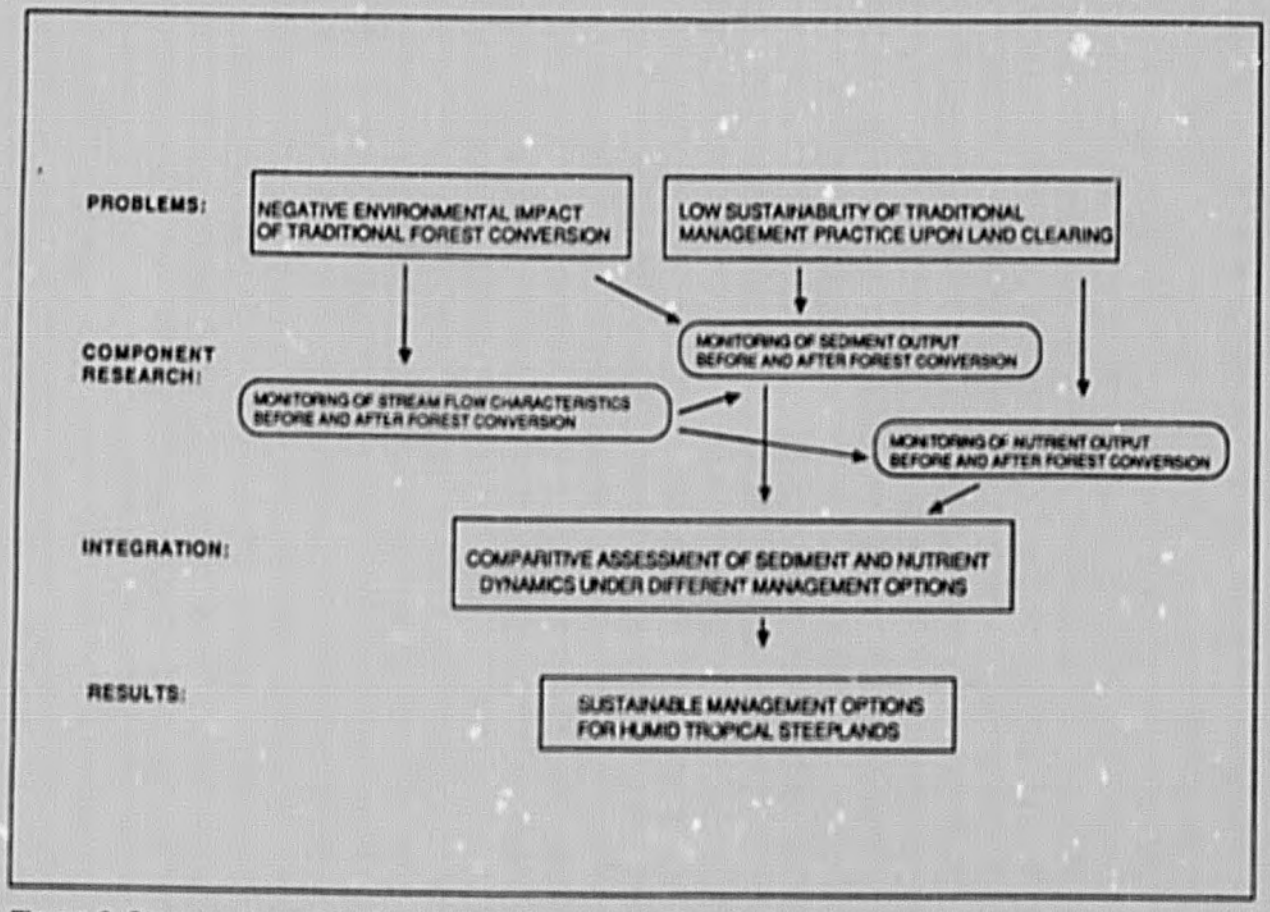

Figure 6. Steeplands project flow (NC-5). Rounded boxes represent proposed TropSoils-sponsored research.

Project Number

NC-6

Project Title

Comparative Dynamics of Production Systems

Project Leaders

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Problem Statement

Over the past twelve years, much of the research at the Yurimaguas Experiment Station has been devoted to defining and refining production systems for different soil/landscape positions and socioeconomic conditions found throughout the humid tropics. Although it is clear that such systems differ in terms of their biological, chemical, physical, and economic characteristics, differences in underlying processes are not well understood. Past attempts at comparing specific processes (eg., soil dynamics) in some of these systems did not deal rigorously with the problem of the confounding effects of time and spatial variability.

In establishing this experiment (Y-412) two years ago, we hypothesized that 1) different management practices associated with the systems would create different environmental conditions which would, in turn, differentially affect soil chemical, physical, and biological properties and processes; 2) differences in soil properties and processes could be related to differences in plant production; and 3) the interaction of the timing and quantity of biological production with the timing and requirements of labor and capital would determine the suitability of such systems in different socioeconomic contexts.

Objectives

1. To systematically compare the processes and characteristics of promising management systems for the humid tropics in order to understand how and why these options differ.
2. To be able to recommend, based on this understanding, the use of specific production systems in specific biological and socioeconomic environments.

Operational Plan

Systems differing greatly in their biological and economic characteristics and management were installed in 1985 at Yurimaguas. The systems included the following: shifting cultivation; high-input cropping; low-input cropping; multistrata tree-crop agroforestry; a peach palm plantation; and a young secondary forest control treatment. All treatments were started at the same time, on the same site, on two well-characterized Typic Paleudult soils differing in texture. These textural differences were shown by past work to have strong effects on plant production. Plots 1875 m^2 in area were cleared from a 10-year-old secondary forest in June 1985; the forest was not cleared in the control treatment. Clearing was done by hand, using the slash-and-burn method, in all treatments except for mechanized clearing in the high-input system. The six options were arranged in a randomized complete block design with three replications; blocking was done on the basis of topsoil texture (sandy loam vs. loamy sand).

Research on the performance of these systems falls into four major groups: 1) water flow and retention; 2) C, N, and P cycling; 3) weed population dynamics, and 4) economics (Figure 7). For the first three groups, quantification of the major states and processes and their integrative effect on plant production is a primary objective. Plant production, in turn, will be combined with economic factors, such as the cost of inputs and prices of products, to determine economic productivity.

Research on water flow and retention concentrates mainly on constructing a water balance for each system, determining the quantities of nutrients lost by leaching, and characterizing the spatial variability of water flow and retention and its relationship to nutrient-cycling processes, such as plant residue decomposition, organic matter mineralization, and denitrification. Measurements related to water balance and leaching have been under way since initiation of the project. A more detailed examination of water flow and retention is planned.

The cycling of C, N, and P are interrelated. Moreover, the latter two are important determinants of plant productivity. Quantification of soil organic matter and nutrient pools and fluxes in the different management systems is a major objective of this research area. Specifically, this includes the estimation of 1) above- and below-ground inputs (litterfall, crop residues, root litter) of C, N, and P; 2) the size of specific C pools in the soil (i.e., light fraction/plant residue, microbial, humified, and total) and the quantities of N and P associated with each; 3) the relationship between rates of decomposition and plant litter quality; and 4) rates of C, N, and P mineralization from soil organic matter in the various management systems. In addition, we intend to estimate rates of biological N_2 fixation and denitrification and to assess the relative importance of inorganic and organic P pools to plant uptake, based on changes in P pool size over time. The composition of soil macrofauna and the extent and type of mycorrhizal infection of the major crops and native vegetation species are also under study.

The majority of the C- and N-related work was initiated in 1986 using the standard methodology suggested by the Tropical Soil Biology and Fertility (TSBF) Network. In so doing, this study became part of a tropics-wide comparison of soil organic matter dynamics in natural and managed systems sponsored by TSBF. Studies of soil macrofauna and mycorrhizal infection were also started in 1986. Estimation of rates of fixation and denitrification and changes in soil inorganic and organic P pools will begin in 1988.

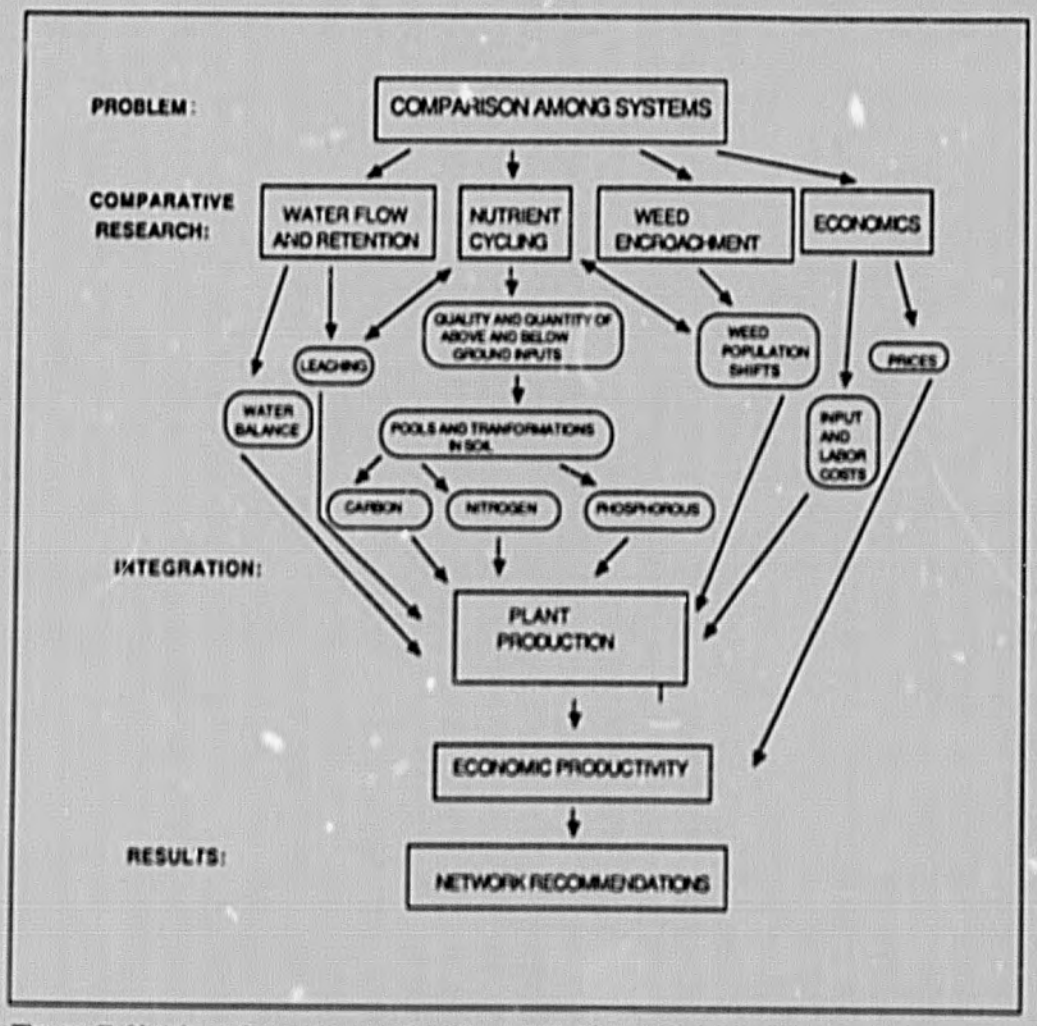

Figure 7. Nutrient dynamics project flow (NC-6). Rounded boxes represent proposed TropSoils-sponsored research.

Weeds and their control are often major determinants of the biological productivity of a crop and of a system's economic productivity and viability. We intend to quantify differences among the systems in the biomass of the major weed species, as well as changes in weed populations over time, and to relate these changes to specific management practices or soil conditions. This work will be initiated in 1988.

The economic measurements are chiefly bookkeeping operations designed to estimate the costs and benefits associated with management practices. These include the costs and benefits of different land-clearing methods; costs associated with periodic operations such as planting, weeding, harvesting, and thinning; and revenues from the harvest of primary and secondary products. Such measurements have been on-going since initiation of the project and will continue. Economic flows will be discounted to ensure fair comparison among systems differing in length of the production period or in the timing of production. Estimates of wider social costs and benefits are outside the scope of this study.

We expect that this project will be particularly useful in clarifying the biological and economic differences among low-input systems which currently attract much interest (eg., low-input cropping, agroforestry, and tree fruit plantations). Results will be transferred to network sites under Project NC-8. Results related to soil organic matter will be communicated to the TSBF Network via periodic meetings planned by that organization.

Assessing Accomplishments

Contributions to the scientific literature on soil C, N, and P processes and weed dynamics in natural and managed humid tropical ecosystems are of major importance. As a result of this project we should be better able to recommend well-defined management systems to farmers differing in economic capacity. Many of the myths and confusions associated with land-use practices in the humid tropics will be clarified by this project.

Project Number

NC-7

Project Title

Soil Characterization and Interpretation

Project Leader

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Problem Statement

Soils in the humid tropics contrast in mineralogy, texture and chemical composition. To obtain maximum relevance of agronomic research, long-term field experiments need to be conducted on sites that are representative of these different soils, and when information of practical importance and usefulness is obtained from management-related research, that information must be targeted to areas where the soils responsive to such practices are located. This requires that 1) the soils at the research sites be well characterized and 2) areas with the potential to benefit from the new technology be identified so as to better guide extrapolation through extension activities. This linkage of the subdisciplines of soil fertility and soil classification has always been a pivotal aspect of the TropSoils Program at North Carolina State University. The two main problems facing the 1987-92 quinquennium are 1) lack of sufficient knowledge about the soil resource base and 2) ineffective interpretation of existing soil survey data for agronomic purposes (Figure 8).

Characterization of soils in the humid tropics provides data that is needed to improve the classification of these soils that are, by far, less studied than soils in the temperate zone. North Carolina State University faculty in this project need continuing involvement in various committees of the Soil Management Support Services (SMSS) project, which seeks to amend Soil Taxonomy to better reflect current knowledge by improved criteria used to classify soils. Present activities include ICOMOX (Oxisols), ICOMMAND (Andisols) and ICOMAQ (poorly drained soils). SMSS covers direct costs of these activities. Interpretation of the FAO soil map of the world for practical agricultural interpretations via grouping of FAO units into FCC units as part of their land evaluation project is also needed. The improved

data base will be used by the International Soil Reference and Information Centre (ISRIC) in Holland, which is commissioned to develop a worldwide soil reference system.

The project's overall hypotheses are:

H-1. Improved characterization of selected areas of the tropics where little information is currently available will significantly improve the extrapolation of research results.

H-2. Refinements in the Fertility Capability Classification System will facilitate the interpretation of soil surveys for management purposes.

Objectives

1. To increase knowledge of soils and soil properties in the humid tropics.
2. To provide soil characterization and classification at agronomic and agroforestry experimental sites used in the other projects.
3. To improve interpretation and extrapolation of research results via Fertility Capability Classification System (FCC) use and expansion.

Operational Plan

This project consists of seven subprojects supported either partially or totally by the Soil Management CRSP. Figure 8 shows the project's flow, including primary benefits, secondary benefits and interactions. Projects Y-601 and Y-602 seek to improve the Fertility Capability Classification system through critical reviews of potential users and by incorporating recent findings from the literature and existing data bases from other soil mapping and classification efforts into FCC. Project Y-605 provides for characterization and classification of soils at network research sites selected as part of other research activities in the overall project. Projects Y-603, Y-611, and Y-612 propose to study the soil characteristics and their distribution in areas adjacent to past and continuing research activity. This information is then to be made available to extension personnel charged with the extrapolation of research results to agronomic activities remote from the research sites. Project Y-613 is designed to investigate the nature of soil chemical and physical alteration engendered by the decomposition of soil organic matter, derived from different natural and induced vegetation, upon oxidation associated with agronomic practices.The following are synopses of selected subprojects.

FCC Worldwide Testing, Feedback and Revision (Y-60)

The FCC system is envisioned as the standardized method of information delivery with regard to the prediction of response to management practices. The system is directed primarily to agricultural extension personnel and other users of agronomic research worldwide. The project continuation seeks to update the system by collection, evaluation and incorporation of existing and new data and international experience. As often stated, "classification follows science." Thus, there is a continuing need to keep FCC, as a technical system of soil classification, up-to-date with the findings of the researcher and the needs of users of agronomic information.

Continual updating will be recorded on an interactive personal computer diskette, developed under existing project Y-602. Copies will be made available to those wishing to access the most recent agronomic interpretations applicable to their

kinds of soil. During the course of the project, a written evaluation of the system will be solicited from known users of the system in an attempt to determine both desirable and undesirable aspects of the existing system and to obtain guidance as to desirable features to incorporate in future editions. An extensive written documentation of the existing system and the data leading to the present criteria is planned during the project period.

FCC Map of the World (Y-602)

The vast amount of data generated by soil survey projects around the world is stored in terms of natural soil classification systems such as Soil Taxonomy, the FAO World Soil Map, ISRIC, and several independent national soil classification systems. Much of this information relates to features of the subsoil which are of importance to pedologists. Presentation of only those portions of the soil's characteristics that are most directly related to agronomic practices, which are usually the characteristics near the surface, facilitates the use of this information by agronomists and planners.

Physical conversion has been demonstrated to be feasible for the Africa portion of the FAO World Soil Map at FAO headquarters utilizing NCSU personnel. At this writing we are awaiting the results of this effort. If it is successful, project personnel are prepared to assist with the translation of the remainder of FAO map into the FCC system. In addition, national and regional maps prepared in soil survey programs of countries in the humid tropics will be reviewed and, as requested by users, converted to FCC unit maps.

Lower Amazon Basin Alluvial Soils (Y-603)

Alluvial floodplains are often the only existing sites of food production in many parts of the Amazon Basin. This can be attributed to either favorable soils or access to river transportation. Results of a previous project (Y-606) revealed that the composition and agronomic constraints of such soils in Peru are related to the source area of the sediments in each watershed. The study revealed that the soils varied considerably in important agronomic properties, soil pH values ranged from four to eight, while montmorillonite was the universally dominant clay mineral regardless of pH. Alluvial soils, identified by their landscape and geographical location, are frequently considered by agronomists to present an homogeneous set of constraints to agronomic development. This is clearly not the case in the upper part of the Amazon Basin.

Four distinct geological controls presently appear probable in the lower basin: 1) main channel control from the Andes; 2) Brazilian shield control along the tributaries in the southern portion of the Amazon River Basin; 3) Sandstone control in the Rio Negro Basin; and 4) Guyana shield control east of the Rio Negro Basin. Other subdivisions appear probable, and a detailed study of available geological maps will be completed before sampling. Sampling will be at sites presently cultivated along straight reaches of the rivers, avoiding point bars if possible, in areas accessible by boat or seaplane. Complete soil profile samples will be taken for agronomically related and mineralogical analyses. Results will be portrayed on a regional map and generalizations assembled to guide extrapolation efforts.

Characterization of Network Sites (Y-605)

Any meaningful research of soil-related agronomic work should contain information about the soil properties at the site as well as providing readily recognized classifications of the soils involved to guide readers in evaluating the conditions where similar results are probable. As requested by RISTROP, IBSRAM, TSBF or others researchers, project personnel are made available for the detailed soil mapping and sampling of typifying pedons at networks sites. Chemical, physical and mineralogical characterization of the samples will be conducted and the soils classified according to Soil Taxonomy and FCC.

Element Release upon Soil Organic Matter Oxidation (Y-613)

When soils are subjected to cultivation, they almost universally experience a decrease in organic matter content. This loss is in the range of 20 to 40 percent the first few years depending on the climatic conditions, the crop grown, and the extent of mechanical cultivation. All soil organic matter is not the same. Quality depends on the type of vegetation native to the site before cultivation and on the nutrient composition of the soil upon which the vegetation is growing. This project addresses the question of how different soils respond to the decomposition of a portion of their organic matter component.

Samples from the surface and near-surface soil horizons will be gathered from samples existing at NCSU and new sites selected to represent as wide a range of soil, climatic, vegetative and mineralogic conditions as possible. In addition to native vegetation, some sites will be selected to represent old pastures, recent forests, abandoned farmland and continuous agriculture. The samples will be subdivided and a portion subjected to soil test and exchangeable cation analysis. Another portion will be subjected to a rapid, chemically induced, oxidation designed to oxidize about 30% of the soil organic matter. Another portion will be allowed to incubate under elevated, aerobic but moist conditions so as to simulate biochemical organic matter decomposition under cultivated conditions. After the decomposition has reached either a level of about 20-40% of the SOM or a uniform amount of time, the samples will be analyzed for the same properties as the original sample.

Assessing Accomplishments

By the end of this quinquennium a computerized interactive system on FCC should be available as well as a draft version of the FCC maps of the world. Greatly expanded knowledge on soil characteristics, particularly for network sites, should be available.

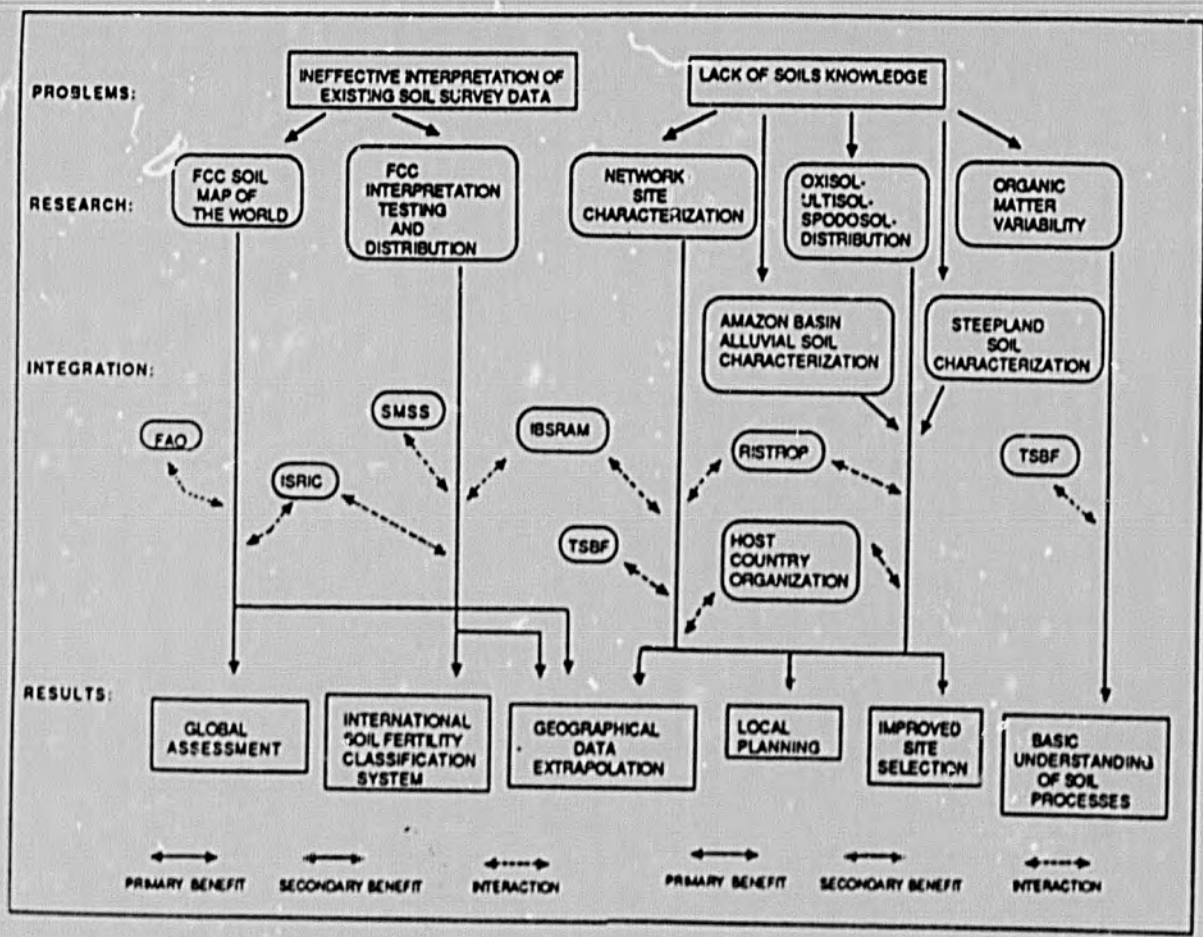

Figure 8. Soil characterization and interpretation flow (NC-7). Rounded boxes represent proposed TropSoils-sponsored research.

Project Number

NC-8

Project Title

Technical Support for Research Networks in the Humid Tropics

Project Leader

T. J. Smyth, North Carolina State University

Collaborators

National institute scientists and USAID Missions in Latin America, Caribbean, Africa and Asia
IBSRAM, TSBF, FAO, ICRAF, EMBRAPA and INIAA
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D. E. Bandy, North Carolina State University
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Problem Statement

Many key components of soil-management options (Figure 1) can now be transferred to national institutions for validation and extrapolation across the humid tropics. National institution involvement is important for several reasons:

1. Available resources limit the extent to which TropSoils alone can systematically validate developed technology.
2. If developed technology is to be used, information must be disseminated, and local soil-management expertise must be acquired.
3. Feedback to TropSoils from its eventual users will enhance TropSoils' ability to develop agronomically and economically sound soil-management practices through refinements or modifications of ongoing research.

Attempts to perform such technology transfer require a minimum level of on-site expertise in participating national institutions and an organizational framework conducive to and supportive of systematic evaluations of their results. Research networks are an effective means for both tapping personnel resources and providing useful training to scientists in collaborating countries.

Throughout the humid tropics, there are several soil-management networks at various stages of development which are fostering technology transferral, validation and extrapolation with emphasis on specific research areas. A Latin American tropical soil-management research network (named RISTROP for Red de Investigatión en Suelos Tropicales) was developed by participants of a training workshop conducted by North Carolina State University at Yurimaguas during 1986. RISTROP is now operative in eight Latin American countries with network experiments in low-input systems, mechanized continuous cropping, agroforestry, legume-based pastures, and paddy rice. Network coordination and technical backstopping support is provided by NCSU/TropSoils.

The Tropical Soil Biology and Fertility (TSBF) network initiated the research phase after its third workshop, held in Yurimaguas during 1986. The TSBF network

focuses on the role of soil biological processes in tropical soil fertility. Their research program is based on four major themes: 1) synchrony of decomposition processes with plant growth demands, 2) soil organic matter management, 3) soil-water relations in natural and managed systems, and 4) socioeconomic characteristics of traditional and improved management systems. Research was initiated in late 1986 at "program centers" selected on the basis of their commitment to perform a set of measurements by standardized procedures on natural and managed ecosystems. Current centers are in Australia, Cote d'Ivoire, Peru (Yurimaguas), Puerto Rico, Sri Lanka, Venezuela and Zimbabwe.

Since its creation in 1983, the International Board for Soil Research and Management, Inc. (IBSRAM) has sought to promote the development and utilization of sustainable soil-management technologies in developing countries as a means of removing constraints to food production. Emphasis on acid tropical soils results from their large areal extent and geographical concentration in the humid tropics and savannas of least-developed countries. After several workshops and regional meetings on acid soils in Latin America, Africa and Asia, regional research networks were developed among countries in Africa and Asia. Two types of network studies have been developed: core experiments, designed to compare alternative management options for acid tropical soils; and component research projects, focusing on liming, germplasm screening for soil constraints, residual fertilizer P effects, quality of organic inputs, and fertility capability classification. National cooperators in Africa have expressed concern for the lack of expertise in tropical soil management among their scientists who would conduct such investigations. Consequently, IBSRAM was encouraged to develop training courses which would provide exposure of front-line scientists in participating African countries to recent advances in acid tropical soil-management research techniques.

The commonalities in overall goals among these research networks and the similarities in soil constraints throughout humid tropical regions make it fitting for NCSU/TropSoils, through its accumulated experience during 15 years of research in humid tropical Latin America, to support these endeavors to extrapolate and validate soil-management technology. The project's hypotheses are as follows:

1. Adequately trained national institute soil scientists will serve as an important linkage for the validation of TropSoils technology to local conditions.
2. Active technical support by TropSoils in ongoing soils research networks will ensure that proper mechanisms are developed and used in technology validation and adaptation.
3. Feedback of information from ongoing networks will improve TropSoils' capabilities to focus on user-oriented soil-management problems.

Objectives

The goal of this project is to foster transferral of TropSoils' knowledge of acid soil management to national research institutions participating in existing research networks in humid tropical regions. In so doing, it provides a bridge between CRSP-sponsored research and its utilization by national research institutions. Specific objectives are:

1. To strengthen capabilities of personnel at network-collaborating national research institutions to conduct, interpret and report user-oriented soil-management research.

2. To systematically validate and extrapolate available soil-management technologies to regions beyond the TropSoils primary research sites.

Operational Plan

The strategy for operation of this project is a sequential progression of activities as described in Figure 9. This approach provides the project with flexibility to adapt to the differences in needs and stage of development among research networks. Tentative activities for the upcoming five years are further described in Table 1. Activities for years eight through 11 represent our best estimate, based on knowledge of current progress in the different networks. Unforeseeable factors and progress achieved during year seven may require subsequent adjustments.

Table 1.Tentative distribution of project activities for targeted networks and non-network groups during the upcoming five years.

ACTIONS	YEAR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11
1. On-the-Job Training:					
IBSRAM	■				
TSBF			■		
Non-Network:					
Bolivian scientists		■			
2. Design Extrapolation Plan:					
IBSRAM	■				
Non-Network:					
Manaus workshop	■				
Agroforestry mtg.	■			■	
3. Field Experiment Establishment:					
IBSRAM:					
Africa	■	■			
Asia		■	■		
4. Monitoring Tours:					
RISTROP	■	■	■	■	■
IBSRAM:					
Africa		■	■	■	■
Asia			■	■	■
5. On-Campus Support Research:					
All networks	■	■	■	■	■
6. Decision Workshops:					
RISTROP	■				
Non-Network:					
Manaus Workshop	■				

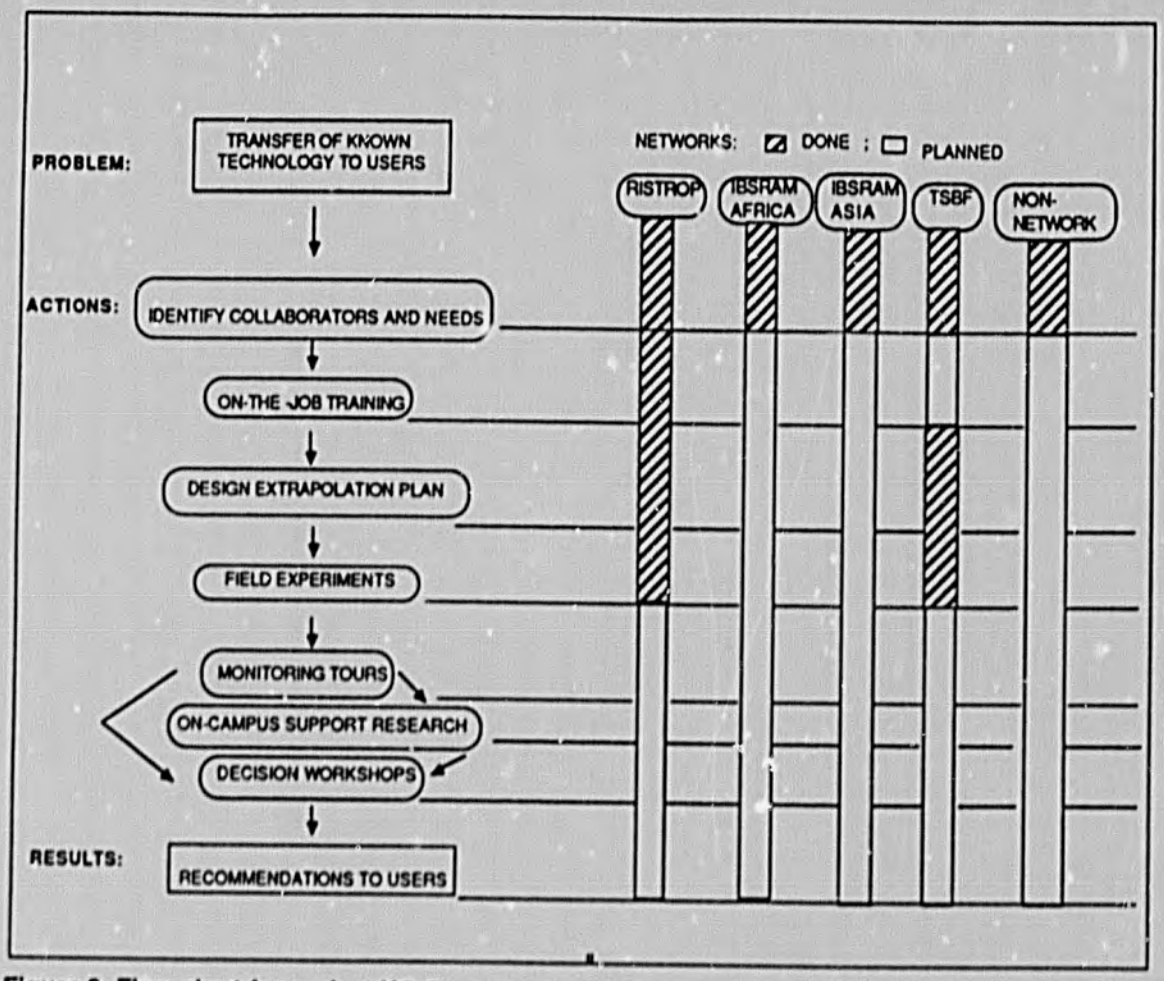

Figure 9. Flow chart for project NC-8.

Although these activities are primarily targeted to participants in existing research networks, opportunities to foster transferral and use of TropSoils knowledge to other user groups cannot be ignored. Examples of such opportunities are 1) the Yurimaguas workshop for planning agroforestry research, 2) the Manaus workshop for formulation of soil test interpretations and recommendations for Oxisols and Ultisols in the state of Amazonas, and 3) on-the-job training, at Yurimaguas, of Bolivian scientists in soil-management research methodologies for the USAID/La Paz Chapare Program.

Identification of National Institute Collaborators and Their Technical Needs

All targeted research networks have completed this phase of development. Participation of NCSU personnel on coordinating and steering committees for the targeted networks provides the project with direct knowledge of existing capabilities and deficiencies of collaborating national institute scientists. Additional contacts with USAID Missions will be helpful in delineating how research network endeavors might fit into the overall scheme of country agricultural development strategies.

Training at NCSU/Tropsoils Research Sites

Training of network participants is a principal means for research validation. These activities will center around specific technical needs of groups identified during step 1. On-the-job training will be provided to participants at the Yurimaguas research station in a format similar to the workshop which led to the formation of RISTROP. Emphasis will be placed on providing participants with exposure and hands-on experience to the most recent soil science field and laboratory techniques and computer software used in research within different soil-management options. Station infrastructure has been successfully used in previous international workshops. Laboratory and field facilities are conducive to the implementation of practical field exercises. On-going field experiments exemplify the majority of technologies which are sought by soil scientists in humid tropical areas and are supported by 15 years of on-site research. In addition to using the NCSU/INIAA research staff in teaching activities, close cooperation is expected with TropSoils scientists from Hawaii and Cornell to take advantage of their expertise and to provide a feedback mechanism to them.

Arrangements are currently under way, at IBSRAM's request, to organize a similar workshop for participants in the African and Asian Regional Networks on Acid Tropical Soil Management. The proposed dates are September 4-25, 1988. As a current TSBF program center for testing and standardizing measurement procedures, Yurimaguas may also provide a training course for these methodologies to TSBF network cooperators wishing to participate in future studies. Training will also be provided in 1988 for Bolivian scientists working in a USAID-funded Chapare program, at the request of the Mission in La Paz.

Design and Plan Extrapolation Research

Plans for the upcoming IBSRAM training workshop include the development of network studies for management of soil acidity and P fertilization. Based on the information gained during the Yurimaguas workshop, and with the supervision of the teaching staff, participants will define objectives, design experiments, and plan methodologies for studies to be conducted in the regional networks. The Manaus workshop for elaboration of soil test interpretations and recommendations in the state of Amazonas will also provide an opportunity to design future research on existing gaps of knowledge for this region. The Yurimaguas agroforestry workshops, sponsored by IDRC, scheduled for November and December 1987, will focus on peach palm technology validation and alley-cropping in acid soils. After comparing Yurimaguas results with experiences of participants from Bolivia, Brazil, Colombia, Costa Rica, Panama, Hawaii and Venezuela, experiments will be designed to address existing information gaps.

Assistance in Field Experiment Establishment

Improper decisions about site selection and in the adjustment of methodologies to local conditions can lead to costly errors in network research programs. Our experience with RISTROP has shown that such problems can be avoided by providing on-site technical assistance to participants during critical phases of the field studies.

Research Progress Monitoring Tours

This activity provides a mechanism for continued transferral of new information and for streamlining assistance to individual needs. Potential obstacles to ongoing research can be identified and corrected. Improved knowledge of the country development strategies can be used to strengthen the use of newly acquired in-country soil-management expertise.

On-Campus Research Supportive to the Networks

Specific information gaps may have to be answered before technology can be effectively transferred and evaluated in certain network sites. A common problem to all networks is the diversity of soil testing procedures used by participating national research institutes. Although procedures have been standardized within networks, there is a growing concern among country participants as to the compatibility between data acquired within network activities and the data base developed through individual national institute activities. Efforts will be made to alleviate this concern by establishing usable correlations between widely used soil testing procedures through a review of existing literature and, if necessary, campus-based laboratory work with soil samples from network research sites. This activity has been initiated for the RISTROP network.

Decision and Comparative Analysis Workshops

Common motivators for participation in research networks are the opportunities for information exchange and comparison between sites. To do this effectively, we perceive the need to hold a second network workshop where participants would present results on field experiments and elaborate recommendations for the developed technology. Despite extensive field research in yield responses to fertilizers and soil test calibrations on Oxisols in the state of Amazonas, use of these results are limited by the absence of an integrated recommendation of soil test analyses for users. By reviewing existing results and formulating recommendations collaboratively with EMBRAPA scientists in the Brazilian Amazon, TropSoils can improve the availability of its technology to users and provide a catalyst for similar activities in other states of the Central Amazon region.

Assessing Accomplishments

A direct measure of this project's activities will be through the review of the comparative performance of acid soil-management technologies across the humid tropics. An indirect measure of its accomplishments can be gauged by the extent to which TropSoils soil-management technologies will be refined and modified to suit the needs of users in the humid tropics.

Project Number
NC-9

Project Title
Program Backstopping

Project Leader
P. A. Sanchez, North Carolina State University

Collaborators
R. H. Miller, Soil Science Department Head, North Carolina State University
Bertha Monar, Program Administrator, North Carolina State University
Milagro Rumble, Bilingual Secretary, North Carolina State University
Dale Bandy, Chief, North Carolina Mission in Peru
Mariela González, Administrative Secretary, Lima

Problem Statement
Many researchers in the tropics devote most of their time to tackling administrative and logistical problems, which are by nature vastly more complicated than conducting research in the United States. Such a situation detracts from their role as scientists. On the other hand, if these chores are not done, the program does not function.

Objective
To provide the means for TropSoils staff to conduct research at difficult humid tropical locations by providing the necessary administrative backstopping.

Operational Plan
A backstopping system is in operation at our work locations which successfully tackles the logistics of shipping, custom clearances, travel documents, allowances, revolving fund accounts, travel arrangements, reimbursements, relationships with collaborative institutions and network partners, budgeting, reports to the Management Entity and production of publications. This system is in place and is considered highly cost-efficient.

Staffing Pattern. North Carolina State University

Category	Year 1987-1988	1988-1989	1989-1990	1990-1991	1991-1992	Total CRSP-Funded	Total Other
				FTE			
Campus-based Scientist	3.30	3.20	3.30	3.30	3.30	0.70	15.70
Field-based Scientist	2.00	2.00	2.00	2.00	2.00	10.00	0
Graduate Student	8.50	9.00	9.50	9.00	8.50	17.00	27.50
Other	35.50	35.20	35.50	35.50	35.50	17.20	160.00
Total	49.30	49.40	50.30	49.80	49.30	44.90	203.20

Projected Budget for Objects. North Carolina State University

Object	Year 1987-1988	1988-1989	1989-1990	1990-1991	1991-1992	Total
			x $100			
Salaries	2017	2087	2212	2345	2486	11147
Benefits	310	299	317	336	356	1618
Allowances	222	230	244	258	274	1228
Travel	335	347	368	390	413	1853
Supplies	361	374	396	420	445	1996
Equipment	280	51	54	57	61	503
Other Direct Costs	742	768	814	863	915	4102
Indirect Costs	957	984	1044	1107	1170	5262
Total	5224	5140	5449	5776	6120	27709

Projected Budget for Projects. North Carolina State University

Project Short Title	Year 1987-1988	1988-1989	1989-1990	1990-1991	1991-1992	Total
			x $100			
Continuous Cropping	804	985	1044	1107	1173	5113
Low-Input Cropping	547	544	577	611	648	2727
Legume-Based Pastures	612	428	449	476	505	2466
Agroforestry Systems	509	492	522	553	586	2662
Steeplands	266	57	60	64	68	515
Comparative Dynamics	689	734	778	825	874	3900
Soil Characterization	213	225	239	253	268	1198
Research Networks	769	693	735	779	825	3801
Backstopping	1015	986	1045	1108	1173	5327
Total	5224	5140	5449	5776	6120	27709

Semiarid Tropics

Department of Soil and Crop Science
Texas A&M University

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Introduction: The TropSoils Semiarid Tropics Program

The objective of the TropSoils-SAT program is to develop and adapt appropriate soil-water- and fertility-management practices for the Sahelian environment. The goal is to increase food production on a sustained basis, while considering the risks of land degradation. Management practices should be evaluated within the framework of the socioeconomical model promoted by the national institutions.

The initiation of the TropSoils-SAT program into the Sahel has been very timely. The significance played by the soil-water-fertility component for the development of appropriate crop management technologies has been fully recognized by national and regional agricultural institutes. Extended periods of drought, which are recurrent in the Sahel, have accentuated the need for assistance in this area of expertise. With its professional expertise, research facilities, administrative support structure, in addition to its similarities in agroecological conditions, Texas A&M University is in an advantageous position to provide leadership for the TropSoils program in the Sahelian region. The agenda and focus of the Collaborative Research Support Program (CRSP), promoting a collaborative approach with host country institutions, Agency for International Development (AID), and International Agricultural Research Centres (IARCs), provides the structure for this contribution.

A Redefinition of Focus and Approach for the Next Five Years

The research program for TropSoils-SAT started with a very broad set of goals. Original objectives included soil characterization and classification, wind and water erosion control, and development of soil- and crop-management practices under water stress conditions in rainfed agriculture. The possibility of supplemental irrigation research was also considered. However, priorities among these different goals were not clearly defined. Uncertainties about specific research needs from the national institutions coupled with lack of firsthand information about some basic aspects of the behavior of a completely new ecosystem partially explained this lack of specificity in the initial approach. With current budgetary constraints, and at this phase of the project, the focus must be sharpened. The program should address a few, well-defined areas where TropSoils-SAT has comparative advantages, and all research activities should be fully integrated.

This evolution has already started. Program objectives have been reevaluated and prioritized, and a modified research agenda is being established. TropSoils-SAT has investigated small farmers' needs and constraints, and the research program is being adjusted to directly address these issues. A new research organizational

structure is also proposed to gain integration and effectiveness (see Figure 1). It consists of a multilocational central project supported by selected component technology trials and experiments. This field station research will be gradually coupled with on-farm activities, exposing researchers to the farmers' reality, and promoting an interactive method for identifying problems and possible solutions. The participation of the host country's scientists is promoted by all throughout the research process: objective identification, project design and implementation, and evaluation.

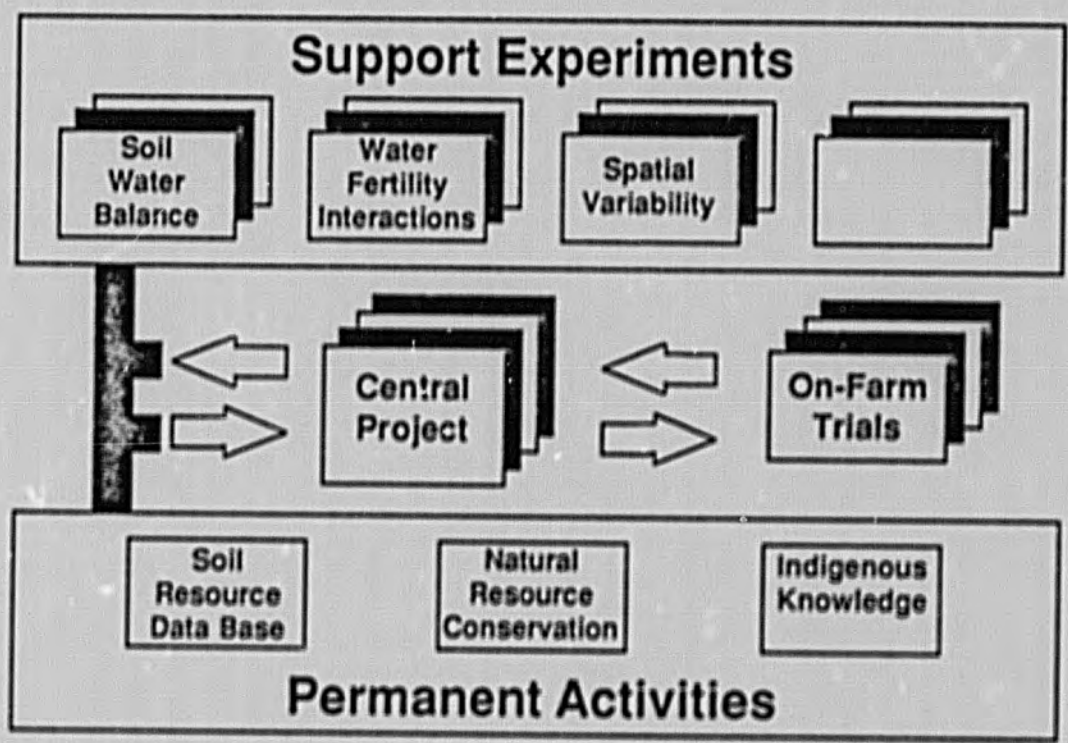

Figure 1. Research organizational structure of the TropSoils-SAT program for the next five years. The long-term central project is the backbone of the program. It will be implemented both in Niger (at three different agroecological regions) and Mali. The central project will be coupled by several "support experiments" in topics such as modification of the water balance, water-fertility interactions, and crop and soil spatial variability. There will also be various permanent research activities dealing with characterization of soil resources and studies on the indigenous knowledge base. Natural resource conservation will be considered at all levels. On-farm trials of improved soil- and crop-management systems are scheduled for the second/third year of this plan.

Project Number
TAMU-401

Project Title
Program Coordination

Program Coordinator
E.C.A. Runge, Texas A&M University

Project Leader
Lloyd Hossner, Texas A&M University

Program Manager
Ruben Puentes, Texas A&M University

Secretary
Margaret Parker, Texas A&M University

Project Number

TAMU-402

Project Title

Development and Evaluation of Soil-, Water-, and Crop-Management Practices for Rainfed Agriculture in Low Water-Holding-Capacity Soils in the Sahel

Project Leader

A. Manu, Texas A&M University

Collaborators

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L. Wilding, Texas A&M University
C. Zaongo, Texas A&M University
M. Ouattara, INRAN
M. Gandah, INRAN

Problem Statement

Rainfall in the Sahel is scarce, but its variability is the major constraint to stable food production. There is plenty of supporting evidence showing that if the water constraint is not minimized, the goal of food production stability at an adequate level will never be achieved. However, it has also been demonstrated that soil fertility is also a limiting factor and water-fertility interactions need to be better understood to make efficient use of the limited water resources.

Sahelian farmers are well aware of these constraints, and farming strategies reflect a long process of adaptation to low and variable rainfall, poor and fragile soils, and readily available land, with the main goal of spreading risks. Some of these local strategies have high development potential. It is possible to manipulate the soil water-fertility-plant system in such a way as to increase total yields or decrease year-to-year yield fluctuations by improving these traditional strategies through the application of scientific soil- and crop-management principles.

Alternatives for system manipulation are multiple. They include simple tillage practices designed to increase water infiltration, systems of water diversion or collection, microclimate modification to decrease evaporative demands, biomass control to increase water-use efficiency, and supplemental irrigation. There are also several alternatives to remove chemical constraints and benefit from moderate fertility inputs to improve water-use efficiency. Most of these practices are based on adequate fertilization and use of other soil amendments. The introduction of high-yielding varieties is complementary to these soil management practices.

The traditional rainfed cropping system (including intercropping) on sandy, acid soils with low water-holding capacity, is one of the most common situations; it provides the bulk of food for the smallholders' family. Since it is the major type of land utilization, it merits first priority.

The hypothesis of this study is that it is possible to manipulate several elements of the soil water-fertility-plant system in such a way as to increase total yield, decrease year-to-year fluctuations, or both.

Objectives

The general objective is to develop and evaluate low to intermediate soil, water, and crop-management practices to increase and/or stabilize yields of rainfed crops in the sandy, droughty, acid soils of the Sahel.

Operational Plan

The strategy to be employed will be to adapt soil- and crop-management principles successfully proven in other semiarid areas of the world, test these principles in the field, then combine them with previous TropSoils-SAT research results for the modification and improvement of traditional cropping systems in the Sahel.

Target soils will be deep, sandy, acid, low water-holding-capacity soils (Psammentic Paleustalfs, Alfic Ustipsamments, and Ustic Torripsamments). Experiments will be replicated at three different agroecological regions within an increasing gradient in rainfall from north to south. Possible experimental sites are the INRAN research centers at Chikal, N'Dounga, and Kala Pate.

Average annual rainfall varies from 230 to 430 mm. Experimental sites will be carefully selected and characterized, and experiments replicated to consider spatial variability, so that results have a good chance of being applicable to other areas with similar environmental conditions. The comparative advantages and potential for adoption and extrapolation can only be determined after these variables have been evaluated.

The following will be studied:

1. a combination of cultural practices to modify the soil water balance (i.e., tillage, water harvesting practices);
2. fertilization treatments and other soil amendments;
3. crop management practices that may interact with the above (i.e., planting dates and densities);
4. improved cultivars and local varieties.

This central project in Niger is a long-term effort. Long-term field research is essential when the goal is to develop or adapt soil- and crop-management practices for a specific environment. Several uncontrolled variables, particularly total rainfall and its distribution, make it necessary for field research to continue for a number of growing seasons. This will provide an evaluation of long-term or residual effects of treatments.

These studies will be closely coordinated with similar experiments which will be carried out in Mali.

Assessing Accomplishments

1. Changes in the parameters measured (soil moisture, nutrient status, plant growth, yield) due to treatments.
2. Acceptance of significant findings by national institutions.
3. Acceptance of significant findings by farmers.
4. Acceptance of research by peers.
5. Publication of reports and peer-reviewed publications.

Project Number

TAMU-403

Project Title

Tillage, Cultural Practices, and Fertilization Effects on Infiltration, Soil-Water Storage and Crop Yield

Project Leaders

C. W. Wendt, Texas Agricultural Experiment Station
Z. Kouyate, IER

Collaborators

A. Onken, Texas Agricultural Experiment Station
R. Louis Baumhardt, Texas Agricultural Experiment Station
D. McCool, Agricultural Research Service, USDA

Problem Statement

The Sahel has a deteriorating ecosystem which is commonly manifested in widespread famines. Inefficient use of the rainfall received is a major factor in this deterioration. Declining soil physical properties are caused by low organic matter, high soil temperatures, raindrop impact on exposed soils, and poor tillage practices. These combine to destroy soil structure which results in compaction, reduced infiltration, increased runoff, decreased soil-water storage and erosion.

Other factors in the deteriorating ecosystem of the Sahel are the soil fertility (low N and P) and soil chemistry (low pH, Al toxicity) problems. In some cases these problems are so severe that crops and rangelands cannot use the limited precipitation efficiently. Thus, two major problems in the declining productivity of the Sahel are the deteriorating physical and chemical properties of the soil. Both qualitative and quantitative information on the factors causing this deterioration is lacking. In developed countries tillage techniques, engineering structures, and cropping systems have been developed to increase soil-water storage and crop yields. Concepts derived from these techniques can possibly be adapted to the Sahel. Additionally, the deteriorated fertility and/or chemical properties of the soil need to be amended so crops can use the stored water most efficiently.

The hypothesis of this study is that tillage, cultural, and fertilization techniques can be developed so that rainfall can be used more efficiently in the Sahel.

Objectives

1. To increase infiltration and soil-water storage with tillage and cultural practices.

Developmental relevance: Crusting is a major problem on most agricultural soils in West Africa. Techniques are needed in order to minimize crust effects to increase infiltration and soil-water storage.

Expected products: Low-input cost-effective tillage methods and cultural practices which will augment traditional farming practices.

2. To increase efficient use of rainfall with tillage, cultural practices and fertilization.

Developmental relevance: The rainfall received in the Sahel is not being used efficiently. Although the principles to make most efficient use of water are universal, their application is site-specific. In some cases, tillage and cultural practices to increase soil-water storage will be adequate. In other cases it will be necessary to modify the chemical and/or fertility status of the soil so the plant can use the stored soil-water efficiently.

Expected products: Recommendations on the tillage, cultural practice and fertilizer combinations which will enable rainfall to be most efficiently utilized.

Operational Plan

The strategy to be employed will be to transfer concepts proven in other semiarid areas of the world and adapt them to the fragile ecosystem (climate, soil, people, and economic resources) of the Sahel. This will be a collaborative program between Malian scientists and TAMU-TAES TropSoils. Mali is the main secondary experimental site forTropSoils-SAT in West Africa.

Studies are underway in Mali on sorghum treated with different tillage techniques (deep plowing, bedding, bed tieing, traditional) with and without the fertility treatment recommended by the Institut d'Économie Rurale (IER). To date these studies show that sorghum yields can be increased 50 percent with fertilization and 24 percent with tillage. These studies will be continued through the 1989 growing season. The experimental design is a split plot with five replications. The main plots are the fertilizer treatments and the subplots are tillage treatments. Soil characteristics to be measured in the laboratory are texture, carbon, nitrogen, phosphorus and pH. Field measurements to be made are bulk density, strength, rooting depth and weight, soil water and potential evapotranspiration. Additional measurements of plant height, plant density, head number, head weight, and grain yield will be made.

Studies on millet will be initiated in 1988. Before initiating the studies on millet, studies of the infiltration, soil-water storage and erodibility of the different soils on the Cinzana station will be conducted using a rainfall simulator. After these studies are completed a site will be located and a study of different tillage and cultural practices with and without fertilizer will be initiated. It is commonly known that the addition of plant residue to tropical soils has a major impact on soil properties. However, it has been difficult to have residue available because of competition for the residue by people and livestock. One approach we are proposing is to plant excess hills of millet, harvest the excess four to six weeks after the plants emerge and lay the residue on the soil surface. This approach along with other tillage and cultural practices will be evaluated with a rainfall simulator to determine their effect on infiltration and soil-water storage. The most promising of these treatments will be evaluated under millet production. These studies will eventually include different fertility treatments as recommendations are developed from the water-use efficiency and soil fertility relationship studies.

The project will be backstopped by rainfall simulation studies at Lubbock, Texas. These studies will be conducted on a variety of crop species treated with different tillage and cultural practices. The concepts developed from these studies will be further evaluated in Mali.

These studies will be closely coordinated with similar experiments which will be carried out in Niger.

Assessing Accomplishments

1. Changes in the parameters measured (soil, plant growth, yield) due to treatments.
2. Acceptance of significant findings by national institutions.
3. Acceptance of significant findings by farmers.
4. Acceptance of research by peers.
5. Publishing of reports and peer-reviewed publications.

Project Number

TAMU-404

Project Title

Water-Use Efficiency and Soil Fertility Relationships

Project Leaders

A. B. Onken, Texas Agricultural Experiment Station
C. W. Wendt, Texas Agricultural Experiment Station

Collaborators

Z. Kouyate, IER
A. Manu, Texas A&M University
W. Payne, Texas A&M University

Problem Statement

In many arid and semiarid regions, rainfall is the primary or only source of water, and each increment must be used to the fullest extent to increase food production. Cultural practices that reduce runoff and evaporation and enhance infiltration are important in making the maximum amount of water resource available to a crop. However, such practices are economical only if the crop utilizes the water made available as efficiently as possible. Water-fertility interactions have been identified as a priority research topic in the TropSoils-SAT Five-Year Plan. One factor significantly affecting efficient water utilization by crops is the chemical nature of the soil, including but not limited to soil fertility. In West Africa, soil fertility is a major consideration because most soils of the region are deficient in one or more nutrients, principally nitrogen and phosphorus.

Water-use efficiency (WUE) is defined as either yield (Y) per unit of transpired water (T) or yield per unit of evapotranspiration (ET) and is expressed as follows:

$$WUE_T = Y/T \quad \text{or} \quad WUEE_T = Y/ET$$

Yield can be as total biomass or usable product such as grain. WUE_T is known as the transpiration efficiency, while $WUEE_T$ is known as the evapotranspiration efficiency. WUE_T is important in basic studies of crops, while $WUEE_T$ is the common parameter evaluated under field conditions.

The effects of soil moisture content, soil type, cultivation, cropping, soil temperature, climate, parasites, plant treatment, leaf area, age and plant species on water requirement have been reviewed. Crops such as wheat, oats, barley and rye had lower WUE_T than corn, sorghum, and millet.

Research on soil chemistry and fertility effects on water-use efficiency show that water requirement of crops grown on poor soil may be reduced one-half to two-thirds by the addition of fertilizers. Many studies have been conducted to show that fertilizers increase yield, but there has been little emphasis on using fertilizers to increase water-use efficiency. Management practices can increase the efficient use of water, but the influence of nutrients on WUE_T is hard to assess under field conditions because of the variation in water loss to soil evaporation among treatments.

Cultivars have been found which differ in nutrient-use efficiency. Further, little consideration has been given to the effects of specific nutrients on WUE_T. Also, there is little quantitative data on the influence of different moisture levels on WUE_T.

In preliminary studies, we investigated the relationship between yield and ET and yield and Y/ET for grain sorghum genotypes differing in nutrient-use efficiency (lb grain/lb nutrient available) on nutrient-deficient soils. Four genotypes were grown dryland on nutrient-deficient (N and P) soil at three locations.

The data show a significant positive linear relationship between grain produced and ET. This relationship, however, was not as good as the one we found between grain yield and $WUEE_T$, for which we found a highly significant positive linear correlation. Thus, factors that affect grain yield for sorghum will also affect ET and $WUEE_T$. For example, we have found interaction effects due to fertilizer application and sorghum line.

The results with ET were mixed, with some increases in ET with increasing yield due to breeding line or N application, and little change or decreases in other cases. However, with respect to $WUEE_T$ it was apparent that increasing yield due to N application or breeding line resulted in increased $WUEE_T$. With respect to N application, the greatest increases in $WUEE_T$ occurred with those breeding lines most responsive to N application. Thus, if $WUEE_T$ is to be increased through fertilizer application, it will be necessary to select sorghums most responsive to fertilizer.

Our preliminary studies show the potential importance of selection of the proper variety for fertilizer response, correction of nutrient deficiencies, and combination of various other cultural practices having a positive effect on yield for increasing yields and WUE. The individual and interaction effects of these factors on WUE_T and $WUEE_T$ need to be delineated and quantified.

Results from chemical and physical analyses we made on a toposequence of soil profiles from the Cinzana Experiment Station in Mali indicate these soils, with only a few notable exceptions, contain large amounts of sand (>70%) with small amounts of clay (<20%) and low cation exchange capacities (< 4 meq/100 g). These soils were generally acid (pH < 6.0) with exchangeable acidity ranging from 10 to 40% and have deficiencies in phosphorus and possibly potassium. They also have low buffering capacities and thus are chemically fragile, making it mandatory that thorough investigations of fertilizer reactions be conducted before recommendations for their use are made.

Our preliminary investigations show significant pH depressions with the use of urea, indicating potential problems from applying acid-forming fertilizers to these acid soils with low-buffering capacities. Results from a study of Telemsi rock phosphate and six surface soils from the Cinzana Experiment Station suggest that a reliable method needs to be developed for evaluating Malian soils for potential use of rock phosphate and that all acid soils in Mali may not be suitable for use of rock phosphate.

Based upon our research and that reported in the literature, we propose to test the following hypotheses as documented:

1. Crop utilization of available soil moisture in the Sahelian environment is closely linked with fertility levels.
2. Increased crop production and introduction of new cereal germplasm can be facilitated by minimizing soil physical and chemical constraints.

Objectives

1. Enhance water-use efficiency of crops with applied plant nutrients and cultivar selection.
2. Improve soil physical and chemical properties through use of fertilizers and soil amendments.

Expected outputs include:

1. An understanding of the interactions between level of available water, soil fertility and cereal genotype such that limited water resources can be used more efficiently to increase crop production.
2. Procedures adapted or developed to evaluate nutrient status and determine fertilizer reactions in the acid, low-buffered soils of West Africa to provide data necessary to conduct research and for recommendations involving fertilizers.
3. Acidifying effects of nitrogen fertilizer and usefulness of rock phosphate determined for specific soils.
4. Determination of the required rates of fertilizers to increase cereal yields in Sahelian Mali and Niger while maintaining yield stability.
5. Data to improve the research design of the projects "Development and evaluation of soil-, water-, and crop-management practices for rainfed agriculture in low water-holding capacity soils in the Sahel" and "Increasing soil water and crop yield through tillage and fertilization."

Operational Plan

Objective 1

A combination of laboratory, greenhouse, rainout shelter and field studies at Lubbock, Texas, will be combined with pot and field studies in Mali and Niger.

Studies to identify and quantify factors responsible for fertility effects on WUET will be conducted in a greenhouse and/or rainout shelter at Lubbock. Based upon preliminary results, initial factors to be investigated will be 1) nitrogen and phosphorus rates and their interaction, 2) soil pH, 3) crop genotypes (sorghum and millet) in relation to responsiveness to fertilizer application, architecture and nutrient translocation efficiency of root systems, and available soil water, and 4) interaction effects of available soil water and nutrient levels. Field studies to identify and quantify factors responsible for fertility effects on WUEET will be conducted at the Texas Agricultural Experiment Station, Lubbock-Halfway, Texas, and at Cinzana in Mali.

Primary factors to be investigated will be 1) nitrogen and phosphorus rates, 2) soil pH, 3) crop genotypes (sorghum and millet) in relation to responsiveness to fertilizer application and available water, and 4) interaction effects of available soil water and nutrient levels. Field and pot studies at Cinzana, Mali, will utilize a toposequence of soils and will be designed based upon data from studies in Texas.

Genotypes will be obtained through the Texas Agricultural Experiment Station sorghum breeding program. They will include improved types, West African and other exotic materials from the Sorghum Conversion Program, and those materials from West Africa that will bloom in Texas. Studies in Mali will allow for the use of photoperiod sensitive materials.

Data obtained will include phenological measurements at defined physiological

growth stages, leaf water potentials by psychrometers or hydraulic press, photosynthesis and conductance by LiCor Li6000, and tissue nutrient contents.

Objective 2

Initial focus will be on the reactions of nitrogen and phosphorus with soils obtained from Niger and Mali. Analytical procedures to evaluate rock phosphate materials and compatibility of rock phosphate materials with specific soils will be evaluated for use with soils of Niger and Mali and adapted if necessary. Initial laboratory research will be conducted in Texas. Further evaluation will be conducted in pot studies in Niger and Mali before final evaluation in field trials.

Solubility and rates of phosphorus reactions as affected by source and temperature with soils from Niger and Mali will be determined.

Our preliminary research indicates substantial pH-decreasing effects due to urea on low CEC Malian acid soils. A field study will be initiated consisting of urea applications on selected soils at Cinzana.

Assessing Accomplishments

1. Output of high quality data.
2. Development of developing country research programs.
3. Timely reports.
4. Favorable review from External Evaluation Panel.

Project Number
TAMU-405

Project Title
Nutrient Balance of Selected Sandy Soils of Niger

Project Leader
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Collaborators
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L. Hossner, Texas A&M University
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Problem Statement
The constant gains and losses of material by the soil makes it a dynamic system that does not represent a state of equilibrium. Plant nutrients enter as well as leave the soil system. The soil gains nutrients through fertilizers. Nutrients can also enter the soil system through dust inputs and precipitation. There are also nutrients that are taken up by plants but returned to the soil in crop residue left in the field.

Like gains of plant nutrients, the soil can also lose nutrients in one of several ways. There is the constant removal by harvested crops. Losses can occur through physical erosion of topsoil and also through surface runoff. Nutrients are also lost from the soil through leaching, and these losses can be significant in sandy soils. Even phosphorus which is known to be retained close to the application site has been observed to be leached down soil profiles in sandy and poorly-buffered soils.

For efficient fertilizer management the need to understand the dynamics of nutrients in the soil system is very important, especially how the dynamics relate to the intensity factors of temperature and moisture. The importance of understanding the relationships between gains and losses of nutrients in the very porous deep sandy soils cannot be overemphasized.

By monitoring gains and losses of nutrients as they relate to temperature and moisture, this study will help in the comprehension of the fate of fertilizer-applied nutrients in these sandy soils and thereby help in the identification of efficient fertilizer-management systems. The study also offers the opportunity to investigate the efficiency of nutrient uptake by three millet varieties and how the nutrient uptake relates to yields.

Objectives
1. To monitor the movement of plant nutrients (Ca, N, P, Mg, K), both native and fertilizer-applied, on selected sandy soils of Niger.
2. To relate movement of nutrients to the intensity factors of temperature and water.
3. To monitor the efficiency of nutrient uptake by three pearl millet varieties.

4. To determine nutrient dynamics and establish a balance between gains and losses of nutrients in the soil system.

Operational Plan

The study will be carried out on sandy soils at three locations in Niger. Complete characterization of study sites will be made by digging and describing pits that will be located just outside the experimental plots. Plot size will be six meters by eight meters, and randomized complete block experimental design involving four chemical treatments and a control will be used. Three millet varieties will be used and treatments will be replicated three times. Bare plots will be given the same treatment and replicated three times. Treatments are:

T1: control
T2: nitrogen applied as urea
T3: phosphorus applied as triple superphosphate
T4: nitrogen and phosphorus applied as urea and triple superphosphate, respectively
T5: calcium applied as gypsum

The three millet varieties are "local," CIVT and HKP. Neutron probe access tubes will be placed at the center of each plot to monitor soil moisture with depth, and thermocouples will be installed to take soil temperature measurements. Rain gauges will also be placed at sites to record rainfall.

Plots will be sampled immediately after the land is cleared to determine the original fertility status of the soil. Sampling will be done at 20 cm increments to a depth of two meters. Next, soil sampling will be done after land preparation when chemical amendments have been added and after the first 35 mm of rain is obtained. All plots will subsequently be sampled each month, until the end of the growing season. Selected plots will be sampled each month after crops are harvested.

Soil samples will be analyzed for the following: pH, exchangeable aluminum, ammonium acetate extractable calcium, magnesium and potassium, total phosphorus, available phosphorus, total nitrogen and free iron.

Leaf samples will be taken at different developmental stages of three millet varieties. They will be analyzed for calcium, magnesium, potassium, sodium, aluminum, phosphorus and nitrogen. At the end of the growing season, whole millet plants will be sampled. Roots, stem, leaves and grain will be analyzed for the same elements listed above.

Assessing Accomplishments

1. Changes in the parameters measured.
2. Acceptance of significant findings by national institutions.
3. Acceptance of research by peers.
4. Publishing of reports and peer-reviewed publications.

Project Number

TAMU-406

Project Title

Extent, Cause, and Control of Pronounced Plant Growth Variability Over Short Distances

Project Leaders

L. R. Hossner, Texas A&M University
L. Wilding, Texas A&M University

Collaborators

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Z. Kouyate, IER
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Problem Statement

Stands of millet on the deep sandy soils of Niger and Mali commonly display a remarkable degree of variability. Such variability seriously reduces yields and also means that some fraction of the soil will be exposed to the erosive forces of wind and water. Variable and sometimes toxic levels of Al, due to low soil pH, are reported to be responsible for the uneven growth of millet in Niger. Deficiencies of N, P, K and toxic levels of Mn may also be factors.

The patterns and extent of spatial variability in millet fields of Niger have not yet been verified. The 1986 External Evaluation Panel (EEP) TropSoils Review Team recommended that such research should be prerequisite to future efforts to develop management technologies to rectify this production constraint.

After considering alternative approaches of ground surveys and remotely sensed imagery, the application of infrared (IR) video imagery appears ideally suited to this problem. IR video imagery has the advantages of real time access, accuracy, rapid transferability, automated image analysis, and cost effectiveness. In 1987, a Texas counterpart study was initiated to evaluate the applicability of video IR imagery to quantify the extent and spatial pattern of poorly responsive soil areas in fields undergoing surface mine reclamation. This work established imagery calibrations (scale, climatic conditions, plane speed, plane altitude, ground truthing procedures, and image analyses methods) for subsequent technology transfer to Africa under similar conditions of poorly responsive soil patterns. Expansion of such work into Mali and other SAT TropSoils target research sites could be a valuable research tool to complement spatial variability research and verify stationarity of the poorly responsive areas under different climatic and management variables.

Many authors have examined Sahelian soils in terms of P content and the ability to provide this element in sufficient quantities to crops. In general, the sandy acid soils in West Africa have a relatively low P-fixing capacity. Pronounced residual effects from P application have been taken as an indication of the low ability of

these soils to fix phosphorus. Correcting soil acidity, without inducing additional nutrient imbalances due to overliming, and supplying ample phosphorus appear to be management practices which will be necessary to provide optimum yield of millet and sorghum and efficiently utilize scarce water resources.

Objectives

1. To document the patterns and extent of spatial variability in millet fields in sandy soils using IR-video imagery techniques.
2. To provide ground truth of selected areas imaged to verify probable causes of spatial variability.
3. To document soil characteristics and determine agronomic practices capable of improving productivity in regions of poor growth.
4. To determine relative contributions of soil acidity and phosphate deficiency to improve productivity of sandy Sahelian soils.
5. To determine root growth patterns of millet and sorghum in relation to chemical and physical properties of Sahelian soils.

Operational Plan

A survey of the extent and distribution of poorly responsive areas within sandy millet fields in Niger will be conducted from July to September 1988 by Ms. Anne Pfordresher. Video IR imagery will be flown in late July or early August when such plant responses are best expessed. Three north-south flight lines representing climatic gradients will be obtained over different soil/geomorphic regions of major millet production in the country (dallol bosso, sand plains and plateau/dry valley toposequences). Dr. Robert Maggio, Associate Professor of Forest Science Department at Texas A&M University, and a video IR expert will be a part of the video imagery team. Ground truthing of 35 to 50 responsive and non-responsive millet areas will be conducted to calibrate the IR spectra and help partition probable causal factors. Drs. Wilding and Manu along with DRE-INRAN specialists will assist in the field phase of this work. Data from IR video imagery will be summarized in terms of: (1) total % of millet fields with poorly responsive soil areas; (2) distribution of these areas in different soil/geomorphic regions; and (3) interactive climatic impacts on these responses. Similar overflights will be conducted in subsequent years to evaluate stability of observed spatial variability.

From the above survey, the sites which exhibit differential plant response will also be sampled for laboratory analysis. Soil samples will be taken in depth and the profiles characterized with regard to pH, exchangeable acidity, exchangeable basic cations, texture and available P.

At a given location to be determined from prior work, a factorial experiment with varying rates of lime and phosphorus will be initiated. An adequate number of rates each will be used to provide a range so that the individual effect and interaction variable can be evaluated. Biomass and grain yields will be the primary indicators of response to treatment variables.

Root trench-profiles will be made after sampling the aboveground parts of the plants. A 1 m x 1 m grid with 10 cm x 10 cm squares (100 squares per grid) will be laid over the side of the trench with a plant stem in the upper right hand corner of the grid. Soil samples will be taken from each square for determination of various soil properties such as soil water content, pH, available P, exchangeable acidity and

exchangeable cations (Ca, Mg, K and Na). After sampling, the pit face will be smoothed, a centimeter of soil will be washed off with a water spray, and root number within each square will be counted. The distribution of roots will be correlated with various soil amendments and soil properties. The field studies will be supplemented by appropriate laboratory and pot experiments.

Assessing Accomplishments

1. Quantification of extent, patterns, and stability of areas with spatial variability.
2. Increasing yields due to altering chemical properties of soils by amendments.
3. Correlation of yield parameters (grain and/or biomass) with soil properties (native or altered).
4. Acceptance of significant findings by national institutions, farmers and peers.
5. Published reports and journal publications.

Project Number
TAMU-407

Project Title
Modification of Microclimate: Growth and Yield of Cereals Between Rows of Neem Windbreaks

Project Leader
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Collaborators
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CARE staff

Problem Statement

The neem tree (*Azadirachta indica*) introduced from India is now ubiquitous in the zone south of the 250-300 isoyet in Niger. In 1975 CARE International, with cooperation from local residents, initiated a systematic planting of neem trees in the Maggia Valley of South Central Niger. To date, about 360 km of trees have been planted in double rows 100 m apart, oriented NNW-SSE across the long axis of the valley. These plantings provide an opportunity for studying the role of shelterbelts and windbreaks in Niger for improving crop growth and yield in millet. Cropping between shelterbelts is one of the four targeted "favorable conditions" to decrease risks associated with rainfall variability.

The government of Niger is interested in extending these plantings. Motivation may be due mainly to the villagers' acceptance of this soil and water conservation practice. Farmers may not clearly perceive effects in moisture conservation, crop growth or yields. But they do perceive increase in comfort and protection for themselves, their dwellings, and animals as a result of being shielded from high winds and dust. They are also interested in harvesting wood from these trees.

Careful studies are needed to understand the effects of the present windbreak rows on the physical environment of the crop and to relate these effects to crop growth and yield. Such studies will provide a rational basis for further plantings and, thus, optimize benefits from expended time, money, efforts, and land removed from production. It is also necessary to study various wood-harvesting procedures to decide the optimum method to obtain economic wood yields without significant reduction in the protective efficiency of the windbreak rows.

The hypothesis of this study is that by modifying the influence of hot, dry, desiccating winds in Niger, tree windbreaks serve as a semi-permanent method for soil-water conservation and as a practice against wind erosion. The trees, if rationally harvested, can provide much-needed fuel wood without seriously impairing their wind protective efficiency. In addition to its effects on grain yield, there is an implicit and strong resource conservation component on this technology, although Sahelian farmers' adoption may be triggered by perceived increase in comfort and protection. The approach is in agreement with the strategy to include environ-

mental and resource conservation aspects as integral components of research aiming at increasing and securing yields.

Objectives

1. To determine if and how climate and cereal growth and yield are modified when alley-cropped between neem tree windbreak rows.
2. To investigate the influence of several possible wood-harvesting methods on wind protection between the windbreaks rows.

Operational Plan

A field study was conducted during the 1984 and 1985 growing seasons to evaluate the response of millet and sorghum to shelter from double-row neem windbreaks.

The data show that protection by the windbreak rows significantly increased dry matter production, although grain and dry matter yields were reduced near the windbreak rows. Fertilizer application significantly increased grain yield and average head weight but did not affect dry matter production. Fertilizers increased grain yields regardless of distance from the windward row. Effects on reduction in average windspeed, average daily maximum and minimum temperatures, maximum daily air temperature, average daily relative humidity, and pan evaporation were also recorded. Partial pollarding proved to be the best harvest method, with the lowest loss of efficiency. It may not yield as much total wood as the other methods, but reduction in prevailing windspeeds greater than 30% can be maintained between the rows.

Analysis of data collected from these experiments will continue up to completion. A final report is expected in 1988. Field studies will be re-started in 1989. They will address further investigation on windshelter/fertilizer interactions, the inclusion of water-harvesting techniques within the system, and evaluation of wind erosion control effects.

Assessing Accomplishments

1. Changes in the parameters measured (microclimate elements, soil, plant growth, yield) due to treatments.
2. Acceptance of significant findings by national institutions.
3. Acceptance of significant findings by farmers.
4. Favorable review from External Evaluation Panel.
5. Acceptance of research by peers.
6. Publishing of reports and peer-reviewed publications.

Project Number
TAMU-408

Project Title
Water Requirements and Supplemental Irrigation of Food Crops in West Africa

Project Leaders
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Collaborators
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Problem Statement
The Sahel of Africa is characterized by rainfall which is extremely variable in yearly amount, distribution, and intensity. Over the long term the rainy season can fail for several years in succession. Such failures occurred in 1909-1916, 1940-1948, and most recently 1968-1973.

Additionally the soils are sandy with a low pH and fertility. In many cases the fertility-chemistry problems appear to be so severe that the crops cannot use the water available.

The Sahel thus has problems not only of erratic rainfall but of poor soil resources. Before the productivity of the area can be increased, basic information is needed on the water requirements of the crops grown in the area. Since the soil resources are so poor, information is also needed on the water requirements when different levels of soil chemical amendments (lime and fertilizer) are added.

Once the water requirements are known, it should be possible to design low input supplemental irrigation systems to stabilize crop yield. Utilization of supplemental irrigation is one of the four "more favorable" conditions identified. Supplemental irrigation would be better than full irrigation for the Sahel. In this type of irrigation, rainfall is supplemented so that maximum use is made of precipitation. Yields are not normally as high as those obtained under full irrigation. However, the salinity and water-logging problems often associated with full irrigation are not as frequent, and the quality of the soil and water resources is maintained. According to a recent survey, 1480 million cubic meters of water resources over and above the normal flow of the Niger river are available for irrigation. The survey also pointed out that the small schemes are more successful than the large schemes.

The overall hypothesis of this study is that low-input supplemental irrigation and liming/fertilization techniques can be developed to overcome the variability in water and soil resources after the water and soil requirements for the crops are known. Cereal cropping under supplemental irrigation is one of the "favorable" situations identified as a target in the TropSoils-SAT Five-Year Plan.

Objectives

1. Determine the yield of West African food crops grown at different water and liming/fertility levels.
   Developmental relevance: A major information gap exists in the yield of West African food crops grown at different levels of water and lime/fertility. Until such information is obtained, it will not be possible to design optimum systems to ameliorate the problems.

   Expected products: Water requirements and yields of West African crops grown at different lime/fertility levels will be obtained.

2. Increase and/or stabilize crop yields in West Africa through supplemental irrigation and optimum liming/fertilization.
   Developmental relevance: Once information on the water and fertility requirements is obtained the next logical step is to develop supplemental irrigation and fertilization techniques. It will be necessary that such techniques be low cost and labor intensive.

   Expected products: Low cost methods of applying water to food crops will be devised. Techniques to efficiently apply and use soil chemical amendments (lime, fertilizer) will be developed.

Operational Plan

Objective 1

Studies by TropSoils have attempted to determine the water requirements (evapotranspiration) of millet and sorghum. Problems have been encountered due to rainfall which was erratic in amount and distribution. In some cases it was not possible to establish crops. In these studies we propose to use line-source gradient irrigation systems capable of applying water of 0 to 100 percent of evaporative demand. These would be used to supplement rainfall received during the growing season so that water amounts ranging from rainfall received to 100 percent of potential evapotranspiration would be applied. Initial studies would be concerned with determining the yield levels of millet and sorghum at the recommended fertility level. Studies at Lubbock, Texas, have shown that water-use efficiency of crops can be increased by optimum fertilization. Following initial water requirement studies, different rates of lime and/or fertilizer as well as water will be applied to determine the lime/fertilizer requirements at different water levels.

Appropriate measurements of the soil chemical properties will be made. These include texture, pH, N, P, K, CEC, and exchangeable Al. Measurements of the water applied (rainfall and irrigation) and soil water will be made to determine the water use by millet and sorghum. Appropriate statistical designs will be used with the line source gradient irrigation systems. Potential evapotranspiration will be estimated according to a modified Penman model.

During the first year of the study, the equipment will be bought, assembled, and used on a sandy soil site near Lubbock. Staff from Niger and Mali will come to the site for training. Sites will be located in Niger and/or Mali. After it is assured that the equipment is operational, it will be shipped to Niger and/or Mali.

Objective 2

After the water and lime/fertility requirements are determined, a program to develop low-input and labor-intensive supplemental irrigation and fertilization techniques will be initiated. Surveys indicate that the potential for shallow wells and both small and large reservoirs exist. The techniques to be developed will depend on the findings in Objective 1. For instance, if it is found that small amounts of water and fertilizer are needed in the early stage of growth, a barrel on a sled or trailer could be pulled into the field and a water-nutrient mix could be applied to each hill with a cup. If the farmer cannot handle the water from a large reservoir, it may be necessary to design and construct smaller reservoirs from which water could be applied at a rate he could handle.

Assessing Accomplishments

1. Changes in the parameters measured (soil, plant growth, yield) due to treatments.
2. Acceptance of significant findings by national institutions.
3. Acceptance of significant findings by farmers.
4. Acceptance of research by peers.
5. Publication of reports and peer-reviewed publications.

Project Number

TAMU-410

Project Title

Soil Resource Evaluation in the Semiarid Tropics

Project Leader

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Collaborators

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Problem Statement

A knowledge of soil resources is fundamental for selection of target sites for future research, interpretation of research, results and technology transfer. It provides a means to prioritize those land areas best suited for crop production and soil-management systems which minimize capital inputs and maximize risk avoidance. Soil resource inventories and characterization data bases serve as the only meaningful basis for linkage among international centers and specific TropSoils target research sites. Further, such research is necessary to determine which of the various technology packages, research innovations and farmer experiences can appropriately be transferred among soil regions of the tropics. Principles of soil management are universal, but applications are site-specific and dependent on soil resource knowledge.

This research will provide TropSoils scientists with a comprehensive knowledge of the quality, extent, distribution, classification and constraints of major soils. Soils at target research sites will be characterized, and soil constraints to crop production will be assessed. Soil resources in the Sahel region of Africa are highly fragile, droughty, and commonly exhibit chemical toxicities and/or nutrient deficiencies. Soil and climatic constraints pose the major limitations to agricultural development. Soil physical, chemical and mineralogical conditions control soil/water/fertility interactions, which in turn are closely interlinked to topography/geomorphology/hydrology. Considerable focus will be placed on toposequence relationships of soils, because watershed hydrology, chemical flux of nutrients, and crop productivity are believed to be closely tied to this element. This is well demonstrated by current land use patterns.

Most of the grain production in the Sahel is on sandy and loamy Ustalfs, Ustults, and Psamments. These soils exhibit low water-holding capacity, restrictive subsurface layers (plinthite iron pans and laterite), weak structural stability (soil

compaction and surface crusting), infertility (low organic matter content, low cation-exchange capacity, few weatherable minerals, and low available P and N contents), soil acidity (Al and Mn toxicities), and susceptibility to wind and water erosion.

Vertisols, while not extensive in Niger and Mali, are extensive in semiarid tropics. Potential productivity of Vertisols is high, but management is extremely difficult under traditional technology because of the high energy demand and unique soil/water interactions, which result in a narrow soil moisture workability range and highly critical timing of operations. Shrink-swell volume changes upon wetting and drying cycles directly or indirectly govern soil tilth, infiltration, water recharge, internal drainage, fertilizer-use efficiency, aeration, surface runoff, flooding and erosion. Vertisols in the Cameroon are representative of these conditions; they exhibit seasonal flooding, seasonal reduction, periods of soil moisture deficit, low P availability, high P-fixation, and dense root and water-restrictive subsurface compaction zones.

Animal traction, improved varieties, timely application of fertilizers, bedding tillage practices (ridge and furrow system), intercropping, and improved crop-management systems have been used to overcome many of the constraints for subsistence agriculture on Vertisols. While the principles of these management systems may be transferable to the Sahel, the farming system developed will likely need to be adapted to local conditions. Because soil structure and water movement are so critical to successful utilization of these resources, research is currently needed and underway in the TropSoils-SAT CRSP to develop technology to quantify the dynamics of structural evolution, stability and degradation relative to water content, and movement under different cropping systems. It will couple micromorphological with traditional physical and biochemical determinations. This information will serve as a basis to evaluate transferability and sustainability of cropping systems for Vertisols.

Eolian dusts from "harmattan" winds derived from the Sahara Desert during the dry season have been postulated to enrich soils with nutrients. Research at two TropSoils sites in Niger verify that dust inputs are apparently quite significant to long-term nutrient renewal. Chemically, the dust samples analyzed contain ten to 30 times higher levels of exchangeable Ca, Mg, Na and K, and five times higher CEC than reference soils of the area. Dust samples are base-saturated, compared to base saturation of 20 to 30% for the dominantly Al-satured reference soils. Most dust samples are distinctly finer-grained than reference soils; about 60% of the dust samples have clay contents of 15 to 30%, compared to one to five percent for surface soil horizons. Long-term impact of dusts on surface horizons of soils is evident in the accumulation of small quantities of smectite and mica common to dust samples but less evident in subsoils. Secondary quantities of feldspars occur in coarser separates of dusts. Mica and feldspars in dusts are sources of K reserves, which may explain why these soils rarely respond to K fertilization.

Objectives

1. Establish baseline soil resource conditions for major soils and target research sites in the semiarid tropics to facilitate understanding of soil/ water/fertility interaction and technology transfer.

2. Establish the quantity and composition of dust inputs into semiarid tropics as a nutrient renewal vector to soil/water/fertility interactions.
3. Quantify dynamics of soil moisture movement and chemical characteristics of sandy soil toposequences of Niger.
4. Develop and verify the usefulness of micromorphological procedures for describing, quantifying and interpreting changes in the structure, hydrological behavior and risk of structural degradation of soils under different cropping and tillage systems.

Operational Plan

Objective 1

In Niger, a program has been initiated in collaboration with the INRAN staff and the INRAN Soils Laboratory to sample and characterize 25 to 30 benchmark soils that represent major soil resource regions of that country. Routine physical and chemical data will be analyzed in the INRAN Laboratory, with quality assurance provided by the Soil Characterization Laboratory, TAES, College Station, Texas. Mineralogical, elemental and thin-section analyses for these soils will be conducted in the TAES Soil Characterization Laboratory.

This project will continue to backstop scientists and collaborators conducting research in Niger and Mali. It will serve the needs of the soil spatial variability project, where ground thruthing of remotely sensed IR imagery is needed to determine soil properties in paired-responsive and non-responsive localized areas.

Objective 2

Dust-trap monitoring will be continued on a three-month seasonal basis to attempt to better define trends in dust characteristics correlative with harmattan, rainy, post-rainy and pre-harmattan seasons. Samples already collected will be submitted for wet chemical analyses and total Ca and K elemental reserves. The need to continue sample collection at two heights above the soil surface (2.5 m and 5 m) will be re-evaluated, and possibly only the 2.5 m height will be retained. Methods developed to analyze water-soluble salts, exchangeable cations, and CEC of microsamples (<0.5 g) will be further evaluated for precision and accuracy.

Objective 3

In Niger, two sandy toposequences of soils overlying Continental Terminal deposits will be selected to quantify systematic variability in physical-chemical properties, configuration of restrictive layers, and dynamics of soil moisture movement from laterite-capped summits to dry valley floors. The toposequences will be in regions of major millet production representing increasing rainfall gradients north to south. Three to four areas along the toposequence will be selected for detailed study representing major soil resource elements of the landform.

At each of these detailed study areas, pedons will be described, classified and characterized for physical, chemical, mineralogical and microfabric parameters pertinent to crop production. Soil moisture, crop growth, and site productivity will be monitored periodically during the wet season.

A survey of local farmers proximal to these sites will be conducted to determine their assessment of land classification, cropping systems, perception of soil problems, and observed environmental changes. This indigenous technical knowledge of

farmers who have developed empirical adaptations to soil and water constraints may help researchers more rapidly develop suitable technologies for farmers use. From this work we expect to develop a correlation between landform position and crop productivity under rainfed agriculture of western Niger. We expect to identify potential problems for crop management within each landform position and compare these with indigenous technical knowledge of farmers and adaptations developed locally to overcome these constraints.

The field work for this research by Mr. Ouattara will be initiated in January 1988 (site selection, reconnaissance survey and initiation of instrumentation). During the first rainy season (May to October 1988), pedon sampling, monitoring of soil moisture and crop growth, and the farmers survey will be conducted. Laboratory work will be done at both the INRAN Laboratory and in laboratories at Texas A&M University. This objective will continue for three to five years.

Objective 4

Macro- and micro-fabric coupled with more traditional physical and biochemical measurements will be employed under different cropping systems to monitor changes in Vertisols, including porosity, structural stability, hydrological behavior, and biological activity. Methodologies currently being developed for Vertisols will be continued until 1988. Once calibrated and tested, these procedures will be used for cropping-system evaluation in Africa. The Cameroon initiative, which is currently under consideration for TropSoils-SAT, would be a probable Vertisol target site. Alternatively, Vertisols in Mali or Niger could be utilized as African sites.

Assessing Accomplishments

1. Establishment of a basis on which soil research may be interpreted and transferred to new regions.
2. Correlation of soil resources with crop productivity as a basis for developing land evaluation systems and for promoting soil and water conservation practices.
3. Acceptance of significant findings by national institutions, farmers and peers.
4. Publication of reports and journal articles.

Staffing Pattern. Texas A&M University

Year	Total						
Category	1987-1988	1988-1989	1989-1990	1990-1991	1991-1992	CRSP-Funded	Other
				FTE			
Campus-based Scientist	.75	.75	.75	.75	.75	.50	3.25
Field-based Scientist	1.00	1.00	1.00	1.00	1.00	5.00	0
Graduate Student	6.50	6.50	6.50	6.50	6.50	22.50	10.00
Other	10.50	10.50	10.50	10.50	10.50	22.50	30.00
Total	18.75	18.75	18.75	18.75	18.75	50.50	43.25

Projected Budget for Projects. Texas A&M University

	Year					
Project Short Title	1987-1988	1988-1989	1989-1990	1990-1991	1991-1992	Total
			x $100			
Central Project (Niger)	1951	2078	2203	2335	2475	11042
Central Project (Mali)	230	241	255	270	286	1282
Water/Fertility	280	300	318	337	357	1592
Spatial Variability	281	300	318	337	357	1593
Windbreaks	231	300	318	337	357	1543
Water Requirements	281	300	318	337	357	1593
Soil Resources	280	301	319	338	358	1596
Traditional Farm Syst.	0	137	145	154	163	599
Backstopping	801	808	857	909	965	4340
Total	4335	4765	5051	5354	5675	25180

Projected Budget for Objects. Texas A&M University

Object	Year 1987-1988	1988-1989	1989-1990	1990-1991	1991-1992	Total
			x $100			
Salaries	1895	2057	2180	2311	2450	10893
Benefits	335	342	363	385	408	1833
Allowances	447	493	523	554	587	2604
Travel	410	524	555	588	623	2700
Supplies	195	264	280	297	315	1351
Equipment	56	36	38	40	42	212
Other Direct Costs	205	223	236	250	265	1179
Indirect Costs	792	826	876	929	985	4408
Total	4335	4765	5051	5354	5675	25180

Communications

Department of Agricultural Communications
North Carolina State University

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Introduction: TropSoils Communications

In order to improve soil management in developing nations and gain support for its programs, TropSoils must promptly disseminate its research results in a useful, highly visible form. The Management Entity has set forth two broad goals for TropSoils' program-wide communications effort. The first is to help focus diverse information gleaned from individual projects and bring it to bear on the practical solution of soil-management problems of global significance. The second is to convey, to a non-technical audience of public officials and policy-makers, TropSoils' objectives and accomplishments.

Project Title

TropSoils Communications

Project Leader

N. C. Caudle, North Carolina State University

Problem Statement

After several years of productive research, TropSoils can now identify a number of topics for which there is considerable technical information. The transfer and application of this information in developing nations presents several problems, including:

- Because traditional channels for disseminating land-grant research information (such as scientific journals and U.S. extension programs) do not reach most of those who most urgently need TropSoils results, it is necessary to interpret findings for use in developing nations, taking into account a diversity of languages, cultures, levels of training, needs and expectations.
- Available information exists primarily in the form of research results from individual projects or experiments, conducted at various sites. Although scientists can perhaps grasp trends and the overall import of such experiments, a non-technical audience cannot.
- The results of soils research typically do not lend themselves to the development of simple, easily understood "products" with universal appeal. Also, soils research tends to produce incremental improvements, not the dramatic "breakthroughs" that attract publicity. These are significant factors in the selection of communications media and messages.

Individual universities address some of these problems through direct collaboration with their respective host-country institutions, and by developing research networks, expert systems and other means of extrapolating and applying research results. Although effective, these efforts tend to be directed at technical audiences in specific regions or zones, and do not diminish the need for coordinated, program-wide communications that extends the program beyond the technical community. Because TropSoils universities maintain their own channels of communication with their collaborators, the following proposal is concerned with communications initiatives that represent TropSoils as a whole.

Objectives

1. To apply the best available soil-management information to the solution of problems of global or regional import.

   Toward this objective, plan and produce a special-topics publications series that will guide users toward improved soil-management practices and sources of information. Also, plan and publish a series of single-topic research reports.

2. Convey achievements to public officials, university administrators and other decision-makers interested in the progress of TropSoils research.

   Toward this objective, prepare and disseminate monthly news briefs. Also, respond to requests for information by providing publications, news releases,

photos and audiovisual materials as appropriate.

3. Assist and improve internal TropSoils communication.

   Toward this objective, help plan and conduct technical workshops in which TropSoils scientists from various institutions discuss special topics, with the goal of formulating soil-management guidelines and fostering program-wide collaboration. Also, promote and facilitate the use of available communications channels, such as electronic mail.

Operational Plan

The operational plan includes identification of primary and secondary audiences, objectives (stated above), communications themes or issues, a strategy, and a presentation of methods.

Primary Audience

1. Those who conduct agricultural research and extension programs in developing nations in the tropics.
2. Those who set or influence agricultural policy or assist agricultural development in developing nations in the tropics.

Secondary audiences include: research and teaching faculty working in soils, agronomy and international programs in the U.S. and overseas; the staff of other foreign-assistance projects; environmental groups; industry and business; all others with a vested interest in the management of tropical soils.

Communications Themes

Considering TropSoils' mandate along with comments gleaned from program reviews suggests a number of issues, or themes, that should be addressed in order to meet the communications objectives:

1. TropSoils' has **authority** in issues related to soil management.
2. TropSoils research has **relevance** to the needs of agriculture in developing nations and in the U.S.
3. There is programmatic **unity** in the TropSoils' approach.
4. The program demonstrates a high level of **productivity.**

Methods and Strategy

A full-scale communications program ideally would include a range of media and methods for reporting and promoting TropSoils research. It would also include direct assistance to the individual projects and collaborators, translation of materials from English into the appropriate languages, and communications research and evaluation. Because of the present need for program-wide economy, however, it has been necessary to carefully screen the potential audiences and communications activities, and to focus on methods that seemed most likely to satisfy critical needs. As a result, some approaches have been eliminated from this proposal, either because of their relative cost or because other techniques seemed more likely to succeed. This screening has been guided by discussions with TropSoils personnel, and by the responses gleaned from interviews with several people deemed knowledgeable about the primary audiences.

In general, the strategy is to concentrate most of the communications resources

into one substantive, authoritative and attractive periodical. This will ensure that high-quality information reaches the primary audiences with sufficient regularity to establish the merits of TropSoils research. Remaining resources will be invested in those program-wide publishing and information activities which promise to deliver the most communications value for the least cost.

Experience has led to the conclusion that while some of the communications approaches employed to date have certain strengths and advantages, they are not ideally suited to TropSoils' audiences, or are not cost-effective. For example, the program-wide annual technical reports are expensive and time-consuming to produce, yet reach a relatively small audience limited to those with advanced technical training. Because they cover work in progress, there is considerable year-to-year duplication and overlap, and the reports contain large amounts of preliminary data and observations not ready for application. The newsletter format of Communiqués makes it suitable for brief features and "in-house" news, but does not allow for the sort of in-depth development of topics needed at this stage in the program. For the methods discussed below, there has been an attempt to incorporate the most valuable features of the technical reports and the newsletter into an entirely new set of communications initiatives. The plan as presented here depends on the addition of a part-time editorial assistant, who could take over routine clerical and production tasks, freeing the editor to plan, write and produce the publications.

Initiative I. TropSoils Special-Topics Series

This publication series, the communication program's centerpiece, will embody a programmatic commitment to collaboration and unity of purpose. Topics will be selected according to the availability and applicability of significant research results, and will not be keyed to individual projects. The series will not attempt to compete with the traditional channels of scientific publishing. Rather, it will distill and present information in a form useful to an audience with limited technical training, and will satisfy some of the demand for a tangible "product" from TropSoils.

Procedures for Developing the TropSoils Special-Topics Series

Audience assessment and distribution plan. Structured interviews with several people from each sector of the audience will be used to help characterize the audience's needs and preferences on such things as article length, reading level, illustrations and topics covered. A distribution plan will also be developed at this stage.

Formatting and design. The format and design will be modified in accordance with the results of audience assessment. A tentative format includes: a brief, illustrated "executive summary"; an in-depth, illustrated article developing a single soil-management topic and stating recommendations for the application of research results; and a bibliography for the topic, citing the relevant research reports, papers or articles. Design considerations include: establishing an atmosphere of authority and competence, while creating a rewarding experience for the reader; using diagrams, photos, charts and drawings to illustrate concepts or methods that are difficult to present in narration; and creating covers with graphic impact and memorable images. Design must also incorporate economy in printing and mailing.

Topic outline and proposal. Topics will be selected in consultation with the Management Entity Director and Program Coordinators. Some of the ones which are considered to be candidates at this time are given in Table 1. The Management Entity Director and the Program Coordinators will recommend scientists working in each subject area, approve planning for the workshops, and determine who should be invited to submit an editorial "perspective" for each topic.

Table 1. Examples of topics suggested for the special-topics series.

Acidity and liming
Soil infertility
Low-input cropping
Water management
Soil degradation
Agroforestry
Land evaluation
Nitrogen management and green manures

Technical workshops. These will consist of small groups of scientists representing a particular subject area, and will require at least two working days each. In advance of the workshop, participants will compile relevant materials and references. The Management Entity Director will moderate and will focus discussion into areas of agreement. As the discussion progresses, the editor will assume the role of audience representative, and will begin composing a statement of what is known about the topic, what is yet to be learned, and what might be recommended to the users.

While the most obvious product of such a process will be TropSoils publications, there will be other important benefits as well. Bringing together scientists who are working on related problems will no doubt improve the ongoing research, reduce the sense of isolation some of the scientists feel, and strengthen cooperation and collaboration among the programs (Objective 3).

Writing and editing. Following the workshop, the editor will complete the narrative and distribute drafts to the workshop participants for comment and corrections. The Management Entity Director and Program Coordinators will review the final drafts of all scripts prior to publication.

Design, layout, production and printing. The special-topics series will employ a standardized design, but will present a new photo or illustration on the cover of each issue. Layout and pre-press production will be handled by the editor and his assistant.

Follow-up research. After the first year, and every two years thereafter, the audience will be surveyed and the mailing list purged and updated. The survey will be used to measure the usefulness of the special-topics series, and illicit information to guide the editor.

Timetable. Table 2 presents a proposed timetable.

Table 2. Projected timetable for the TropSoils Special Topics Series, 1988.

Feb.	Proposal review and response; topic selection.
Mar.	Audience survey; workshop planning.
May	First workshop; draft of narrative ready.
June	Final text, illustrations; production.
Sept.	First publication issued; second workshop.
Nov.	Second publication issued; third workshop.

Initiative II. News Briefs

The news brief series will assume some of the newsletter's functions presenting research news in a capsule form suited to officials and administrators who do not require detailed technical information. News items will be requested regularly, and will be typeset and distributed monthly under a standard format. This format allows quick turnaround at a low cost.

Initiative III. Research Reports

The research reports will be published in a numbered series under a standardized design. The purpose is to present research results that cannot be suitably disseminated through the normal channels of scientific publication, i.e., journals or university research-station series. The expected output is three to four such research reports per year. The authors will be required to submit typescripts and illustrations conforming to the series' specifications and style, ready for publication. The authors will be responsible for proofreading and correcting typeset material, and will provide a mailing list. The communications staff will combine script and illustrations into an attractive publication. The staff will also fill requests and manage distribution.

Assessing Accomplishments

The special-topics series will help TropSoils, and the communications effort in particular, focus on the task of disseminating research results in a useful form. The associated workshops will also serve as a catalyst for fruitful scientific interaction. The special-topics series will provide an important forum for issues in tropical agriculture. It will begin to supply, almost immediately, the kind of tangible product sought by the funding agency. And, over time, it will become a familiar and reliable resource for those who help shape soil management in developing nations.

The news brief series will package TropSoils news in a capsule form suited to officials and administrators who do not require detailed technical information. This series will improve awareness of and support for TropSoils by regularly bringing the program's accomplishments to the attention of key decision-makers.

The research report series will provide an outlet for significant research results in a form useful to scientific or technical audiences.

Staffing Pattern. Communications

Category	Year 1987-1988	1988-1989	1989-1990	1990-1991	1991-1992	Total CRSP-Funded	Total Other
				FTE			
Other	1.00	1.00	1.00	1.00	1.00	5.00	0
Total	1.00	1.00	1.00	1.00	1.00	5.00	0

Projected Budget for Projects. Communications

Project Short Title	Year 1987-1988	1988-1989	1989-1990	1990-1991	1991-1992	Total
			x $100			
Communications	940	1500	1589	1684	1786	7499
Total	940	1500	1589	1684	1786	7499

Projected Budget for Objects. Communications

Object	Year 1987-1988	1988-1989	1989-1990	1990-1991	1991-1992	Total
			x $100			
Salaries	360	390	413	438	464	2065
Benefits	80	90	95	101	107	473
Allowances	0	0	0	0	0	0
Travel	20	140	148	157	167	632
Supplies	20	20	21	22	24	107
Equipment	10	10	11	11	12	54
ODC	140	390	413	438	464	1815
Indirect Costs	310	460	488	517	548	2353
Total	940	1500	1589	1684	1786	7499

Management Entity

North Carolina State University

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The Management Office

The Management Office carries out the responsibilities of the Management Entity, namely, leadership and oversight for program and fiscal affairs for the Soil Management CRSP. This function is carried out through three activity areas: administration, communications and external evaluation. The basic framework and procedures for these operations are set forth in the report of the planning entity, described in the grant documents, or evolved through precedent. The experiences of the first seven years do not suggest the need for any major changes in the basic organizational structure or in the primary mode of operations. Topics for emphasis, however, will vary from time to time as dictated by funding and program developments. Some aspects pertinent to each activity follow.

Administration

Major attention will continue to be given to maintaining the liaison between the subgrantees and AID/Washington, to assisting the subgrantees in prioritizing programs and making adjustments as circumstances dictate, and to promoting greater interaction among subgrantees and other international agricultural development programs. Decreased funding from AID has placed major constraints on the level of research that can be undertaken; thus, additional sources of funding will be sought to permit fuller utilization of collaborating-university expertise.

Increased emphasis will be given to exploring and developing, where opportunities exist, greater collaboration with other CRSPs and with the International Agricultural Research Centers. Initially, the focus will be on the sorghum/millet and bean/cowpea CRSPs and with IITA.

Aggressive efforts will be made to increase the recognition by AID, particularly its regional bureaus and country missions, of the expertise that is available through the CRSP to assist them in identifying and responding to priority problems. If these communications lead to a collaborative program with mission buy-ins, we anticipate using the administrative procedures provided by the Basic Ordering Agreement to implement these actions.

Periodic meetings of the Board of Directors will continue to be held, including, as funds permit, representatives from the collaborating countries, to provide guidance, to act on recommendations, and to evaluate performance. It is anticipated that the Board will assume a greater role in the future in determining basic policies and establishing funding priorities. This development is a normal progressive evolution of the function of the Board.

The two-person full-time administrative staff, consisting of a Program Director

and an Administrative Assistant, is considered adequate to meet the foreseeable needs of the office.

Communications

The highest priority need within TropSoils is more effective communication of our knowledge and understanding of the management of tropical soils to user groups outside the fraternity of researchers. There is a vast amount of relevant information available, which, if properly organized and packaged, can be effectively used to promote and support science-based soil-management programs for the wide range of conditions that occur in developing countries.

A major communications program has been initiated. It is described in a separate Plan of Work included with this document.

Evaluation

The External Evaluation Panel will continue to serve its established role. Membership will remain at three, with additional expertise added on an *ad hoc* basis as necessary. Plans for their activities include a major review of the campus and field activities of one university program each year. Mini-reviews will be conducted as necessary.

Staffing Pattern. Management Office

Category	Year 1987-1988	1988-1989	1989-1990	1990-1991	1991-1992	Total CRSP-Funded	Total Other
				FTE			
Other	2.00	2.00	2.00	2.00	2.00	10.00	0
Total	2.00	2.00	2.00	2.00	2.00	10.00	0

Projected Budget for Projects. Management Office

Project Short Title	Year 1987-1988	1988-1989	1989-1990	1990-1991	1991-1992	Total
			x $100			
Administration	2629	2612	2768	2935	3110	14054
Evaluation	426	307	325	345	367	1770
Total	3055	2919	3093	3280	3477	15824

Projected Budget for Objects. Management Office

Object	Year 1987-1988	1988-1989	1989-1990	1990-1991	1991-1992	Total
			x $100			
Salaries	1008	1058	1121	1189	1260	5636
Benefits	222	233	247	262	278	1242
Allowances	0	0	0	0	0	0
Travel	470	420	445	472	500	2307
Supplies	50	50	53	56	60	269
Equipment	20	20	21	22	24	107
Other Direct Costs	337	232	246	261	276	1352
Indirect Costs	948	906	960	1018	1079	4911
Total	3055	2919	3093	3280	3477	15824

Appendix

Abbreviations

Abbreviation	Name	Country
AARD	Agency for Agricultural Research and Development	Indonesia
AGRHYMET	Centre Regional de Formation et d'Application en Agro-meteorologie et Hydrologie	Niger
AID	Agency for International Development	USA
ARS	Agricultural Research Service (of the USDA)	USA
AU	Andalas University	Indonesia
BIFAD	Board for International Food and Agricultural Development	USA
CARE	Cooperatives for American Relief Everywhere	USA
CEPLAC (CPAC)	Centro de Pesquisa Agropecuaria dos Cerrados	Brazil
CIAT	Centro Internacional de Agricultura Tropical	Colombia
CNPQ	Conselho Nacional de Pesquisa	Brazil
CSIR	Center for Scientific and Industrial Research	South Africa
CSR	Center for Soils Research	Indonesia
CU	Cornell University	USA
DMN	Direction de la Meteorologie Nationale	Niger
EEP	External Evaluation Panel	
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuaria	Brazil
EMPAER	Empresa de Pesquisa, Assistencia Tecnica e Extensao Rural	Brazil
EWC	East-West Center	USA
FERQUIDO	Fertilizantes Quimicos Dominicanos, SA	Dominican Rep.
FLUP	Forest and Land Use Planning Project	Niger
GOV	Government of Venezuela	Venezuela
HB	Herbarium Bogorience	Indonesia

Abbreviation	Name	Country
IADS	International Agricultural Development Service	USA
IBSRAM	International Board for Soil Research and Management	Thailand
ICARDA	International Center for Agricultural Research in the Dry Areas	Syria
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics	Niger
IDB	International Development Bank	USA
IDRC	International Development Research Centre	Canada
IDS	Institute of Development Studies	Finland
IER	Institut d'Économie Rurale	Mali
IFDC	International Fertilizer Development Center	USA
IFRSC	Institut Français de Recherche Scientifique et Coopération	France
IICA	Instituto Interamericano de Cooperación para la Agricultura	
ILCA	International Livestock Center for Africa	Ethiopia
INIAA	Instituto Nacional de Investigación Agraria y Agroindustrial	Peru
INIPA	Instituto Nacional de Investigación y Promoción Agraria	Peru
INRAN	Institut National de Recherches Agronomiques du Niger	Niger
INTSORMIL	Collaborative Research Support Program on Sorghum and Millet	USA
IPB	Institute Pertanian Bogor	Indonesia
IRAT	Institut de Recherches Agronomiques Tropicals	France
IVITA	Instituto Veterinario de Investigacion del Tropico y Altura	Peru

Abbreviation	Name	Country
JCARD	Joint Committee on Agricultural Research and Development	USA
JRC	Joint Research Committee	USA
LDC	Less Developed Country	
MUCIA	Midwest Universities Consortium for International Development	USA
NCRP	Niger Cereals Research Project	Niger
NCSU	North Carolina State University	USA
OICD	Office of International Cooperation and Development	USA
PEPP	Proyecto Especial Pichis-Palcazu	Peru
PP	Project Productivite	Niger
PSG	Program Support Grant	USA
RF	Rockefeller Foundation	USA
RU	Reading University	United Kingdom
SAFGRAD	Semi-Arid Food Grain Research and Development	Burkina Faso
SM-CRSP	Soil Management Collaborative Research Support Program	USA
SMSS	Soil Management Support Services	USA
TAES	Texas Agricultural Experiment Station	USA
TAMRF	Texas A & M Research Foundation	USA
TAMU	Texas A & M University	USA
TSBF	Tropical Soil Biology and Fertility Program	Zimbabwe
UCR	University of Costa Rica	Costa Rica
UEPAE	Unidade de Execucao de Pesquisa de Ambito Estadual de Manaus	Brazil
UF	University of Finland	Finland
UFl	University of Florida	USA
UG	University of Georgia	USA
UH	University of Hawaii	USA
UN	University of Niamey	Niger

Abbreviation	Name	Country
UNA	Universidad Nacional Agraria	Peru
UOA	University of Orleans	France
USAID	United States Agency for International Development	Brazil
USAID	United States Agency for International Development	Indonesia
USAID	United States Agency for International Development	Mali
USAID	United States Agency for International Development	Niger
USAID	United States Agency for International Development	Peru
USDA	United States Department of Agriculture	USA
UW	University of Wageningen	Netherlands