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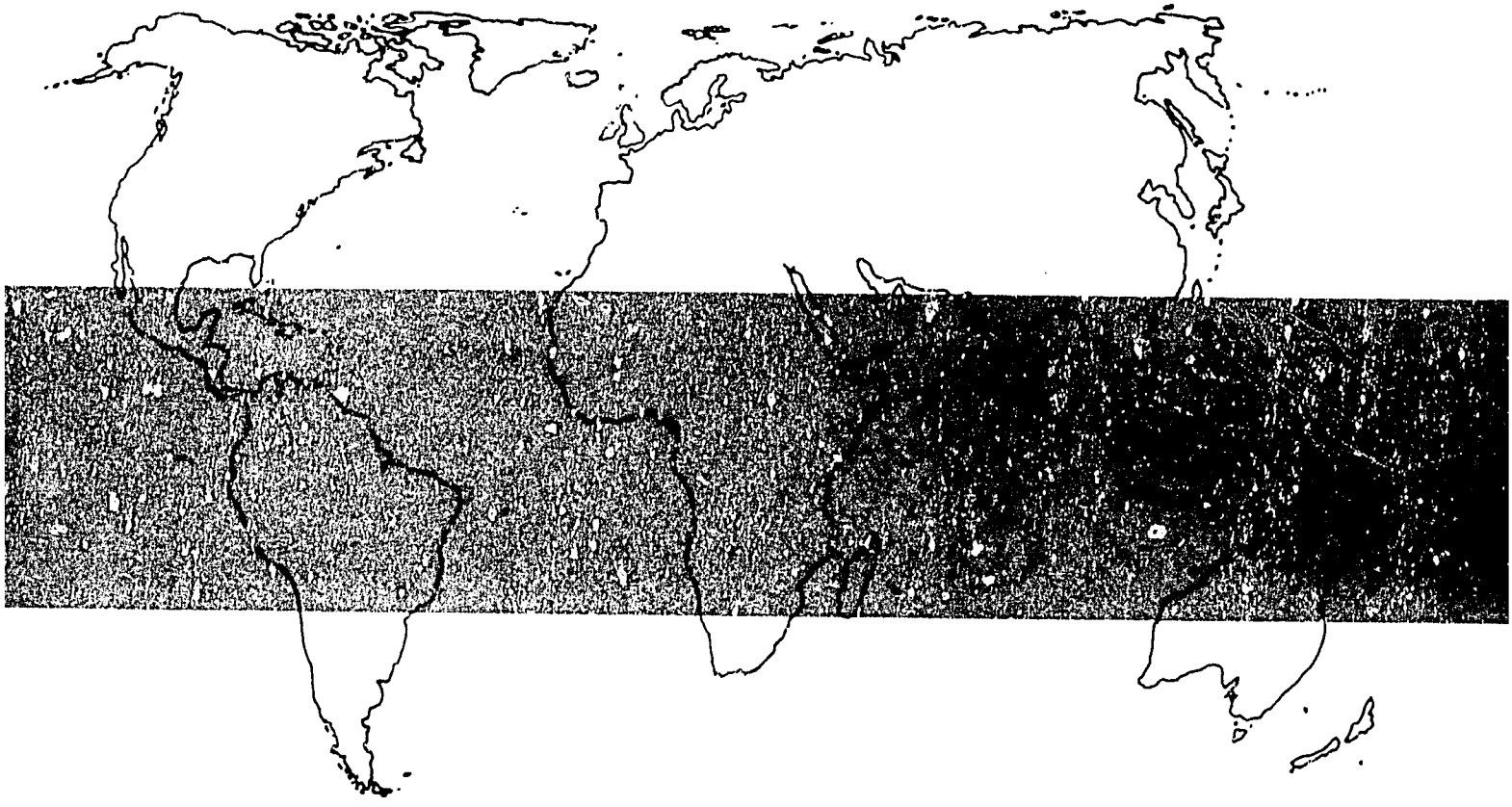
TROPSOILS

PROGRAM PLAN

1984-1989



TROPSOILS

PROGRAM PLAN

1984-1989

TropSoils is a collaborative research program whose goal is to develop improved soil management technology for developing countries in the tropics.

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The formal collaborators in the program are:

- Agency for International Development-USA
- Center for Soils Research-Indonesia
- Cornell University-USA
- Empresa Brasileira de Pesquisa Agropecuaria-Brazil
- Institut National de Recherches Agronomiques du Niger-Niger
- Institute d'Economie Rural-Mali
- Instituto Nactional de Investigacion y Promocion Agraria-Peru
- International Crops Research Institute for the Semi-Arid Tropics-India
- North Carolina State University-USA
- Texas A&M University-USA
- University of Hawaii-USA

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DEVELOPMENT OF THE PROGRAM PLAN

FOR

TROPSOILS

Three years of experience have reaffirmed the need for a research program aimed at relieving soil constraints to crop production in developing countries in the tropics. Collaborative agreements have been signed, the basic organization is in place and TropSoils' research programs are already making significant contributions to this goal. To realize the full potential of this research, however, will require additional time and reliable funding.

Formal development of TropSoils' five-year program plan began in May, 1984, when the Management Entity met with the Technical Committee and the Executive Committee of the Board of Directors. The Technical Committee and the Board accepted a recommendation by the Management Entity that a change be made in program organization and funding-allocation procedures. Under the new arrangement each university would submit to the Management Entity plans for discreet research projects in its area of responsibility. These sets of plans for individual projects would replace the broader, less specific Plans of Work used in years one through three. Each project plan was to be prepared by the scientist responsible for conducting and reporting the research and would contain a budget sufficient to support the work. Competent personnel would review the projects, and funding commitments would reflect the outcome of those reviews.

Proposals for TropSoils research were submitted to the full Board and the External Evaluation Panel on November 13, 1984. Program emphasis and budgets were discussed, and the program coordinators were asked to review the proposals and budgets and to submit revisions reflecting some of the conclusions reached during these discussions. The revised proposals were reviewed in depth January 18-20 by the External Evaluation Panel, which submitted a formal report on its evaluation. The Management Entity has made recommendations to the Board using the Panel's evaluation as a base of reference.

There was not sufficient time to complete all of the revisions recommended by the Management Entity and External Evaluation Panel for the various research projects before the program plan was compiled for submission to AID. Therefore, for some projects, the Management Entity has included a statement outlining the expected changes in the research plans as written.

The Research Plan presented here has been shaped and strengthened by scientists and administrators well qualified to assess the major research needs for the management of tropical soils and to develop relevant programs and realistic budgets. However, the role of soil-management research in developing nations is dynamic, and programs must be able to adapt to changing resources and needs. For this reason, it is expected that, among projects, some research priorities may shift, and some work plans may be refined, in order to maintain an effective program and take advantage of the knowledge gleaned from experience.

SYNOPSIS

SYNOPSIS

OF THE

GLOBAL PLAN

TropSoils' global plan, in outline, is:

--to conduct user-oriented research based on established principles of soil management, along with principle-oriented research as needed, to overcome soil constraints to crop production for developing nations in the tropics.

--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, ensure the research is adapted to both user and setting and link people and institutions into active soil-management networks.

--to deploy the research efforts according to agroecological zones, which are groupings of tropical regions that share many soil and climatic characteristics in common, so as to focus the programs and facilitate the extrapolation of results from one area to another.

--to establish and sustain long-term research at primary sites in each zone and develop secondary sites as needed to adapt new technologies to achieve the efficiency and continuity necessary for sound soil-management programs.

--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.

--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.

--to encourage the broadest exchange among all components of this unified program, through publications, site visits, technical conferences and other regular communications.

SYNOPSIS

OF THE

RESEARCH PLAN

TropSoils' research plan calls for each university to continue to study and solve, through collaboration, the primary soil constraints to crop production in its respective agroecological zone. Because many of these soil constraints are found in more than one zone, the various programs are connected by subjects of common interest and importance, and research in one zone often complements research in another. The following statements briefly describe some of these subjects and the new TropSoils work that addresses them.

Acidity

Soil acidity constrains crop production by limiting root growth and by reducing the absorption of water and nutrients. New research will draw on established principles of acidity management, applying them to site-specific conditions of soil and climate. Liming studies will examine types of lime, methods of incorporation and frequencies and rates of application. A wide range of cultivars is being evaluated for their productivity and tolerance to soil acidity.

Fertility

In their natural state, most tropical soils do not supply enough of the plant nutrients essential for good crop production. Previous research has shown that high crop yields can be sustained if these fertility limitations are corrected. New studies will focus on the rates and times of fertilizer applications, sources of fertilizers, the role of micronutrients and the major elements, primarily phosphorus and potassium.

Nitrogen

Nitrogen is frequently the nutrient most limiting for plant growth and also one of the most difficult to manage. The goal of TropSoils' nitrogen-management component is to develop effective ways to manage nitrogen from both plants and fertilizers, so as to sustain crop production. New studies are designed to improve the use of biologically fixed nitrogen, incorporating legume green manures and crop residues into practical cropping systems.

Water

One of TropSoils' most formidable challenges is to develop management technologies that can minimize soil-water constraints to plant growth across the range of conditions found in the tropics. The approach is to capture and retain rainwater by improving the physical condition of the soil surface with tillage, plant cover and catchments. State-of-the-art mathematical expressions are being used to estimate the quantity of water that will be available to plants and the quantities lost through run-off, evaporation and transpiration. Studies will also focus on water in the root zone, seeking ways to make soil moisture more available to crops by improving the management of tillage, cropping systems, lime and fertilizer.

Agroforestry

The landscapes and climates of the tropics are such that land can frequently be best used by combining crops with trees. TropSoils is investigating agroforestry systems that will provide opportunities for both low- and medium-input production systems. These studies will examine the use of trees in wood and fruit production, in alley cropping and in improved fallows.

Low-input

It is unlikely that many tropical farmers will adopt, in the near future, technologies based on the intensive use of fertilizers, lime and farm machinery. Therefore, a transition crop-production technology is needed. Using low-input techniques developed during previous TropSoils studies, the new research will examine an array of low-input farming options, including the use of adapted cultivars and low levels of fertilizers and herbicides.

Land-clearing

Many of the new lands that must be brought into production will first be cleared of vegetation. The quality of the clearing operations affects how productive the land will be, and therefore, the success of the farm family. In collaboration with IBSTRAM, another organization concerned with soil management research, TropSoils will conduct a comprehensive study of the existing knowledge on land-clearing technology. This information base will then be used to develop (1) a strategy for land-clearing research and (2) a network of land-clearing projects to provide important new information. A TropSoils land-clearing project will be the first link in this network.

Land Reclamation

From the semi-arid regions to the rain-soaked humid tropics, the work of nature and man have combined to degrade farmlands and impair crop production. A number of TropSoils projects will focus on reclaiming barren, eroded or otherwise degraded land through the use of plant residues, cropping systems and tillage practices.

Conservation

To sustain a highly productive and stable agriculture, it is necessary to formulate farming systems that conserve soil. TropSoils will use established principles that relate erosion to rainfall and wind characteristics and will adapt and refine these principles as necessary to develop farming practices that will conserve soil in each agroecological zone.

Soil Characterization

A knowledge of the properties and distribution of soils serves as a cornerstone in the development and extrapolation of soil-management practices. A research program on the characterization, classification and interpretation of soils will provide a better understanding of the edaphic basis upon which soil-management recommendations are developed. This knowledge will enable the researchers to better evaluate successes and failures in the transfer of agro-technology.

Extrapolation

To meet its objectives, TropSoils must develop technology that can be transferred beyond the primary research site, improving food production in developing nations. To predict the performance of a crop on a specific kind of soil, it is necessary to match the requirements of the crop to the characteristics of the soil. A hypothesis being tested by TropSoils is that the success of extrapolating soil-management techniques can be predicted through systems analysis and by simulating the soil, plant and atmosphere continuum. TropSoils is part of a major collaborative effort that includes several organizations also working on this hypothesis, both in the development of equations and in evaluating the accuracy and reliability of the predicted outcomes.

Socio-economics

Before soil-management practices can be adopted they must first be tailored to the needs and resources of the farmers and to their culture. A user-oriented program, TropSoils projects are studying

such factors as seasonal patterns of work, nutrition, diet, income and the division of labor by age and sex. Research teams are including this information, and also farmers' suggestions, in the design of some research projects. These activities help ensure that research results will be useful to the people they are intended to serve.

BUDGET

SYNOPSIS

Expenditures, Years 1 through 3	$ 5,055,000
Proposed Budget, Years 4 through 8	16,695,000
Actual Plus Proposed, Years 1 through 8	21,750,000
Authorized Funding, Years 1 through 5	12,750,000
Requested Funding, Years 6 through 8	9,000,000

Summary of Actual, Estimated and Projected Expenditures for the Composite Program
Years 1 through 8

	From AID			AID			
	Mgt. Entity	Sub Grants	Total	To be Matched	Amount of Match	+ Match	Host Country
			x $1000				
Cumulative, thru year 3	487	4,568	5,055	4,568	1,133	6,188	1,067
Estimated, year 4	417	2,809	3,226	2,809	786	4,012	1,300
Estimated, year 5	480	2,912	3,392	2,912	874	4,266	1,518
Projected, year 6	514	2,975	3,489	2,975	892	4,381	1,489
Projected, year 7	550	2,744	3,294	2,744	768	4,062	1,639
Projected, year 8	575	2,719	3,294	2,719	707	4,001	1,640
Total for Program	3,023	18,727	21,750	18,727	5,160	26,910	8,653

Expenditures by Object Item and Components
Years 1 through 3 (Composite)

Object	Component[1/] CU	UH	NCSU	TAMU	ME	Total
			x $1000			
Salaries and Wages	80	232	810	332	186	1640
Fringe Benefits	14	55	93	61	31	254
Supplies	3	43	171	75	5	297
Equipment	9	40	92	160	12	313
Travel	25	88	223	152	98	586
Allowances	12	12	91	27	0	142
Other Direct Cost	23	51	606	165	17	862
Indirect Cost	59	139	445	180	138	961
Total	225	660	2531	1152	487	5055

[1/] CU: Cornell University
UH: University of Hawaii
NCSU: N. C. State University
TAMU: Texas A & M University
ME: Management Entity

Summary of the Budget by Object Items and the Staffing Plan for the Composite Program; Years 4 through 8

A. Budget

Object	Year 4	5	6	7	8	Total
			x $1000			
Salaries	1006	1133	1194	1150	1170	5653
Fringe Benefits	192	225	229	227	232	1105
Supplies	216	207	210	184	180	997
Equipment	191	160	129	117	81	678
Travel	430	397	416	398	406	2047
Allowances	138	167	167	141	141	754
Printing	25	26	27	28	29	135
Consulting	15	18	20	25	30	108
Special Projects	120	120	120	120	120	600
Other Direct Costs	255	257	252	205	186	1155
Indirect Costs	638	682	725	699	719	3463
TOTAL	3226	3392	3489	3294	3294	16,695

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
			SY/YR			SY	SY
Campus Based Scientist	8.80	9.70	9.70	9.10	9.10	19.65	26.75
Field Based Scientist	11.30	12.20	12.20	11.10	10.80	53.30	4.30
Graduate Student	33.00	31.00	31.00	29.00	29.00	145.00	8.00
Technicians, Secretarial, Administrative	29.80	28.10	27.10	26.00	26.00	93.10	43.90
Management Entity	3.00	3.00	3.00	3.00	3.00	15.00	0.00
Subtotal	85.90	84.00	83.00	78.20	77.90	326.05	82.95
TOTAL, Years and Funding						409.00	

Summary of Actual, Projected and Estimated Expenditures by Participating University and the Management Entity, Years 1 through 8

Component	Expended	Estimated		Projected			Total
	Year						
	1-3	4	5	6	7	8	1-8
	x $1000						
Cornell University	225	336	395	402	416	431	2,205
Univ. Hawaii	660	716	676	682	642	669	4,045
N. C. State Univ.	2,531	1,028	1,089	1,103	945	871	7,567
Texas A & M Univ.	1,152	729	752	788	741	748	4,910
Management Entity	487	417	480	514	550	575	3,023
TOTAL	5,055	3,226	3,392	3,489	3,294	3,294	21,750

THE GLOBAL PLAN

THE GLOBAL PLAN

FOR

TROPSOILS

In establishing and funding the Soil Management Collaborative Research Support Program, TropSoils, the Agency for International Development (AID) drew on a comprehensive set of studies and recommendations from the Planning Entity. The Planning Entity, an experienced group of experts in international agricultural development, assessed the need for such a program, articulated its goals and proposed a mode of operation. At the same time, the Planning Entity submitted what has come to be called a global plan. This global plan, endorsed by AID, has from the beginning been integral to the design and management of TropSoils. The plan that follows, updated to take advantage of new insights gained from the first three years of operation, renews the essential commitment to global attack and coordination on soil constraints to food production first set forth by the Planning Entity.

TropSoils' global plan, in outline, is:

--to conduct user-oriented research based on established principles of soil management, along with principle-oriented research as needed, to overcome soil constraints to crop production for developing nations in the tropics.

--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, ensure the research is adapted to both user and setting and link people and institutions into active soil-management networks.

--to deploy the research efforts according to agro-ecological zones, which are groupings of tropical regions that share many soil and climatic characteristics in common, so as to focus the programs and facilitate the extrapolation of results from one area to another.

--to establish and sustain long-term research at primary sites in each zone and develop secondary sites as needed to adapt new technologies to achieve the efficiency and continuity necessary for sound soil-management programs.

--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.

--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.

--to encourage the broadest exchange among all components of this unified program, through publications, site visits, technical conferences and other regular communications.

The background of this global plan, its components and expected impact, follow.

THE PROBLEM

Projections are that food production must increase at the rate of 3 percent per year during the 1980's and 3.8 percent per year during the 1990's to meet demands in the developing nations. Estimates are that approximately one-third of the additional food will be produced on new land and two-thirds by increasing yields on land already in cultivation. To accomplish this goal, about 200 million hectares of newly cleared land must be brought into production within the next 20 years. This area is equivalent to all of the cropland in the United States.

There is enough land available to meet this need. However, the greatest potential for new cropland, as well as the greatest need for technology improvements, occurs in the tropics, where, without careful management, soil constraints will severely limit plant growth and food production.

THE CHALLENGE

None of the tropical lands available for increasing food production are ideal. 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 semi-arid 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.

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. Appropriate soil-management technology is essential to the task of increasing and sustaining food production under the socio-economic conditions of developing nations. This technology is lacking.

THE GOAL

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

THE STRATEGY

Agroecological Zones. While developing nations in the tropics share in common such soil constraints as soil acidity, nutrient deficiencies, physical problems and water stresses, these constraints manifest themselves in varying ways and degrees from region to region. The strategy conceived by the Planning Entity, approved by AID and implemented by the Management Entity, is to structure the attack on the soil constraints 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. Semi-arid Tropics. This zone of the tropics is characterized by a protracted dry season of six-to-nine months duration. Erratic precipitation, wind and water erosion, desertification, soil acidity (accompanied by phosphorus 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 duration, 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.

Primary Research Sites. The second component of the strategy is to utilize primary 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 the continuity necessary for long-term research. There is a primary research site within each agroecological zone and two in the humid tropics. The countries with primary sties are:

Humid Tropics - (Latin America) - Peru
Humid Tropics - (Asia) - Indonesia
Semi-arid Tropics - Niger
Acid Savannas - Brazil
Steeplands - To be determined

Lead University. A third component of the strategy is to designate research leadership responsibility for a primary research site to a U.S. university that has experience with the predominant soil constraints. 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) - N. C. State University
Humid Tropics (Indonesia) - University of Hawaii
Semi-arid Tropics (Niger) - Texas A&M University
Acid Savannas (Brazil) - Cornell University
Steeplands - undetermined

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. For the various zones these are:[1/]

Humid Tropics (Peru) - NCSU; INIPA
Humid Tropics (Indonesia) - UH; NCSU; CSR
Semi-arid Tropics (Niger) - TAMU; INRAN; ICRISAT
Acid Savannas (Brazil) - CU; NCSU; EMBRAPA

[1/] NCSU: North Carolina State University
INIPA: Instituto Nacional de Investigaciones y Promocion
UH: University of Hawaii
CSR: Center for Soils Research
TAMU: Texas A&M University
INRAN: Institut Nationale de Recherches Agricoles der Niger
CU: Cornell University
EMBRAPA: Empresa Brasileira de Pesquisa Agropecuaria
ICRISAT: International Crops Research Institute for the Semi-Arid Tropics

In addition to the collaborating country institution, attention is given to expanding the sphere of activity to a broad base of organizations with related interests In this group are international agricultural research centers, to include IITA and CIAT, and countries other than those for the primary research sites, for example Mali and Cameroon in Africa and Ecuador and Bolivia in South America.

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 base of reference for determining if a project is likely to contribute to the program's goal:

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. Technology packages generated through research are designed to be flexible enough to accommodate both the user and the resource.

4. The soil-management technology must be effectively transferred from the research sites to other locations, making it 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. This has been demonstrated in developed countries. Recognizing this need for continuity, 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 soil resource.

IMPACT

TropSoils is a research program. Its goal is to develop soil management technology that is user oriented. For the technology to

have an impact on food production, it must be applied. While technology transfer is not a designated TropSoils goal, TropSoils does have a vital interest in the ultimate outcome of the technology developed. Therefore, it will seek opportunities to interface with technology transfer programs, to provide constructive inputs and to use the results of these interactions in assessment and prioritizing its research efforts.

ACID SAVANNAS PROGRAM

CORNELL UNIVERSITY

Acid Savannas Research Program Proposal

Cornell University

Synopsis

Research Topic 1. Nitrogen Management in Acid Savanna Soils

Goal: To find effective ways to manage crop residues, biologically fixed nitrogen, and fertilizer nitrogen for sustained crop production and maintenance of soil fertility in acid savanna soils.

Project 1: Nitrogen Availability from Legume Crop Residues and Green Manures to the Succeeding Non-legume Crops.

Objectives: Develop and evaluate experimental procedures for estimating the ability of legume crop residues and green manures to supply nitrogen to succeeding non-legume crops; estimate the effects of climate and management variables influencing the ability of legume crop residues and green manures to supply nitrogen to succeeding non-legume crops; investigate the effects of incorporating roots vs. tops in the use of organic sources of nitrogen.

Project 2: Evaluation of Mineralization Potential of Legume Residues through Laboratory Incubation Studies.

Objectives: Develop and calibrate a laboratory incubation procedure which will assess the nitrogen mineralization potential of the soil; evaluate legume residues as sources of nitrogen using incubation/cropping experiments; evaluate an incubation procedure as a soil test for nitrogen in field experiments.

Project 3: Soil and Crop Management Systems for Acid Savanna Soils using Green Manures and Crop Residues as Nitrogen Sources.

Objectives: Develop planting sequences and cropping systems to most effectively use legume and plant residue to supply their nitrogen requirements; evaluate the role of legumes and crop residues in nitrogen cycling and soil organic matter maintenance; determine the effects of legumes and crop residues on long term soil productivity.

Research Topic 2. Quantitative Description of Water and Chemical Budgets in Acid Savanna Soils.

Goal: Develop a quantitative understanding of water and soil amendment

fate in acid savanna soils, with particular emphasis on the relationships between water use and crop yield, and on nitrogen, gypsum, and those chemical entities directly participating in associated chemical reactions.

Project 4: Fertilizer Nitrogen Movement in Cerrado Soils.

Objectives: Develop a comprehensive description in simulation model form of nitrogen movement and transformation in cropped soils of the Cerrado; use the model as a guide in interpreting results from previous studies in designing field experiments to increase understanding of nitrogen fertilizer fate; develop a simplified field model of nitrogen fertilizer fate in Cerrado soils that will be useful in guiding nitrogen management.

Project 5: Ion Movement in Cerrado Soils.

Objectives: Determine the physical and chemical processes that influence the movement of ions derived from gypsiferous amendments; develop quantitative methods predicting ion distribution following gypsum amendment application considering the transient dynamics of water flow and chemical reactions.

Project 6: Crop Water Requirements in Cerrado Soils.

Objectives: Determine the components of the water budget in cropped soils; quantify the relationship between crop yield, evapotranspiration, and transient soil water regimes; develop and test a simplified model relating water use to crop yield, constructed to be useful in extending experimental results to other locations.

Research Topic 3. Soil Constraints to Management of Acid Savannas Soils.

Goal: Characterize the chemical and physical conditions that are of most significance to use and management of acid savanna soils, to develop management strategies that alleviate detrimental chemical and physical conditions limiting plant growth, and to understand the genesis of these properties and their landscape relations.

Project 7: Characterization of Root-Restricting Pans in Cerrado Soils.

Objectives: Diagnose soil conditions associated with root-restricting pans in Cerrado soils subjected to continuous annual cropping; identify the natural factors or induced mechanical and chemical processes that result in formation of root-restricting pans; determine which mechanismns are primarily responsible for limiting root develmpment in Oxisol tillage pans.

Summary of Budget by Projects for the Acid Savannas Program
Cornell University

Project Short Title	Year 4	5	6	7	8	Total
			x $1000			
Nitrogen Availability from Legumes	35	33	37	35	39	179
Evaluation of Mineralization	31	33	37	35	39	175
Soil and Crop Management	43	111	108	124	131	517
Fertilizer Nitrogen Movement	22	40	23	24	30	139
Ion Movement	33	28	24	34	28	147
Crop Water Requirements	22	25	39	27	25	138
Characterization of Root Restrictions	84	57	63	64	64	332
Backstopping	66	68	71	73	75	353
TOTAL	336	395	402	416	431	1980

Summary of the Budget by Object Items
and of the Staffing Plan for the Acid Savannas Program
Cornell University

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	96	136	143	154	168	697
Fringe Benefits	11	16	16	21	20	84
Supplies	20	21	20	20	20	101
Equipment	22	23	14	12	12	83
Travel	53	46	51	58	58	266
Allowances	23	40	40	34	34	171
Other Direct Costs	21	17	15	15	15	83
Indirect costs	90	96	103	102	104	495
TOTAL	336	395	402	416	431	1980

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	1.00	0.90	0.90	0.90	0.90	0.00	4.60
Field Based Scientist	2.00	2.00	2.00	2.00	2.00	10.00	0.00
Graduate Student	7.00	6.00	6.00	6.00	6.00	30.00	1.00
TOTAL	10.00	8.90	8.90	8.90	8.90	40.00	5.60

Acid Savannas Research Program Proposal

Submitted by

Cornell University

Douglas J. Lathwell

Program Coordinator

Research already carried out on soils characteristic of the acid savanna regions of Brazil at CPAC has shown these highly-weathered, well drained Oxisols have a very high yield potential. With good management sustained yields of maize of over 6 on of gram per hectare have been obtained. Without adequate lime and phosphorus, crop failure is the result. Research activities at the CPAC have led to an understanding of the management of lime and fertilizer phosphorus and nitrogen. Work on water relations and ion movement proceeded along with the work on soil fertility.

Based on what already had been learned from our previous research effort at CPAC and the ongoing program at the Center, and given the funding available to Cornell for the acid savanna program, careful consideration was given to research topics to be pursued. Within the framework of the agreements with the Management Entity and EMBRAPA, three major research topics were selected for the collaborative research program: 1) nitrogen management in acid savanna soils; 2) quantitative description of water and chemical budgets in acid savanna soils; and 3) soil constraints to management of acid savanna soils.

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.

Several factors have led us to investigate in detail the place of the legumes in the nitrogen economy of the acid savanna soils. Dairy farmers in Northeastern United States have successfully incorporated legumes and manures into their cropping systems. We have had a continuing research program using organic nitrogen sources and we believe we now something of the management of these sources. Aspects

that are important are the degree to which legume and other residue sources of nitrogen can substitute for fertilizer nitrogen. Our experience in New York and some limited experience at CPAC indicates that sometimes higher limiting yields are obtained using legumes and manures when compared to fertilizer nitrogen alone. There are non-nitrogen variables contributing to yield. These may be effects on nematodes, plant diseases, or the rhizosphere. Long-term beneficial effects on organic matter content, soil permeability, and water availability are likely brought about by legumes and manure additions.

In many developing countries, to increase food production, fertilizer nitrogen production and use is subsidized by governments. Money thus spent frequently goes outside the country to pay for imports of raw materials or the finished fertilizer product. It may be as reasonable to subsidize legume green manure production as it is to subsidize inorganic fertilizer nitrogen production. By this means money expended likely will remain within the country.

Since active research and extension activities were under way on this topic within the department an extension of this activity to the acid savanna program followed a natural progression. Faculty involved included Drs. Bouldin, Reid, and Lathwell. Once this research topic was developed, the individual research proposals resulted from the input of the principal investigator. These proposals were then coordinated to comprise the research to be carried out under nitrogen management topic of the acid savanna program.

The second major topic, the description of water and chemical budgets, has as its goals the development of a quantitative understanding of water and the fate of soil amendments in the acid savanna soils. Experiments have been carried out or are being planned 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.

From the beginning of the earlier collaborative program at CPAC methods to increase rooting depth of plants and overcome water shortages during the growing season have been actively pursued. This interest has broadened in recent years to include movement of nitrogen as well as calcium into the subsoil. Field work on several aspects of these problems has been carried out by scientists at CPAC. The arrival of Dr. Wagenet on the Cornell faculty with his interests in soil physics provided a base for collaboration that had not existed previously. As a consequence of his visits to CPAC the research topic on water and chemical budgets was developed and the research projects prepared.

The third research topic on soil constraints to management of acid savanna soils has as its goals the identification of chemical and physi-

cal 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 active project is under way to determine the relationships between soil color patterns and natural drainage characteristics and to develop means of identifying those Oxisols with restricted drainage. Projects to investigate the effect of soil compaction and erosion on limitations on crop production have been prepared.

The project on soil drainage developed naturally with the arrival at Cornell of a scientist from CPAC to work on an advanced degree with Dr. Bryant. Their interests fitted into the overall goals of the program and the project has grown out of that. The proposals developed to characterize barriers to root growth and to overcome physical and chemical barriers to root growth have resulted from a growing recognition that these kinds of problems will become more important in the future. The interests of Dr. Stoner along with the addition of Dr. Snyder on the Cornell faculty and the interest of the CPAC staff made this an appropriate time to develop these projects.

To ensure that scientific exchange and scientific staff development proceeds in a rational and consistent pattern a project on scientist exchange has been developed. The purpose of this project is to broaden the understanding of the faculty and staff of both the U.S. university community and the scientists of the collaborating institutions to enhance their scientific capabilities. It is anticipated that this project will span the life of the entire program.

All of these research topics and associated research projects have been developed in collaboration with Brazilian counterpart scientists at the CPAC. These 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.

Program: Acid Savannas

Research Topic:

Title: Nitrogen Management in Acid Savanna Soils

Goal: To find effective ways to manage crop residues, biologically fixed nitrogen, and fertilizer nitrogen for sustained crop production and maintenance of soil fertility in acid savanna soils.

Project:

Title: Nitrogen Availability from Legume Crop Residues and Green Manures to the Succeeding Non-legume Crops.

Objectives:

(A) To develop and evaluate experimental procedures for estimating of legume crop residues and green manures to supply nitrogen to succeeding non-legume crops.

(B) To estimate the effects of climate and management variables influencing the ability of legume crop residues and green manures to supply nitrogen to succeeding non-legume crops.

(C) To investigate some of the effects of incorporating roots vs. tops in the use of organic sources of nitrogen.

Project Leader: W. S. Reid, Cornell University,

Collaborating Scientist: Allert Rose Suhet, CPAC, EMBRAPA

Reasons for the Investigation:

Nitrogen management is the most difficult of the nutrients especially under conditions of excess rainfall. The nitrogen not utilized during the current cropping season is usually lost or incorporated into the soil biomass. Fertilizer nitrogen is not only expensive, but time of application is critical to obtaining high use efficiencies. Legumes and green manures have the potential to overcome both of these disadvantages provided (1) the legume growth and nitrogen fixation can fit into the cropping system, (2) the time and quantity of nitrogen release from the organic residue is sufficient to meet the needs of the growing crop. Currently the quantity and rate of release of the nitrogen is not well known.

There are many species of legumes that could be used for grain crops and/or green manure crops. Techniques must be developed to

permit estimating the nitrogen behavior without extensive field testing each legume. Thus a procedure is needed for screening the many variables so that a few of the most promising management parameters can be selected for inclusion in the expensive and time-consuming cropping evaluations.

Relevance to other programs:

A quantitative evaluation of the nitrogen release from organic residues permits the soil incorporation of the residues and crop development to be timed to make maximum use of the available N. This evaluation could then be incorporated into the N model being developed by R. J. Wagenet, et al. Likewise, the crop and nitrogen data can be used to test the laboratory incubation studies by D. R. Bouldin, et al.

In addition to the experimental use of the data, the information can be used for predicting the behavior of the organic residues in other parts of the world. Studies of this nature have been conducted in the U.S. Incorporating this information along with crop field data and climatic information, cropping systems can be developed that maximize the use of organic N sources for crop production, or the available N from organic residues within a particular cropping system can be estimated.

General Procedures:

A field experiment was begun in October 1983 on the Red-Yellow Latasol at the CPAC in which two legume crops were planted; soybeans in which the grain would be harvested and the residue left on the soil and a green manure crop, Mucuna, where the entire crop was incorporated. These crops were grown through to April 1984. The quantity of organic material was estimated. Some plots received both tops and roots while other crops received only roots or tops. Some plots were also left fallow. Soil samples were taken periodically to determine the rate of inorganic N release. The uptake of N by the corn crop will be determined. (Note: The corn grown on the plots with only the Mucuna tops incorporated showed P deficiency even though the area received an adequate quantity of P applied prior to planting.)

The experiment begun in 1983 utilized the wet season to grow the legume and the corn was grown under irrigation during the dry season. A similar, but smaller, experiment was begun in 1984 growing the green manure crop during the dry season. A corn crop will be grown during the wet season.

Following the N in the fallow plots, check plots, plots receiving organic residues and/or fertilizer N, one can evaluate the quantity of N mineralized from the soil & organic residues as well as the relative efficiency of N use by the crop. Likewise, attempts are being made to evaluate the use of plastic bags buried in the fallow plot to determine total mineralization without leaching as a means of predicting the N release from green manures.

Additional field experiments to define parameters for predicting N mineralization and plant uptake will be carried out.

Principal Site for Experimentation:

Centro de Pesquisa Agropecuaria dos Cerrados CPAC), Planaltina, Brazil will be used for field and some laboratory studies and analyses; Cornell University, Department of Agronomy may be used for laboratory studies and analyses.

Duration: October 1, 1984 - August 31, 1989.

Nitrogen Availability from Legume Crop Residues
and Green Manures to the Succeeding Non-Legume Crop
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	10	11	11	12	13	57
Supplies	3	3	3	3	3	15
Equipment	2	2	2	2	2	10
Travel	6	3	6	3	6	24
Allowances	5	5	5	5	5	25
Other Direct Costs	2	2	2	2	2	10
Indirect Costs	7	7	8	8	8	38
TOTAL	35	33	37	35	39	179

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.10	0.10	0.10	0.10	0.10	0.00	0.50
Graduate Student	1.00	1.00	1.00	1.00	1.00	5.00	0.00
TOTAL	1.10	1.10	1.10	1.10	1.10	5.00	0.50

Program: Acid Savannas

Research Topic:

Title: Nitrogen Management in Acid Savanna Soils.

Goal: To find effective ways to management crop residues, biologically fixed nitrogen, and fertilizer nitrogen for sustained crop production and maintenance of soil fertility in acid savanna soils.

Project:

Title: Evaluation of Mineralization Potential of Legume Residues Through Laboratory Incubation Studies.

Objectives:

(A) To develop and calibrate a laboratory incubation procedure which will assess the nitrogen mineralization potential of the soil.

(B) To evaluate legume residues as sources of nitrogen using incubation/cropping experiments.

(C) To evaluate an incubation procedure as a soil test for nitrogen in field experiments.

Project Leader: D. R. Bouldin, Cornell University

Collaborating Scientist: Allert Rose Suhet, CPAC, EMBRAPA

Reasons for the Investigation:

Bouldin, Reid and Stangel (1980) described the use of the general equation:

$$N_P = N_S + N_M + N_L + K_F N_F$$

where: N_P is the amount of nigrogen the above-ground dry matter which is required to reach the yield goal selected.
N_S is the amount of nitrogen supplied by the soil organic matter.
N_M is the amount of nitrogen supplied by manure.
N_L is the amount of nitrogen supplied by legume residues.
K_F is the expected amount of nitrogen derived from each pound of fertilizer nitrogen.
N_F is the amount of applied fertilizer nitrogen.

This equation is the basis for current recommendations in New York and conceptually is the basis for recommendations in many other states and regions.

With most upland crops in most situations we know how to apply fertilizer nitrogen so that $K_F = 0.6$. There seems to be little reason to do much more research on fertilizer since it is unlikely that we can increase K_f much beyond 0.6 (probably an additional 0.2 and 0.3 of fertilizer is incorporated into the root system at some time during the growing season and 0.1 to 0.2 will be lost by various agents).

Thus the major problem in using equation [1] is to evaluate the time course of mineralization of the various organic sources of nitrogen (soil, legume and other crop residues, and manure nitrogen) and develop cropping systems which take up the mineralized nitrogen as soon as it is produced (or at least reduce to the extent practical the time during which large amounts of inorganic N are in the soil).

Quintana (1980) and Fox et al. (1983) report that several procedures for estimating yields of corn on plots receiving no fertilizer were not very useful. Since then Quintana and Bouldin (unpublished data) have investigated an incubation procedure for evaluating manure and legume residues in different plots of the same experiments. The rationale is that it will be easier to find a procedure which will predict differences among treatments in one experiment than differences among locations. The results to date illustrate that this is true but that extremely important variables are soil drainage and treatment of the samples between the time they are taken from the field and placed in the incubation vessel. On well drained soils with proper pretreatment of the sample, correlations between N mineralized during incubation and yields of corn in plots of the same experiment are on the order of 0.6 to 0.7.

Relevance to Other Programs:

These laboratory incubation and screening studies are an integral component of the overall nitrogen management and research effort. A soil test for nitrogen availability that would predict reliably the nitrogen supply from soil organic matter and green manure crops could be used widely for many soil and climatic conditions. It would reduce the amount of costly field experimental work required to predict fertilizer nitrogen requirements of cropping systems. If this effort is successful then the results from laboratory and field experiments already under way could be used directly to translate results to farmers.

General Procedures:

In the first experiments in Brazil the utility of the incubation procedure using soil samples taken from on-going field experiments will be utilized. The effects of field moisture, air drying, and oven drying on mineralization in laboratory incubations will be measured. The procedures will be evaluated by correlation with yields obtained in the field plots.

The initial experiments will be aimed at predicting differences among treatments in one experiment. If the correlations with yield (or

measured mineralization in the field) are reasonably good, then the procedure will be used to screen the literally hundreds of legume residue treatments which can be devised. This screening procedure will then be used to select a limited number of the most promising treatments for final evaluation in cropping experiments.

If indeed the incubation procedure is useful in comparing treatments in one experiment it will be evaluated as a soil test for nitrogen in the topics. The initial evaluation will be carried out in the Planaltina station using existing experiments where nitrogen fertilizer are variables. If this proves successful then experiments will be run on cooperating farmers' field in the Planaltina area.

Principal Site for Experimentation:

Centro de Pesquisa Agropecuaria dos Cerrados CPAC), Planaltina, Brazil (field studies); Cornell University, Department of Agronomy (laboratory studies and modeling).

Duration: October 1, 1984 to September 30, 1989.

Evaluation of Mineralization Potential of Legume Residues Through Laboratory Incubation Studies
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	10	11	11	12	13	57
Supplies	3	3	3	3	3	15
Equipment	2	2	2	2	2	10
Travel	3	3	6	3	6	21
Allowances	5	5	5	5	5	25
Other Direct Costs	2	2	2	2	2	10
Indirect Costs	6	7	8	8	8	37
TOTAL	31	33	37	35	39	175

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.10	0.10	0.10	0.10	0.10	0.00	0.50
Graduate Student	1.00	1.00	1.00	1.00	1.00	5.00	0.00
TOTAL	1.10	1.10	1.10	1.10	1.10	5.00	0.50

Program: Acid Savannas

Research Topic:

Title: Nitrogen Management in Acid Savanna Soils.

Goal: To find effective ways to manage crop residues, biologically fixed nitrogen, and fertilizer nitrogen for sustained crop production and maintenance of soil fertility in acid savanna soils.

Project:

Title: Soil and Crop Management Systems for Acid Savanna Soils Using Green Manures and Crop Residues as Nitrogen Sources.

Objectives:

(A) To develop planting sequences and cropping systems to most effectively use legume and plant residue to supply their nitrogen requirements.

(B) To evaluate the role of legumes and crop residues in nitrogen cycling and soil organic matter maintenance.

(C) To determine the effects of legumes and crop residues on long term soil productivity.

Project Leaders: David R. Bouldin, Cornell University
D. J. Lathwell, Cornell University
W. S. Reid, Cornell University
Senior Research Associate, Cornell University

Collaborating Scientist: Allert Rose Suhet, CPAC, EMBRAPA

Reasons for the Investigation:

This project is intended to integrate the results from the more narrowly defined research projects on nitrogen availability from legumes and crop residues and on screening procedures for evaluating the effectiveness of organic nitrogen sources into viable cropping systems.

In many developing countries the amount of nitrogen contained in manures and residues far exceeds the amount of fertilizer nitrogen available. We are assuming that legume green manures and residues containing significant amounts of nitrogen are available or can be made

available to use in the cropping system. Bouldin et al. (1980) developed a framework by which to evaluate nitrogen as a constraint to production. Their model is as follows:

$$Np - Ns + Nr + KfNf$$

where:

Np = N uptake by the plant
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 plant

The relationship between yield and nitrogen content of the above ground dry matter of a crop provides a good estimate of the amount of nitrogen that must be accumulated by the crop. Each component in 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. Jallah (1984) evaluated Nr in experiments in New York and was able to relate mineral nitrogen fluctuations to yields of maize. The experimental work already under way will contribute further to this effort.

In a long term rotation study carried out in New York, Baldock and Musgrave (1980) have shown clearly that the nutrient requirements of field crops grown in rotation can be supplied completely by legumes and manure, by mineral fertilizer, or by some combination of them. Soil fertility and soil organic matter was maintained in a wide range of cropping combinations.

Ebelhar, et al. (1984) in Kentucky have shown that certain legumes used as a cover crop in no-tillage corn production supplied biologically fixed nitrogen equivalent to 90 to 100 kg/ha fertilizer nitrogen annually to corn. In addition to functioning as an effective mulch, certain legume cover crops provided a substantial portion of the nitrogen for no-tillage cover production, decreasing the amount of fertilizer nitrogen needed.

There are relatively few areas in the world, however, where farmers produce non-legumes with residual nitrogen from legumes. Manures and crop residues are used where they are available, but in many cases the nitrogen is mostly lost and is not recycled. Important reasons why farmers do not make better use of biological sources of nitrogen include the ease with which fertilizer nitrogen can be managed but more importantly is the lack of knowledge of how to manage organic sources of nitrogen. Management of organic nitrogen sources is complicated and may require 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. In the tropics an additional factor that may limit the use of green manure crops is the lack of symbiotic fixation of nitrogen by the available legume plants.

Relevance to Other Programs:

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. The research program in New York has evaluated components of cropping sequences and manure management already in place. 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 savanna regions as well as other ecological zones 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. We expect to take some of the most promising legumes and cropping sequences to other regions as the project develops.

Generalized Procedures:

Field experiments will be carried out to develop practical means of increasing utilization of 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, the forage legume mucuna (Mucuna aterrima) was planted in March 1984 at the end of the rainy season to be used as a green manure nitrogen source for the maize crop to be planted in the following rainy season beginning November 1984. The potential of these materials to supply nitrogen to the non-legume crop component will be evaluated and the 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.

Principal Site for Experimentation:

The detailed field experiments will be carried out at the CPAC at Planaltina, Brazil. The necessary analytical work will be carried out at CPAC. As this work develops experiments derived from these results should be extended to sites with other soils and environmental conditions in Latin America and West Africa.

Duration: October 1, 1984 to September 30, 1984.

Soil and Crop Management Systems for Acid Savanna Soils
Using Green Manures and Crop Residues as Nitrogen Sources
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	10	41	44	48	53	196
Fringe Benefits	1	6	6	7	8	28
Supplies	3	6	6	6	6	27
Equipment	2	10	2	2	2	18
Travel	10	10	10	20	20	70
Allowances	3	14	14	14	14	59
Other Direct Costs	5	5	5	5	5	25
Indirect Costs	9	19	21	22	23	94
TOTAL	43	111	108	124	131	517

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.10	0.10	0.10	0.10	0.10	0.00	0.50
Field Based Scientist	1.00	1.00	1.00	1.00	1.00	5.00	0.00
Graduate Student	1.00	1.00	1.00	1.00	1.00	5.00	0.00
TOTAL	2.10	2.10	2.10	2.10	2.10	10.00	0.50

Program: Acid Savannas

Research Topic:

Title: Quantitative Description of Water and Chemical Budgets in Acid Savanna Soils.

Goal: Develop a quantitative understanding of water and soil amendment fate in acid savanna soils, with particular emphasis on the relationships between water use and crop yield, and on nitrogen, gypsum, and those chemical entities directly participating in associated chemical reactions.

Project:

Title: Fertilizer Nitrogen Movement in Cerrado Soils.

Objectives:

(A) Develop a comprehensive description in simulation model form of nitrogen movement and transformation in cropped soils of the Cerrado.

(B) Use the model of (A) as a guide in interpreting previous studies and in designing further field experiments to increase understanding of nitrogen fertilizer fate in Cerrado soils.

(C) Develop a simplified model of nitrogen fertilizer fate in Cerrado soils that will be useful in guiding nitrogen management programs.

Project Leader: R. J. Wagenet, Cornell University

Collaborating Scientist: Elias de Freitas, CPAC, EMBRAPA

Reasons for the Investigation:

There is a need for nitrogen management strategies based upon comprehensive understanding of the physical chemical and biological processes that affect nitrogen fate in Cerrado soils. A great many field experiments have addressed this issue and a substantial data base have been assembled. It remains to generalize these studies into a broadly based set of nitrogen management guidelines useful in acid savanna soils. One method of achieving this goal is to summarize nitrogen transport and transformational processes into a simulation model of nitrogen fate in cropped systems, and to use the model in a prospective manner to manage nitrogen fertilizer and crop residue. Several models useful in such applications have been developed and

applied to field cases. Nitrogen management programs based upon a and are being used in the United Kingdom on a continuing basis. Although a number of such nitrogen fate models have been developed, they are principally research, not management, tools have have been tested primarily on nitrogen fertilizer studies conducted in soils of the temperate climates of the Northern hemisphere. The basic formulation of these models provides a starting point for description of nitrogen in Cerrado soils. This project will use an existing research-type model of nitrogen leaching in agricultural soils as the starting point for development of a management model useful in Cerrado situations. Data already collected at CPAC will be used to test the model, and several additional experiments will be conducted to complement existing data.

Relevance to Other Programs:

Quantitative description of nitrogen movement, and nitrogen soil fertility are both strong components of Cornell's continuing research programs. Nitrogen management in Cerrado soils has been a primary focus of Cornell/CPAC research efforts during the first three years of this program, and will continue as a research topic in Cornell's efforts over the next five years. Nitrogen modeling studies are currently in progress as a component so the applied soil physics program at Cornell, and have evolved from extensive experience in similar studies conducted by the project leader in California and Utah. These efforts are currently being pursued as part of Regional Research project W-155, a cooperative effort focusing on the quantitative description of spatial and temporal variability of water and solute movement in field soils.

General Procedures:

Field experiments are currently in progress at Planaltina in which the leaching and transformation of $(^{15}NH_4)_2 SO_4$ is being measured in plots planted to corn. Data are available from soil, plant and drainage water samples. These data will be used to test a currently existing model of nitrogen fertilizer transport, transformation and plant uptake. Initial testing of this model will be conducted during a visit to Cornell in year one of the proposed project by Dr. Elias de Freitas of CPAC, director of the ^{15}N experiments. The results of these modeling exercises will be used to guide the design of further experiments at Planaltina.

A Cornell graduate student will spend year two of the proposed project working on-site at Planaltina to organize and analyze existing data, and to develop new data according to experimental designs developed in year one during Dr. de Freitas' visit.

As increased understanding is gained of fertilizer nitrogen in such systems, the presently quite complicated research model will be simplified to a form useful in management applications. This will

require a minimum of three additional field seasons of data, although preliminary work on a simplified model will be initiated early in the research program and will continue as a parallel activity with the field experiments.

Substantial effort will be expended in developing a nitrogen mineralization component of the model that describes the results of crop residue incorporation studies conducted in previous Cornell/CPAC studies and proposed as a research topic for the next five years.

The pertinent CPAC personnel involved in the ^{15}N studies have been contacted and have agreed to collaborate in all efforts.

Principal Site for Experimentation:

Centro de Pesquisa Agropecuaria hos Cerrados CPAC), Planaltina, Brazil (field studies); Cornell University, Department of Agronomy (laboratory studies and modeling).

Duration: September 1, 1984 - August 31, 1989.

Fertilizer Nitrogen Movement in Cerrado Soils
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	10	11	11	12	13	57
Supplies	1	1	1	1	1	5
Equipment	1	1	0	0	0	2
Travel	0	5	0	0	3	8
Allowances	0	6	0	0	0	6
Other Direct Costs	1	2	1	1	1	6
Indirect Costs	9	14	10	10	12	55
TOTAL	22	40	23	24	30	139

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.10	0.10	0.10	0.10	0.10	0.00	0.50
Graduate Student	1.00	1.00	1.00	1.00	1.00	5.00	0.00
TOTAL	1.10	1.10	1.10	1.10	1.10	5.00	0.50

Program: Acid Savannas

Research Topic:

Title: Quantitative Description of Water and Chemical Budgets in Acid Savanna Soils.

Goal: Develop a quantitative understanding of water and soil amendment fate in acid savanna soils, with particular emphasis on the relationships between water use and crop yield, and on nitrogen, gypsum, and those chemical entities directly participating in associated chemical reactions.

Project:

Title: Ion Movement in Cerrado Soils.

Objectives:

(A) Determine the physical and chemical processes that influence the movement of ions derived from gypsiferous amendments in Cerrado soils.

(B) Develop quantitative methods of predicting ion distribution in Cerrado soils following gypsum amendment application considering the transient dynamics of water flow and chemical reactions within the soil profile.

Project Leader: R. J. Wagenet, Cornell University

Collaborating Scientist: Djalma G. de Souza, CPAC, EMBRAPA

Reasons for the Investigation:

A number of previous experiments have been conducted at Planaltina that provide substantial preliminary information on ion movement in Cerrado soils following the application of gypsum amendments. For example, the effects on subsoil pH, calcium and magnesium status, and aluminum saturation were studied following application of gypsum, and the results shown to have implications with respect to root growth. More recently, Espinoza and Dos Reis (1982) estimated cation fluxes in savanna soils from field measurements of the oil solution. Although these studies have generated useful data, they have not been analyzed using a comprehensive approach that combines description of soil solution chemistry, ion exchange reactions and the dynamics of water and solute movement. This has limited the interpretation of these experiments, as without the unifying thread of basic physical and chemical principles, each field study has stood somewhat alone. The proposed

project will use a simulation modeling approach similar to those used in describing salt movement in semi-arid regions of the world and will focus on developing a comprehensive description of ion chemistry and transport in Cerrado soils. The existing models, although developed to describe a completely different soil chemical system (saline, alkaline soils), will serve as useful guides in developing new approaches useful in acid soils. It is expected that a comprehensive model of gypsum fate in acid soils will provide quantitative interpretation of past experiments, and, with several supplementary experiments, will provide a means of extrapolating experimental results to new locales.

Relevance to Other Programs:

Quantitative description of solute movement through analytic and numeric modeling techniques is a primary objective of the applied soil physics program at Cornell. Studies are currently in progress focusing on pesticide transport/transformation and nitrogen leaching in cropped systems. These studies are utilizing a combined experimental/modeling approach, in which laboratory and field studies provide experimental feedback to guide continuing model development and refinement. A similar approach will be used in the proposed project. Traditionally, field studies are currently in progress at Cornell developing methods of measuring water and chemical movement either in-situ or in undisturbed soil cores. These methods are particularly appropriate for highly structured soils, such as might be expected at certain Cerrado sites. The proposed project will utilize these methods, extending and complementing studies currently in progress.

Generalized Procedures:

The project will use previously collected experimental data, conduct new experiments as necessary, and will involve substantial efforts in development of the simulation model. Several experiments have been conducted at Planaltina that will be used as tests of initial modeling efforts. Further experiments will include frequent sampling of soil and soil water in plots subjected to different chemical and water regimes. A range of transient conditions will be chosen to test model credibility over extremes of soil water and chemical movement.

The influence of soil properties will be included by locating study sites on different soil types at Planaltina and elsewhere as appropriate. Crop type effects will be included by splitting plots into several sub-blocks, each planted and managed with crops determined in consultation with CPAC personnel.

This project will be designed to complement other projects within the Cornell/CPAC program, and the soil types and crop management aspects of the leaching studies will be designed to provide relevant information to other components of the program.

CPAC scientists involved in gypsum leaching studies have been contacted and have agreed to collaborate in these efforts.

Principal Site for Experimentation:

Centro de Pesquisa Agropecuaria dos Cerrados CPAC), Planaltina, Brazil (field studies); Cornell University, Department of Agronomy (laboratory studies, modeling).

Duration: September 1, 1984 - August 31, 1989.

Ion Movement in Cerrado Soils
Projected Budget and Staffing

A. Budget

Objective	Year 4	5	6	7	8	Total
	x $1000					
Salaries	10	11	11	12	13	57
Supplies	2	2	1	1	1	7
Equipment	4	1	1	1	1	8
Travel	3	2	0	5	0	10
Other Direct Costs	1	1	1	1	1	5
Indirect Costs	13	11	10	14	12	60
TOTAL	33	28	24	34	28	147

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.10	0.10	0.10	0.10	0.10	0.00	0.50
Graduate Student	1.00	1.00	1.00	1.00	1.00	5.00	0.00
TOTAL	1.10	1.10	1.10	1.10	1.10	5.00	0.50

Program: Acid Savannas

Research Topic:

Title: Quantitative Description of Water and Chemical Budgets in Acid Savanna Soils.

Goal: Develop a quantitative understanding of water and soil amendment fate in acid savanna soils, with particular emphasis on the relationships between water use and crop yield, and on nitrogen, gypsum and those chemical entities directly participating in associated chemical reactions.

Project:

Title: Crop Water Requirements in Cerrado Soils.

Objectives:

(A) Determine the components of the water budget in cropped Cerrado soils.

(B) Quantify the relationship between crop yield, evapotranspiration, and transient soil water regimes in a manner useful to irrigation and crop production programs.

(C) Develop and test a simplified model relating water use to crop yield, constructed to be useful in extending experimental results to other locations.

Project Leader: R. J. Wagenet, Cornell University

Collaborating Scientist: Luis Costello Branco Caralho, CPAC, EMBRAPA

Reasons for the Investigation:

A knowledge of the influence of evapotranspiration and soil water management on plant growth is important to agronomic and economic evaluation irrigation development and for comparison of the relative benefits of water used for irrigation compared to other water uses. In fact, irrigated agriculture is based on the strong relation between plant growth and water use (evapotranspiration and drainage). However, this relationship is quite complex and interrelated to many other factors of which soil fertility and climate are quite important. A number of non-soil scientists attempt to describe such relationships in statistical or regression form without considering many of these physical, chemical and biological factors. The rather gross models obtained are thereby quite site specific

and limited in their ability to describe experimentally unstudied locations. The work proposed here will develop a physically-based, simple model to predict yield of several Cerrado crops as related to water use. Several such models already exist in the scientific literature, that provide substantial guidance or development of a model useful in Cerrado soils, and from these approaches a suitably modified simple model will be developed and tested. In the process, the sensitivity of the model to soil, climate and plant input parameters will be determined, and general guidance produced or future field studies. The model should be immediately useful or estimating the potential benefits of increased irrigation, will identify differences in yield response on different soils and in wet or dry years, and will produce simulations useful in economic analysis of irrigation programs. Additionally, the model will be amenable to future modification to reflect the influence of gypsum or nitrogen amendments upon crop growth, a revision that will become possible as other research projects under this topic are accomplished.

Relevance to Other Programs:

Soil water management and resulting impact on crop yield are primary considerations in a number of Department of Agronomy research programs. The project leader is investigating such issues through participation in Regional Research Project W-155, titled "Soil Water Properties, Spatial Variability, and Implications in Soil-Water Management", and through current USDA-funded work on "Crop Response to Water Management in the Presence of Spatially Variable Soil Hydraulic Properties". Development and testing of simulation models of water movement and crop growth has been a research activity of the project leader for the last eight years, as is apparent from his curriculum vitae. Cornell University has historically had a strong interest in crop yield/water management questions, as evidenced by previous cooperative Cornell/CPAC efforts, and by present activity in the Department of Agronomy on SCS funded research investigating the relationships between corn yield, soil erosion and available soil water (a project that includes the project leader). Additionally, other faculty of the Department are working on crop growth simulation models and measurement of climatological data related to plant growth.

Generalized Procedures:

Measurement of soil-water, rainfall, irrigation, potential evapotranspiration (PET) and crop yield will be made within on-going crop growth experiments at Planaltina. Initial attention will be focused on those studies directly involved in the cooperative Cornell/CPAC project, although other studies will be considered for inclusion at a later date. Meteorological information necessary in calculating PET will be measured at Planaltina in locations proximate to the field experiments. It is hoped that at least two different crops can be monitored at two physically separated loca-

tions on the Planaltina station. It will also be necessary to select crops that will be grown for more than one season, so that crop response to different climatological conditions can be determined. If possible, a continuously variable line source irrigation design (Hanks et al. 976) will be used in several cases. This will allow several irrigation regimes to be studied in one concise field experiment. Data generated will be used to test and appropriately adapt to Cerrado conditions a simple model of water use and crop yield. Model development will proceed parallel with field experiments.

A graduate student working toward the Ph.D. degree will spend year three at Planaltina conducting field experiments, explaining modeling approaches to CPAC scientists, and becoming familiar with the local considerations important in describing yield/water-use questions.

It is anticipated that field studies will be initiated in year one by making appropriate measurements in on-going studies, and will be expanded to the above mentioned line-source design in years 3-5.

Principal Site for Experimentation:

Centro de Pesquisa Agropecuaria dos Cerrados (CPAC), Planaltina, Brazil (field studies, data reduction); Cornell University, Department of Agronomy (modeling, data reduction).

Duration: September 1, 1984 - August 31, 1989.

Crop Water Requirements in Cerrado Soils
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	10	11	11	12	13	57
Supplies	1	1	1	1	1	5
Equipment	1	2	2	0	0	5
Travel	0	0	3	4	0	7
Allowances	0	0	6	0	0	6
Other Direct Costs	1	2	1	1	1	6
Indirect Costs	9	9	15	9	10	52
TOTAL	22	25	39	27	25	138

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	(Included in other projects)					0.00	0.00
Graduate Student	1.00	1.00	1.00	1.00	1.00	5.00	0.00
TOTAL	1.00	1.00	1.00	1.00	1.00	5.00	0.00

Program: Acid Savannas

Research Topic:

Title: Soil Constraints to Management of Acid Savanna Soils.

Goal: To characterize the chemical and physical conditions that are of most significance to use and management of acid savanna soils, to develop strategies and alleviate detrimental chemical and physical conditions limiting plant growth, and to understand the genesis of these properties and their landscape relations.

Project:

Title: Characterization of Root-Restricting Pans in Cerrado Soils.

Objectives:

(A) Diagnose soil conditions associated with root-restricting pans in Cerrado soils subjected to continuous annual cropping.

(B) Identify the natural factors or induced mechanical and chemical processes that result in formation of root-restricting pans.

(C) 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.)

Project Leader: Eric R. Stoner, Cornell University,

Collaborating Scientists: Victor Snyder, Cornell University
Airton Alonco, CPAC, EMBRAPA

Reasons for the Investigation:

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 Cerais State, a decade of intensive cultivation has resulted in the formation of an extremely hard compacted layer 10 to 15 cm deep at the top

of the horizon beneath a very loose or fluffy plough layer, forming conditions very conductive to erosion under high intensity rainfall. Shallow rooting of the predominant crop in this region, soybeans, has been attributed to 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 a 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 shoping, 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 characteristic marks of the harrowsole in cultivated fields. Deep gully formation where runoff water is channeled along contour ridges or be discharged at field edge is a serious 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.

A thorough diagnosis has been helpful for situations in which soil constraints to deep rooting are evident Kashirad et al., 1967; Taylor et al., 1964). The 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.

Most importantly, the mechanisms which are primarily responsible for limiting root development in cultivated Cerrado subsoils should be studied so that the effects of microporosity, high soil strength, or continued toxicity can be validated under controlled conditions. A better understanding of these mechanisms should help orient the development of management strategies for alleviation of barriers to subsoil utilization.

Relevance to Other Programs:

A major area of emphasis of the TropSoils/Acid Savanna program is that of enhancement of the use of biologically fixed nitrogen and nitrogen in organic residues for sustained crop production and maintenance of soil productivity. Production systems utilizing legume green manure crops, which may be developed as part of this program, are likely to help alleviate some of the effects of mechanical impedence 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.

Generalized Procedures:

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 impedence, moisture content, organic matter content, particle size distribution, and Fe, Al, and Si. Mineralogical analysis may be performed at Cornell University. Appropriate chemical analyses will be performed to verify the existence of possible chemical barriers to root penetration. Cropping history, fertilizer and lime applications, and tillage sequences will be recorded for each cultivated site.

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.

Laboratory studies will be designed to study the mechanisms responsible for limiting root development in compacted Cerrado soils.

Principal Site for Experimentation:

EMBRAPA/CPAC, Planaltina, Brazil and outlying sites in the Cerrado region (field studies and laboratory analyses). Cornell University, Department of Agronomy (mineralogical analyses).

Duration: October 1, 1984 - September 30, 1989

Characterization of Root Restricting Pans in Cerrado Soils
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	18	20	22	23	25	108
Fringe Benefits	5	5	5	8	6	29
Supplies	5	3	3	3	3	17
Equipment	8	3	3	3	3	20
Travel	9	3	6	3	3	24
Allowances	10	10	10	10	10	50
Other Direct Costs	9	3	3	3	3	21
Indirect Costs	20	10	11	11	11	63
TOTAL	84	57	63	64	64	332

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.20	0.10	0.10	0.10	0.10	0.00	0.60
Field Based Scientist	0.50	0.50	0.50	0.50	0.50	0.00	2.50
Graduate Student	1.00	0.00	0.00	0.00	0.00	0.00	1.00
TOTAL	1.70	0.60	0.60	0.60	0.60	0.00	4.10

Program Backstopping Support
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	18	20	22	23	25	108
Fringe Benefits	5	5	5	6	6	27
Supplies	2	2	2	2	2	10
Equipment	2	2	2	2	2	10
Travel	22	20	20	20	20	102
Indirect Costs	17	19	20	20	20	96
TOTAL	66	68	71	73	75	353

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.30	0.30	0.30	0.30	0.30	0.00	1.50
Field Based Scientist	0.50	0.50	0.50	0.50	0.50	2.50	0.00
TOTAL	0.80	0.80	0.80	0.80	0.80	2.50	1.50

HUMID TROPICS PROGRAM

UNIVERSITY OF HAWAII

Humid Tropics Research Program Proposal

University of Hawaii

Synopsis

Topic 1: Site Characterization

Objective: To prepare a detailed soil survey of research sites and to describe soil variability, use it to design agronomic experiment and farming methods, and to increase reliability of extrapolation research.

Project 1. Soil Variability in Mechanically Cleared Forest Land

Means to attain objective:

Determine the soil chemical and physical properties most influential in causing the extreme crop yield variability in the gardens and fields of transmigrant farmers; determine the structure in the variance of soil chemical and physical properties by geostatistical methods; relate soil and crop variablity patterns using geostatistical approaches to quantify and understand the nature of soil variability in mechanically cleared forest.

Topic 2: Baseline Farming Systems Research

Objective: Improve quality of life for transmigrant and local farmers by tailoring soil management practices to fit cultural and resource characteristics of farmers.

Project 1: Time Allocation Study

Means to attain objective:

Ascertain the current division of farm labor, by sex and age; determine how people were choosing to use their labor; determine important seasonal variation in activities; maintain ongoing communication between researchers and farming families.

Project 2: Nutrition/Diet/Income Survey

Means to attain objective:

Ascertain a baseline for nutritional status, dietary patterns and income levels in the area of field research investigations.

Project 3: Cooperator Farmer Interview Series

Means to attain objective:

Monitor characteristics of the farming families with whom the team is working; compare their lives with those of a randomly selected group of "control" farming families.

Topic 3: Improving and Sustaining Soil Productivity in Farmers' Fields

Objective: Develop alternative soil and crop management systems that will lead to economically, socially and environmentally workable outcomes that can be transferred to other regions of the humid tropics.

Project 1: Farmer and Research Designed and Managed Cropping Systems Experiments

Means to attain objective:

Compare fertilizer packages, including rock phosphate or lime against the current government supplied package of urea and treble superphospate; enhance interaction with local farmers so as to better understand a) their problems and b) their goals; learn and get ideas from the farmers, drawing on their knowledge and experience to help generate more appropriate research.

Project 2: Matching Crop Requirements of Rice, Maize, Soybean and Peanut to Soil Characteristics with Crop Simulation Models

Means to attain objective:

Identify the minimum soil, crop and weather data needed to predict the performance of rice, maize, soybean and peanut cultivars in the humid tropics; test, validate and modify existing rice, maize, soybean and peanut simulation model as screening device for varietal testing.

Project 3: Assessing Field Inoculation with Introduced and Indigenous VA Mycorrhizal Inocula by Crop Growth and Yield on Soil Cleared of Tropical Rainforest

Means to attain objective:

Compare and evaluate the influence on mungbean growth by field inoculation with organic debris (considered as indigenous VA mycorrhizal inoculum) and pot culture inoculum

(*Glomus fasciculatum*) in a soil cleared of tropical rainforest; determine the effect of land clearing on the population and inoculum potential of VA mycorrhizal fungi in the highly acid soils of the Sitiung area.

Project 4: Modeling Phosphorus-Lime Interactions

Means to attain objective:

Predict phosphorus and lime interactions in high acidity, low activity clay soils for crop modeling

Topic 4: Land Reclamation: Land Clearing and Soil Conservation

Objective: Produce economically feasible, environmentally safe and transferable methods for sustaining agricultural productivity in land cleared from tropical rainforests.

Project 1: The Role of Soil Physical Properties on Land Quality for Sustained Agricultural Production in Land Cleared by Heavy Equipment

Means to attain objective:

Identify land clearing methods that are cost-effective, agronomically sound, and enviromentally safe, identify the soil physical parameters that are adversely modified by mechanized land clearing; be able to recommend safe, inexpensive and acceptable, post land clearing soil management practices to reclaim soils damaged by mechanized land clearing; develop economic model to identify the best combination of land clearing and post land clearing method.

Project 2: Pasture Grass and Legumes for the Humid Tropics

Means to attain objective:

Evaluate germplasm in a range of environments representative of the humid tropics and to identify suitable cover crops for eroded lands.

Project 3: Management of Organic Matter in Indonesian Farming Systems

Means to attain objective:

Evaluate the importance of soil organic matter in agricultural production in Indonesia, determine its role in nutrient cycling and effect on physical and biological processes in soil; identify optimum farming systems for the management of organic materials. These should be appropriate

to the conditions in Sitiung and the constraints of subsistence level farmers; identify the major groups of soil organisms involved in organic matter decomposition in Sitiung and to study the effects of management.

Project 4: Conservation-Effective Rainfed Farming Systems for the Sitiung Area, West Sumatra

Means to attain objective:

Quantify the rainfall erosion potential for major agroenvironments in the area; evaluate the effectiveness of alternative cropping systems and land management practices for controlling the erosional losses of soil and water resources; integrate the above with other agroeconomic and socioeconomic information for use in developing productive and stable watershed-based farming system in the area.

Summary of Budget by Projects for the Humid Tropics Program
University of Hawaii

Project Short Title	Year 4	5	6	7	8	Total
			x $1000			
Soil Variability	51	53	54	55	55	268
Time Allocation Studies	29	30				59
Nutrition/Diet/Income	25	23	27	29	24	128
Farmer Interview Series	22	23	30	33	37	145
Farmer Cropping Systems	14	14				28
Crop Requirements	45	57	59	62	59	282
Field Inoculation	39	33	40	41	44	197
Modeling Phosphorus-Lime	82	59	56	61	70	328
Soil Physical Properties	131	84	95	91	97	498
Pasture Grass and Legumes	22	20	25	21	21	109
Management of Organic Matter	51	44	47	3	3	148
Conservation Systems	97	120	110	102	106	535
Backstopping	108	116	139	144	153	660
TOTAL	716	676	682	642	669	3385

Summary of Budget by Object Item and
of the Staffing Plan for the Humid Tropics Program
University of Hawaii

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	180	198	210	202	215	1005
Fringe Benefits	54	64	63	65	68	314
Supplies	63	59	54	47	42	265
Equipment	55	31	26	1	1	114
Travel	104	68	66	69	69	376
Allowances	25	28	29	27	27	136
Other Direct Costs	67	56	46	45	55	269
Indirect Costs	168	172	188	186	192	906
TOTAL	716	676	682	642	699	3385

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	3.00	3.00	3.00	2.50	2.50	5.50	8.50
Field Based Scientist	3.90	3.90	3.90	3.80	3.80	15.00	4.30
Graduate Student	6.00	6.00	6.00	6.00	6.00	30.00	0.00
Other	5.50	5.50	5.50	5.50	5.50	27.50	0.00
TOTAL	18.40	18.40	18.40	17.80	17.80	78.00	12.80

Humid Tropics Research Program Proposal

Submitted by

University of Hawaii

Goro Uehara

Program Coordinator

A major goal of the TropSoils Project is to produce soil management research results that can be successfully transferred from one research site to other locations in the Humid Tropics. The aim is to establish the cause and effect relationship between soil properties and soil behavior so that users of soil resources can understand, predict, and control the behavior and performance of soils. To say that research results can be successfully extrapolated implies that outcomes can be predicted in other locations.

To predict the performance of a crop on a specific kind of soil, it is necessary to match the requirements of the crop to the characteristics of the soil. Soil management, in one sense, is the science and art of rectifying mismatches between crops and soils. To match crop requirements to soil characteristics, one must know how soil characteristics vary spatially and temporally. It is the inability to deal with spatial and temporal variability of soil properties that prevents soil users from matching crop requirements to land characteristics, and therefore, from predicting soil behavior and performance.

In addition to the problem of soil variability and matching crop requirements to soil characteristics, there is the equally important task of matching crop and soil management requirements to the cultural and resource characteristics of the farmer. The subsistence farmer's reluctance to rectify mismatches between crop and soil arises not so much from ignorance, as from lack of resources. The adoption of soil management practices by farmers hinges on producing soil management practices tailored to fit the cultural and resource characteristics of the users.

Implicit in Figure 1 is that research on "alternative soil and crop management systems" and "land clearing practices" will lead to economically, socially, and environmentally workable outcomes that can be extrapolated to other regions of the humid tropics.

To produce transferable results, it is necessary, as stated earlier, to establish the cause and effect relationships between soil

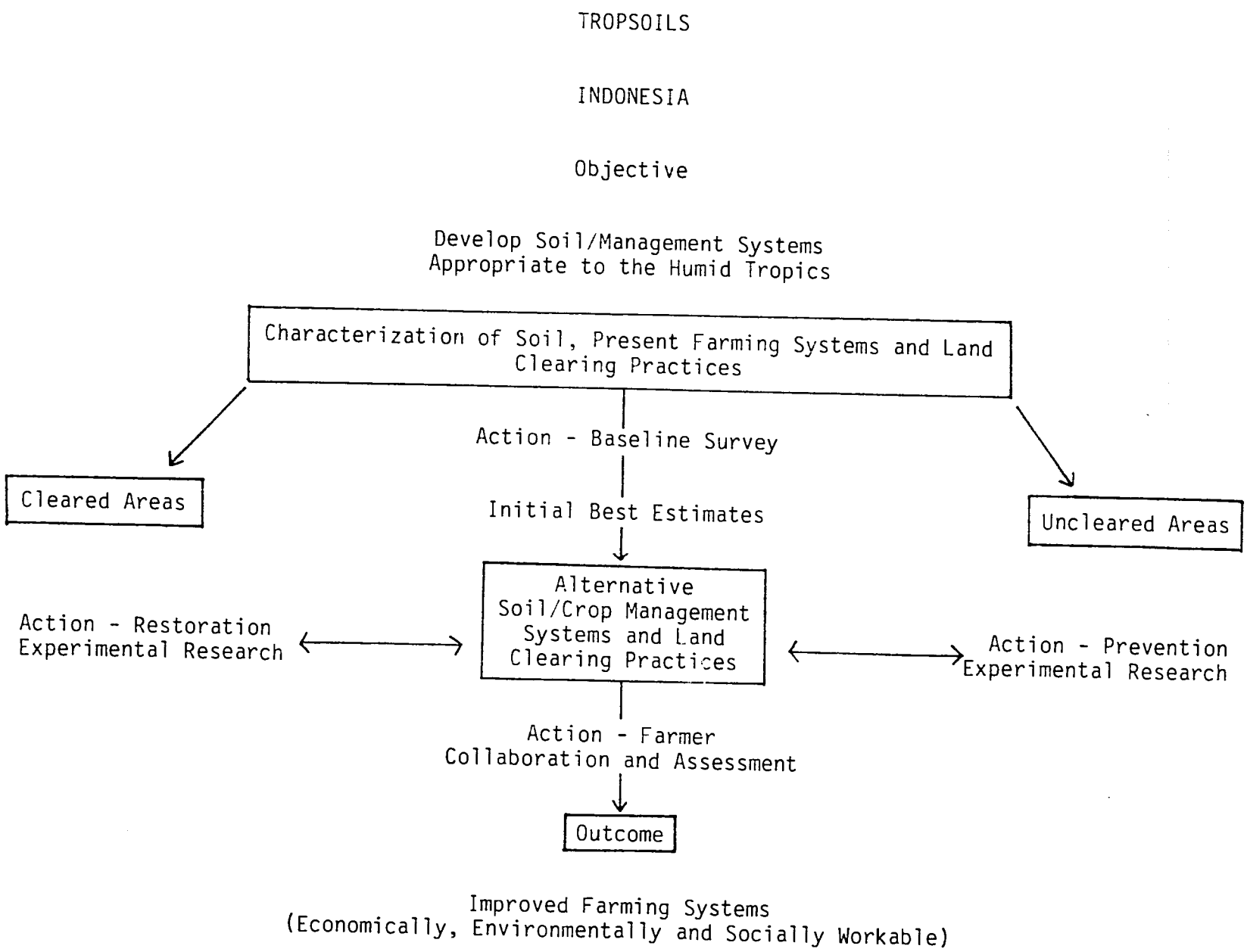

Fig. 1. Flow chart of activities for the Indonesia TROPSOILS Project. This chart was jointly prepared by the Indonesian Center for Soil Research and the collaborating U.S. universities.

behavior or performance and soil properties. It is no longer sufficient to demonstrate that a crop grown on an acid Oxisol will respond, for example, to application of lime or phosphorus. We must now identify the soil properties and understand the processes that control phosphorus dynamics, learn how plant genotype and rhizosphere biology affect soil phosphorus uptake, and document how climate affects the plant that responds to lime and phosphorus.

The Indonesia TropSoils Project is designed to deal with soil management research through systems analysis and simulation. The project is based on the premise that extrapolation and prediction of soil management outcomes can be achieved by analysis and simulation of the soil, plant, atmosphere continuum. Systems analysis and simulation are efficient and logical ways to match crops to soil and climate for extrapolation purposes.

A flowchart for modeling the soil-plant-atmosphere continuum has been developed by the Agricultural Research Service of USDA and the International Fertilizer Development Center and was prepared for use in the TropSoils and IBSNAT (International Benchmark Sites Network for Agrotechnology Transfer) projects of the University of Hawaii by C. Allan Jones of ARS and Upendra Singh of the University of Hawaii.

Over the past two years, the project has been readying itself for systems simulation research, both at the socio-economic and biophysical levels, through farmer interviews, collection of weather data and soil characterization. The collection of soil, plant, weather and human resource data requires backstopping support to develop a data base management system to store and retrieve the immense quantity of information already being generated, to produce the software from the data base with which to make predictions about soil behavior and performance, and to judge the reaction of users to soil management innovations.

A second major aim of the Indonesia TropSoils Project is to ensure that the research methodology, data base management systems, and software producing capability is left in the hands of host country scientists through training activities.

To enlarge the TropSoils training component, the host country has recommended, and the project has agreed, to invite faculty and graduate students from Brawijaya University in Malang, Gajada Mada University in Jojakarta and Pajajaran University in Bandung to participate in TropSoils research activities. The aim of inviting Indonesian university scientists to participate in TropSoils research is to enable the project to benefit from local expertise, and in addition, to enable local faculty to utilize TropSoils research findings in their teaching. Indonesian graduate students supervised by Indonesian professors will have the opportunity to interact with expatriate scientists and graduate students. The planned outcome is that indigenous and expatriate groups will gain from the combined skills and knowledge they bring to the pro-

ject. To ensure that indigenous and expatriate staff interact synergistically, expatriate scientists, graduate students, and their families have been selected not only for their technical competencies, but for their cultural sensitivities as well. The latter attribute has enabled them to work effectively in a collaborative mode with their host country colleagues.

The Indonesia TropSoils Project intends to achieve its aim of developing the means to extrapolate and predict soil management outcomes through linkages with the Agricultural Research Service of the U.S. Department of Agriculture, the International Fertilizer Development Center, the International Board for Soil Research and Management, and the Commonwealth Scientific and Industrial Research Organization of Australia. Three of these units have been selected to provide expertise in systems analysis and simulation in soils research.

TropSoils Indonesia will continue to support and encourage inter-TropSoils activities, and has agreed to take the lead in phosphorus-lime experimentation for all TropSoils institutions. It has been asked by the other TropSoils universities to take the lead in modeling soil-plant-climate processes for prediction and extrapolation, and has agreed to support the other universities in the areas of nitrogen dynamics (Cornell University), soil-water-atmosphere-plant relations (Texas A&M University) and soil dynamics (North Carolina State University).

After three years of research and experience, the Indonesia TropSoils Project is ready to enter a new phase of expanded collaborative research on soil management.

Program: Humid Tropics

Research Topic

Title: Site Characterization

Goal: Develop method to conduct field experiments in plots with high soil spatial variability

Project

Title: Soil Variability in Mechanically Cleared Forest Land

Objectives:

(A) Construct semi-variograms of soil properties to determine structure in the variance of soil properties

(B) Use the structure in the variance of soil chemical and physical properties by geostatistical methods to predict soil properties in unsampled locations

(C) Relate soil and crop variability patterns using geostatistical approaches to match soil management inputs to spatially variable soils.

Project Leaders: Russell Yost, University of Hawaii
Goro Uehara, University of Hawaii

Collaborating Scientists: Soleh Sukmana, Center for Soil Research
John R. Thompson, University of Hawaii, Sitiung
Michael Wade, North Carolina State University, Sitiung
Jean-Pierre N'Diaye, University of Hawaii
H. Rum, Center for Soil Research

Reasons for Investigation:

Soil variability in short distances (2-3 meters or less) appears to be a common attribute of newly cleared land in the Sitiung area (M. Sudjadi, personal communication) and from our observations of local crops on several locations. Indeed local variability may be more prevalent in some areas (Sumatra) than in others (Peruvian jungle) according to some. Agricultural experimentation on such highly variable land is difficult at best. Often variability within a plot of approximately 3 x 5 m can be greater than that occurring between the main treatments (CSR observation, 1980; personal observation, 1984). The result is that such variation is allocated to the error term of the ANOVA and few if any treatments differ significantly. Perhaps more importantly the data from

such experiments is of doubtful utility in making recommendations on highly variable farmers' fields.

Our approach also will include consideration of differences among crop plants in their root configuration. Crop roots vary in the extent of ramification as well as in capability to proliferate in zones of high fertility. Several of the crops we shall compare represent some of the extremes in these characteristics. We suggest that because of differences in root configuration and physiology, some plants are better adapted to highly variable soil conditions.

These crops are being evaluated across the gradient in soil chemical properties (pH 3.9 - 6.5, Al saturation varying from 0 to 96%. If the nature and character of such variation can be understood it is probable that methods can be developed to permit better experimentation and which may suggest practical methods for the individual farmer to correct the numerous low productivity areas in their gardens and fields.

Relevance to Other Programs:

Understanding soil variability is fundamental to agronomic investigation. Evidence is strong that classical field experimentation techniques based on the assumption of uniform experimental material may not be the most appropriate for efficient agronomic investigations on highly variable fields such as those in the Sitiung area. This experiment has already provided indication of the major sources of the microscale variability and suggested the need for detailed sampling in the existing field experiments.

Soil variability which cannot be accounted for by traditional soil survey methods can be dealt with by application of the theory of regionalized variables. This type of soil variability occurs in every agroecological zone and can be accommodated by existing computer software. These softwares are available in a dissertation that has been distributed to all SM-CRSP projects.

Use of these techniques requires access to mainframe computers. It is the intent of this project to train an Indonesian graduate student in this technique when he or she arrives in Hawaii.

Generalized Procedures:

The theory of regionalized variables has been developed by mining engineers to extract the maximum amount of information from a minimum amount of sampling data. The sample data are used to generate a semi-variogram which shows the existence or non-existence of spatial relationships among neighboring samples. If such relationships exist, the information in the semi-variogram can be used to estimate values of soil properties in unsampled locations. This additional information can be used to prepare more accurate soil maps so that problem areas can be more precisely pinpointed.

The theory of regionalized variables will be applied to two sets of data. The first set consists of 88 soil profiles analyzed by the Center for Soil Research. The samples were collected from the 100,000 hectare transmigration site. The second set of data was collected from a plot in a farmer's field by the TropSoils team. The samples were analyzed by the soil characterization laboratory of the Center for Soil Research in Bogor.

A third set of data is planned for the land clearing site. An area of high soil variability has been selected and established. Samples of soil and plants have been collected in the area. Additional samples will be collected of the various crops and fertilization that will follow. After a sequence of crops have been compared for their tolerance to high soil variability we propose to divide the experimental area into standard experimental plots and superimpose fertility treatments which do and which do not take into consideration the inherent soil variability. For the larger scale work we expect to incorporate new data and information in the fertility maps developed by Trangmar (1984).

Principal Site for Experimentation: Sumatra, Indonesia

Duration: July 1982 to September 1988

Management Entity Comment:

A comprehensive review will be made before the end of year five of this and other spatial variability studies supported by the SM-CRSP to determine their actual or potential contribution to program goals and funding for succeeding years reconsidered after the review.

Soil Variability in Mechanically Cleared Forest Land
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	10	11	11	12	13	57
Fringe Benefits	4	6	6	7	7	30
Supplies	10	7	7	8	7	39
Equipment	3	3	1	0	0	7
Travel	7	8	9	9	9	42
Allowances	1	2	2	2	2	9
Other Direct Costs	4	2	2	1	1	10
Indirect Costs	12	14	16	16	16	74
TOTAL	51	53	54	55	55	268

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.20	0.20	0.30	0.40	0.40	0.00	1.50
Field Based Scientist	0.20	0.20	0.20	0.20	0.20	0.50	0.50
Graduate Student	1.00	1.00	1.00	1.00	1.00	5.00	0.00
TOTAL	1.40	1.40	1.40	1.40	1.60	5.50	2.00

Program: Humid Tropics

Research Topic

Title: Baseline Farming Systems Research

Goal: Improve quality of life for transmigrant and local farmers

Project

Title: Time Allocation Studies

Objectives: To tailor soil management research to the cultural and resource characteristics of the farmer by:

(A) Ascertaining the current division of farm labor, by sex and age

(B) Determining how people were choosing to use their labor

(C) Establishing important seasonal variation in activities

(D) Maintaining ongoing communication between researchers and farming families.

Project Leader: Carol Colfer, University of Hawaii

Collaborating Scientists: Atin Kurdiana, Center for Soil Research
Edi Santoso, Center for Soil Research
Veronica Kasmini, Center for Soil Research
Russell Yost, University of Hawaii

Reasons for the Investigation:

Many promising soil management innovations and practices are not adopted by farmers because the effort required to implement the innovation conflicts with the work habits and schedule of the farmer. Farmers generally invest their greatest effort on activities which are critical to their survival and quality of life. Time allocation studies of farmer activities are efficient ways to identify priority soil management research that correspond to farmer needs.

Relevance to Other Programs:

The applicability of these findings will depend on the similarities between this location and others to which one might wish to generalize. However, the process is an easy one to replicate, and other researchers all over the world are conducting time allocation studies (using this

method as well as others). There is considerable probability that transmigrants of similar ethnic groups in other tropical rainforest locations will have similar options for spending their time.

Besides the benefit of allowing the team to answer specific, research-related questions about the population with which they are working, this time allocation study contributes to a growing body of information about how people spend their time. In recent years, there has been an increasing recognition that unpaid work has been underestimated and undervalued. This particularly affects poor people and women, and researchers have begun to develop a body of information on how people spend their time when they are not being paid. The TropSoils studies can contribute to this body of knowledge.

Generalized Procedure:

The approach was somewhat different from many time allocation studies in that people were not asked to remember how much time they devoted to some preselected tasks. Rather a randomized schedule was drawn up at the beginning of the study for the entire year. Visits were then made to the scheduled households, and the activities of all members of the household were noted. Four households were visited each day.

Principal Site for Experimentation: Sumatra, Indonesia

Duration: September 1983 to September 1986

Management Entity Comment:

This activity and the following two, "Nutrition/Diet/Income Survey" and "Co-operative Farmer Interview Series" are to be consolidated into a single project with sharply focused objectives to reflect the contribution of the sociological component to the SM-CRSP goal. The revised project is to be completed prior to the end of year four and budget consolidation made to reflect this action.

Time Allocation Studies
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	8	9	0	0	0	17
Fringe Benefits	3	3	0	0	0	6
Supplies	1	1	0	0	0	2
Equipment	1	0	0	0	0	1
Travel	3	3	0	0	0	6
Allowances	1	1	0	0	0	2
Other Direct Costs	5	5	0	0	0	10
Indirect Costs	7	8	0	0	0	15
TOTAL	29	30	0	0	0	59

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.10	0.10	0.00	0.00	0.00	0.00	0.20
Field Based Scientist	0.25	0.25	0.00	0.00	0.00	0.50	0.00
TOTAL	0.35	0.35	0.00	0.00	0.00	0.50	0.20

Program: Humid Tropics

Research Topic

Title: Baseline Farming Systems Research

Goal: Improve quality of life for transmigrant and local farmers

Project

Title: Nutrition/Diet/Income/Survey

Objective: Establish a baseline for nutritional status, dietary patterns and income levels in the area of field research investigations from which to measure impact of soil management research on quality of life of farmers.

Project Leader: Carol Colfer, University of Hawaii

Collaborating Scientists: Barbara Chapman, consultant
Liek Irianti, IPBNP
Barthoiomeus Wied Apriadji, IPBNP

Reasons for the Investigation:

A purpose of this study is to compare the nutritional status and income levels of the people now with what is obtained at the conclusion of the TropSoils project. In the interim, the team hopes to compare various survey questions in this location and in the urban context of Bogor. It may be possible to make comparisons with other countries which participated in the Street Foods Project. Chapman is quite interested in comparing the findings in Sumatra with those of her previous research in Central Java several years ago. The analysis will provide the team with a means of assessing the appropriateness of proposed new crops for experiments over time. Entry of these data into a computerized data base management system will improve their usefulness.

Relevance to Other Programs:

The relevance of these findings should be reasonably great for other transmigration sites. The findings from Sitiung V, where the people had only recently stopped receiving their government subsidy, should be of relevance for assessing the adequacy of the subsidy. The description of the subsistence adjustment that has been made by the longer term residents can also be of use to the team in suggesting agronomic improvements that are consistent with existing patterns.

Generalized Procedure:

The dietary patterns were of particular interest since the team hoped to select food crops for use in management experiments which would be usable by transmigrants in their subsistence efforts and would supplement nutritional deficiencies. Data were also collected on the agricultural production of families. The team wanted a reading on the relative wealth of Sitiung I compared to II (irrigation and no irrigation, respectively); and Sitiung V which, in contrast to I and II, is newly settled.

The approach was to utilize experienced researchers combined with knowledge of local conditions to construct a survey instrument that would provide the information desired. People were interviewed in their homes, usually in their language. Each of the 80 families was interviewed twice, on consecutive days, so that relying as little as possible on memory would produce more accurate food consumption data. Income data were obtained to include agricultural production that was consumed and not sold, using market prices that were obtained at the time of the interviews.

Principal Site of Experimentation: Sumatra, Indonesia

Duration: April 1984 - March 1988

Management Entity Comment:

Refer to comment under "Time Allocation Studies"

Nutrition/Diet/Income Survey
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	6	7	8	8	8	37
Fringe Benefits	1	2	2	2	2	9
Supplies	1	1	1	1	0	4
Equipment	2	0	0	0	0	2
Travel	3	2	3	4	0	12
Allowances	2	1	2	2	2	9
Other Direct Costs	4	4	4	3	4	19
Indirect Costs	6	6	7	9	8	36
TOTAL	25	23	27	29	24	128

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Field Based Scientist	0.20	0.20	0.30	0.30	0.30	1.30	0.00
TOTAL	0.20	0.20	0.30	0.30	0.30	1.30	0.00

Program: Humid Tropics

Research Topic

Title: Baseline Farming Systems Research

Goal: Improve quality of life for transmigrant and local farmers

Project

Title: Cooperator Farmer Interview Series

Objective: Produce method for matching soil management requirements to cultural and resource-characterization of farmers by:

(A) Monitoring characteristics of the farming families with whom the team is working

(B) Comparing their lives with those of a randomly selected group of "control" farming families.

Project Leader: Carol Colfer, University of Hawaii

Collaborating Scientists: Barbara Chapman, consultant
Veronica Kasmini, Center for Soil Research
Bartholomeus Wied Apriadji, IPBNP
Liek Irianti, IPBNP

Reasons for the Investigation:

The principle of matching the requirements of a soil management innovation to the cultural and resource-characteristics of the farmer entails knowledge of the requirement of the innovation and the characteristics of the user of the innovation. This interview series is designed to understand the cultural and resource characteristics of the farmer so that soil management innovations can be tailored to match the needs and absorptive capacity of the farmer.

Relevance to Other Programs:

The relevance of this interview series derives more from the process of determining what questions need to be answered than from the specific questions deemed important by this particular team in this particular location. It is hoped that soil scientists working in this team will leave the project understanding that information from farmers is relevant and is also accessible by relatively straightforward procedures. If these persons do not try to gain this information themselves

in the future, at least they will understand that it is important and seek help from social scientists.

Generalized Procedure:

The approach involves development of rapport with 40 families, and periodic interaction with them over time. Effort was made to develop a sense of trust and understanding of team goals, and thereby increase the likelihood of getting accurate responses to queries. The families that were surveyed by the nutritionists included those involved in this interview series.

The following represent kinds of questions that have been incorporated into the interview series. Since the people appeared to be quite interested in fruit trees, questions on the kinds, numbers and locations of fruit trees were included. In this way the existence of a variety of fruit trees already planted in people's houselots was verified, as well as the people's interest in these crops. This information is then shared with the soil scientists.

The team wanted a sense of whether the people in the community were experienced in agriculture so a question on land holdings and previous agricultural experience was included. About half of the farmers interviewed had been landless in Java, but virtually all had had agricultural experience as laborers.

At another point the team wanted to get an idea of how much money the people had brought with them. The purpose of this question was to ascertain whether they had funds to buy agricultural inputs. The whole series was designed to monitor and provide ongoing information as the team decided would be useful.

Principal Site for Experimentation: Sumatra, Indonesia

Duration: November 1983 to September 1989

Management Entity Comment:

See comment under "Time Allocation Studies."

Cooperator Farmer Interview Series
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	8	9	9	10	11	47
Fringe Benefits	2	2	2	3	3	12
Supplies	1	1	1	1	1	5
Travel	2	2	2	3	5	14
Allowances	2	2	2	3	3	12
Other Direct Costs	1	1	3	3	3	11
Indirect Costs	6	6	10	11	11	44
TOTAL	22	23	29	34	37	145

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Field Based Scientist	0.25	0.25	0.30	0.30	0.30	1.40	0.00
TOTAL	0.25	0.25	0.30	0.30	0.30	1.40	0.00

Program: Humid Tropics

Research Topic

Title: Improving and Sustaining Soil Productivity in Farmers' Fields

Goal: To develop efficient rations of fertilizer for improved crop production

Project

Title: Farmer and Researcher Designed and Managed Cropping Systems

Objectives:

(A) To compare fertilizer packages, including rock phosphate or lime against the current government supplied package of urea and treble superphosphate (TSP).

(B) To enhance interaction with local farmers so as to better understand their problems and their goals.

(C) To learn and get ideas from the farmers, drawing on their knowledge and experience to help generate more appropriate research.

Project Leader: Michael Wade, North Carolina State University

Collaborating Scientists: Carol Colfer, University of Hawaii
Soleh Sukmana, Center for Soil Research
Suwandi, Center for Soil Research
Atin Kurdiana, Center for Soil Research

Reasons for the Investigation:

Farmers newly arriving at transmigration sites are often working in a vacuum. They have just been moved from an area with very different soils and climate. They, like the researchers, are in a new and different situation. They are very open, and searching for new information and technology. By working closely with such farmers, the researchers can find more appropriate and usable technology that can be of immediate use to other new transmigrants in neighboring or similar areas.

By the close association with these farmers, the researchers also gain insight into the goals, problems, and thinking of transmigrants. This interaction in turn should help guide the component research so as to provide more culturally and economically acceptable technology.

Relevance to Other Programs:

The results of this research should impact on package suitability and management implications for farmers arriving at newly cleared sites. It also gives the researchers the opportunity to monitor soils and farmers from their time of arrival. Information gained can be used for making recommendations and designing research in other new areas.

Generalized Procedures:

On-farm, farmer-managed trials involved 19 participating farmers, one replication per farmer. The initial period was one year, with the intention of making use of established contacts and rapport with these farmers that can be used to test positive results from component trials in years to come.

The cropping pattern used was an intercropping pattern of rice with relay planted cassava. After the rice harvest, peanuts and chili peppers were planted between the cassava. Large plots (20 x 40 m) were divided into four treatments on each farm. The researchers laid out the plots and applied the fertilizers and lime according to the treatments. The farmers were primarily responsible for labor and crop protection decisions. The researchers provided seed and pesticide as required or requested. Planting patterns (species, timing and spacing) were determined collectively by the farmers and the scientists.

Tillage decisions were left to the farmer for the no fertilizer and government packages. The rock phosphate and lime plots were to be hoed after broadcasting the rock and lime. TSP was banded in all cases. Three farmers were selected not to hoe the rock and lime.

Principal Site for Experimentation: Sumatra, Indonesia

Duration: October 1983 to September 1986

Management Entity Comment:

A revised project will be developed, prior to the end of year four to set forth a five year program involving Wade and Colfer with objectives oriented toward on-farm validation of research results and adaptation for farm conditions.

Farmer and Researcher Designed and Managed
Cropping System Experiments
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	3	4	0	0	0	7
Fringe Benefits	2	2	0	0	0	4
Supplies	1	1	0	0	0	2
Travel	1	0	0	0	0	1
Other Direct Costs	4	4	0	0	0	8
Indirect Costs	3	3	0	0	0	6
TOTAL	14	14	0	0	0	28

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Field Based Scientist	0.10	0.10	0.00	0.00	0.00	0.20	0.00
TOTAL	0.10	0.10	0.00	0.00	0.00	0.20	0.00

Program: Humid Tropics

Research Topic

Title: Improving and Sustaining Productivity in Farmers' Fields

Goal: Find crops suited for climate and soils of the humid tropics.

Project

Title: Matching Crop Requirements of Rice, Maize, Soybean and Peanut to Soil Characteristics with Crop Simulation Models

Objectives:

(A) Identify the minimum soil, crop and weather data needed to predict the performance of rice, maize, soybean and peanut cultivars in the humid tropics.

(B) Test, validate and modify existing rice, maize, soybean and peanut simulation models using the minimum data set.

(C) Use rice, maize, soybean and peanut simulation model as screening device for varietal testing.

Project Leaders: Russell Yost, University of Hawaii
Michael Wade, North Carolina State University
Goro Uehara, University of Hawaii

Collaborating Scientists: Upendra Singh, University of Hawaii
John Thompson, University of Hawaii
Patrick Ching, University of Hawaii
Clement P. Y. Chan, University of Hawaii
Gordon Y. Tsuji, University of Hawaii

Reasons for the Investigation:

When a new, high performance cultivar of a food crop is developed, it is widely tested in a number of locations to determine its range of adaptability. This method is called testing by trial and error. How well a crop cultivar performs in a particular location depends on how well the environmental requirements of the crop match the environmental characteristics of the location. Many of the mismatches that cause crops to perform poorly can be rectified by management. This is particularly true of soil constraints.

Trial and error varietal testing is slow and achieved at high social costs. There is currently available (e.g. maize, soybean) well-developed crop models that will simulate performance of a cultivar in a specific location on a specific named kind of soil. Simulation models are currently being developed for rice (IRRI, CSIRO Australia, and ARS) and peanut (University of Florida). These models have been designed to replace trial and error varietal testing with testing by simulation. Simulation is not intended to replace field validation of crop performance, but is designed to screen large numbers of cultivars and to identify the most likely candidate for field testing.

Simulation techniques can also use historical weather data to perform 50 year or even longer simulations, and display the yield distribution for this period as a histogram. The histogram will reveal the number of good, average and bad years. Thus, simulation techniques can provide information about risks due to weather variability that a few years of field experimentation can never provide.

In order to predict the performance of a cultivar, information about the soil, climate and the genetic makeup of the crop must be used in the model. These models enable soil management practices to be analyzed for different cultivars and different climatic conditions and soils. It is potentially a powerful technique to extrapolate soil management techniques not only within agroecological zones, but among them.

Relevance to Other Programs:

This project is directly relevant to the erosion and phosphorus-lime modeling projects. The ability to simulate crop productivity over long periods (50 years or more) is necessary for assessing the impact of erosion on productivity. The Agricultural Research Service of the USDA has an erosion model called EPIC (Erosion Productivity Impact Calculator). EPIC has a crude crop model built into it and can benefit from the more detailed models envisioned under this project. An effort will be made to ensure that a common "minimum data set" is collected from this project, the erosion project, and the phosphorus-lime project so that results from all projects can be used to examine the interdependence of components of the larger system.

Generalized Procedures:

The University of Hawaii has compiled the recommendations of an international group of soil scientists, agronomists and modelers into a document entitled "Experimental design and data collection procedures for IBSNAT collaborators". The minimum data set to collect for rice, maize, soybean and groundnut is outlined in this document and needs to be accepted or revised as needed by the TropSoils group.

The ARS group in Temple, Texas has agreed to develop with the University of Hawaii a rice model. The same group already has an

operating model for maize which can be tested and validated immediately.

The University of Florida (Agricultural Engineering Department) has agreed to modify its soybean model to fit groundnuts (peanut).

Small subgrants to ARS and the University of Florida from the Hawaii TropSoils project will enable these two organizations to accelerate model development for use in Indonesia.

The testing and validation of the crop models will be in Sitiung sites with weather stations. The minimum data sets require daily collection of maximum and minimum air temperature, solar radiation and rainfall.

A central data base management system for storage and retrieval of the minimum data set will be developed at the University of Hawaii. These data will be sent to ARS, Temple, Texas and the University of Florida for analysis.

Training of Indonesian and TropSoils scientists in simulation techniques will be provided in workshops.

Principal Site for Experimentation:

This is a project that can be installed in at least three of the four TropSoils sites, including Peru, Indonesia, and Brazil. The Niger site can restrict their crops to peanut and sorghum. The collection of the minimum data sets guarantees that all project results can be analyzed by the same model for serving a common purpose, namely to find the best soil management practice for a particular crop under specific soil conditions. The result of this project will be greatly increased in value if the experiments are conducted in a range of agroenvironments.

Duration:

This project is designed to test each crop for at least two years. If two crops are tested at any given time, a total of four years of field work will be required. A six-month to one-year planning period will be needed to reach consensus on project design. April 1985 to September 1989.

Management Entity Comment:

The project is to be rewritten, prior to the end of year four, to more clearly show its relationship to the CRSP objectives and the probability of successful completion by the end of year eight. Funding beyond year four is contingent on evaluation of revised project.

Matching Crop Requirements of Rice, Maize, Soybean and Peanut to Soil Characteristics with Crop Simulation Models
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	7	8	8	8	8	39
Fringe Benefits	1	2	2	2	2	9
Supplies	8	10	7	8	7	40
Equipment	1	0	2	0	0	3
Travel	9	11	10	12	12	54
Allowances	1	1	2	2	2	8
Other Direct Costs	3	4	4	5	4	20
Indirect Costs	14	21	25	25	24	109
TOTAL	45	57	59	62	59	282

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.50	0.50	0.50	0.20	0.20	0.00	1.90
Field Based Scientist	0.10	0.10	0.10	0.10	0.10	0.00	0.50
Graduate Student	1.00	1.00	1.00	1.00	1.00	5.00	0.00
TOTAL	1.60	1.60	1.60	1.30	1.30	5.00	2.40

Program: Humid Tropics

Research Topic

Title: Improving and Sustaining Productivity in Farmers' Fields

Goal: Manage soil phosphorus efficiently

Project

Title: Assessing Field Inoculation With Introduced and Indigeous VA Mycorrhizal Inocula by Crop Growth and Yield on Soil Cleared of Tropical Rainforest.

Objectives:

(A) To increase food crop production by field inoculation with organic debris (considered as indigeous VA mycorrhizal inoculum) and pot culture inoculum (Glomus fasciculatum) in a soil cleared of tropical rainforest

(B) To exploit VA mycorrhizal fungi for reclaiming land damaged by improper land clearing methods.

Project Leaders: Russell Yost, University of Hawaii

Collaborating Scientists: Soleh Sukmana, Center for Soil Research
E. Santoso, Center for Soil Research
John Thompson, University of Hawaii
Michael Wade, North Carolina State University
Ruey-Shang Huang, University of Hawaii

Reasons for Investigation:

Soils in the area are P deficient and P has been shown to be economically important from food crop production. VA mycorrhizal fungi have been shown to influence P absorption in situations where the indigenous population is low.

Relevance to Other Programs:

Vigorous mycorrhizae symbiosis is important for an efficient utilization of soil P reserves. We expect that the mycorrhizal status of the selected crops will be influenced by various land clearing options, various soil amendment treatments, various crop residue management options, and that knowledge of the status of the mycorrhizae symbiosis will aid in assessing the influence of these treatments. In addition, we expect that land clearing practices which seek to maintain the orga-

nic matter covering will similarly help assure a high VA mycorrhizal propagule density and also provide favorable conditions for development of the symbiosis.

Generalized Procedures:

Field experiments will be conducted to assess indigenous populations of VAM propagules, evaluate the role of land clearing options on resultant propagule density, and to explore practical methods for farmers to reinoculate fields low in VAM propagules.

Principal Site for Experimentation: Sumatra, Indonesia

Duration: April 1985 to May 1989

Management Entity Comment:

Project to be rewritten prior to the end of year four to state more sharply defined focus and greater detail on procedure. A critical review will be conducted of the project prior to the end of year five and funding beyond that time reconsidered pending outcome of the review.

Assessing Field Inoculation with Introduced and Indigeous VA Mycorrhizal by Crop Growth and Yield on Soil Cleared of Tropical Rainforest
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	7	7	8	8	8	38
Fringe Benefits	2	4	4	5	5	20
Supplies	6	4	5	5	6	26
Equipment	7	0	0	0	0	7
Travel	7	7	8	8	9	39
Allowances	1	2	2	2	2	9
Other Direct Costs	1	1	2	2	2	8
Indirect Costs	8	8	11	11	12	50
TOTAL	39	33	40	41	44	197

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.10	0.10	0.10	0.10	0.10	0.00	0.50
Field Based Scientist	0.10	0.10	0.10	0.10	0.10	0.00	0.50
Graduate Student	1.00	1.00	1.00	1.00	1.00	5.00	0.00
TOTAL	1.20	1.20	1.20	1.20	1.20	5.00	1.00

Program: Humid Tropics

Research Topic

Title: Improving and Sustaining Productivity in Farmers' Fields

Goal: Apply systems analyses and simulation techniques to soil fertility research

Project

Title: Modeling Phosphorus-Lime Interactions

Objective: To predict phosphorus and lime interactions in high acidity, low activity clay soils for crop modeling

Project Leaders: Andrew Sharpley, USDA/ARS
Goro Uehara, University of Hawaii

Collaborating Scientists: Eugene Kamprath, North Carolina State University
Robert L. Fox, University of Hawaii
Allan Jones, USDA/ARS
Russell Yost, University of Hawaii
Douglas Godwin, International Fertilizer Development Center
Upendra Singh, University of Hawaii
Michael Wade, North Carolina State University
Indonesian scientist
Bernardino G. Cagauan, Jr., University of Hawaii
James A. Silva, University of Hawaii

Reasons for the Investigation:

Phosphorus deficiency and aluminium toxicity are two common soil constraints encountered by farmers in the humid tropics. How a crop reacts to these two constraints depends on the genetic makeup of the plant, the weather conditions during the growing period, water supply, and the chemical, physical, and biological conditions of the soil. Most soil fertility research is conducted so that all factors other than the one being studied are held constant and near optimum. But because phosphorus and lime interact with each other and with other nutrients, water supply, plant genetics, and weather conditions, a systems approach is required to integrate information into a model that predicts the effects of lime or phosphorus on crop performance when a host of constraints are operating simultaneously, as it almost always does in a farmer's field.

Until now, the systems approach could not be applied to soil fertility research because the means to integrate large numbers of factors

into a crop simulation model was not available. Recently, ARS scientists at the Grassland, Soil and Water Research Laboratory in Temple, Texas, working with the International Fertilizer Development Center in Muscle Shoals, Alabama have developed mathematical models that simulate nitrogen dymanics and water balance in soils, and predict the effect of genotype and weather on crop performance. These models, which until a year ago could only be executed on large, mainframe computers, can now be run on readily available, inexpensive microcomputers. These models translate daily weather information into soil moisture and soil temperature for assessing the whereabouts and availablilty of nutrients with respect to rooting depth and distribution.

A phosphorus-lime model that operates in concert with nitrogen dynamics, water balance, genotype and weather conditions will enable users of the model to predict the effects of phosphorus deficiency and aluminum toxicity in a wide range of environments. Such models can be used to assess the economics of fertilizer and lime applications when weather conditions and other nutrient levels are not constant and limiting.

Relevance to Other Programs:

The systems approach is by definition an approach that examines components of a farm in the context of the system as a whole. This approach enables the user to simulate crop response to phosphorus or lime application for different genotypes growing under conditions of nitrogen or water stress. It is the capacity to measure the connection and relevance of one part of a system to all other parts that justify adoption of the system approach in soil management research.

Generalized Procedure:

The systems approach requires interdisciplinary planning and designing of the research. Because of limited resources, TropSoils cannot hope to develop a phosphorus-lime simulation model for predicting crop performance without interagency collaboration. To ensure efficiency and cost-effectiveness, the project leaders and collaborating scientists have agreed to the following procedures:

1. Conceptualization of the phosphorus-lime model. This will be achieved by a January 1985 meeting of modelers (Jones, Godwin), agronomists (Fox, Kamprath), soil scientists (Yost, Uehara, Singh, Wade), and chemist (Sharpley). An Indonesian or U.S. scientist from Sitiung will also be asked to attend this meeting. The meeting will be held on the campus of the University of Hawaii.

2. Experimental design. An experimental design for field implementation will be developed during the January 1985 meeting in Hawaii. The experiment will be designed to test and validate a crop model that includes the new phosphorus-lime simulator. The test crop

will be corn for which a good model that is known to work in Sumatra is available.

3. Identifying the minimum data set needed to test and validate the phosphorus-lime simulator. The participants of the interdisciplinary meeting in January 1985 will reach consensus on the minimum data set to collect from the field experiments. The minimum data set will include soil, crop (genotype), weather (daily), and management information. The agreed on minimum data set will be reproduced for distribution to others.

Principal Site for Experimentation:

The principal site for field experimentation to test and validate the phosphorus model will be in Sitiung, West Sumatera where the TropSoils project already has fully characterized soils and an operating weather station. The project is designed so that the same experiment can be installed in any of the TropSoils sites in Brazil, Niger or Peru.

Duration:

The project requires two years of field work consisting of two dry season and two wet season experiments in the principal research site, and one year of field experiment in Brazil, Peru and Niger. The first six months will be for project planning. Project duration will be from January 1985 - September 1989.

Management Entity Comment:

Funding beyond year four contingent upon submission of satisfactory details of experimental procedure, including extent, design, and mode of conducting field experiments, to verify the model and demonstrate its utility for accomplishing SM-CRSP goals.

Modeling Phosphorus Lime Interactions
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	7	8	8	8	8	39
Fringe Benefits	1	1	1	1	1	5
Supplies	11	8	8	9	7	43
Equipment	17	2	3	0	0	22
Travel	11	10	10	10	11	52
Subcontract	10	10	5	10	15	50
Allowances	1	1	1	1	1	5
Other Direct Costs	7	4	4	5	5	25
Indirect Costs	17	16	16	18	20	87
TOTAL	82	59	56	61	70	328

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.60	0.60	0.60	0.40	0.40	0.00	2.60
Field Based Scientist	0.10	0.10	0.10	0.10	0.10	0.00	0.50
Graduate Student	1.00	1.00	1.00	1.00	1.00	5.00	0.00
TOTAL	1.70	1.70	1.70	1.50	1.50	5.00	3.10

Program: Humid Tropics

Research Topic

Title: Land Reclamation: Land Clearing and Soil Conservation

Goal: To sustain agricultural productivity in land cleared from tropical rainforests.

Project

Title: The Role of Soil Physical Properties on Land Quality for Sustained Agricultural Production in Land Cleared by Heavy Equipment

Objectives:

(A) Identify land clearing methods that are cost-effective, agronomically sound, and environmentally safe.

(B) Identify the soil physical parameters that are adversely modified by mechanized land clearing.

(C) Be able to recommend safe, inexpensive and acceptable, post land clearing soil management practices to reclaim soils damaged by mechanized land clearing.

(D) Develop economic model to identify the best combination of land clearing and post land clearing method.

Project Leaders: Keith Cassel, North Carolina State University
Goro Uehara, University of Hawaii
Russell Yost, University of Hawaii

Collaboratoring Scientists: Soleh Sukmana, Center for Soil Research
John Thompson, University of Hawaii
Michael Wade, North Carolina State University
Carol Colfer, University of Hawaii
Gordon Y. Tsuji, University of Hawaii
Bernardino G. Cagauan, Jr.. University of Hawaii

Reasons for the Investigation:

Land clearing of forested lands by bulldozers is fast and inexpensive, on the one hand, and detrimental to the soil on the other. The detrimental effects can be measurably reduced by a combination of operator training, choice of mechanized equipment and method of clearing. On the other extreme, manual clearing provides a non-damaging, but also slow and costly alternative.

The best land clearing method depends on the purpose for which the land is being cleared, the resource available, the speed with which the land needs to be cleared, and the characteristics of the land. This implies that there is no best land clearing method, but that there is a set of best methods for a corresponding set of specific situations.

Relevance to Other Programs:

The quality of land clearing affects subsequent productivity of the land, and therefore, the quality of life for the farm family. The quality of life and problems encountered by the farm family determine to a large degree the nature of the activities for the TropSoils program. Research to rectify damaged soil can be avoided by preventing the damage to occur in the first place. It is highly likely that the Sitiung farmer is today paying a high price for the way in which his land was cleared.

Generalized Procedures:

Much land clearing research has already been done by a number of research groups in several locations, including Indonesia. To avoid rediscovering what has already been done and to ensure that economy of thought, time and action is achieved, the intent of this project is to link its activities to the land clearing program of the International Board for Soil Research and Management (IBSRAM).

IBSRAM is planning a land clearing workshop in Sitiung or Padang in August 1985. The purpose of the conference is to develop (1) a strategy for land clearing research and (2) a network of land clearing projects to answer questions about land clearing. It is the intent to use this workshop to design a research plan on land clearing that avoids rediscovering what has been done in the past and focuses on the objectives listed for this project. The detailed procedures for achieving the stated objectives will be developed during the workshop. The budget is based on estimated need for conducting land clearing research obtained from discussions with local heavy equipment contracting firms and scientists who have worked on the land clearing work in Yurimaguas, Peru. Ten hectares of land have already been cleared with Indonesian funds, and the continued financial and personnel support from the Center for Soil Research has been assured.

Principal Site for Experimentation:

A 220 hectare forested area has been surveyed for vegetation and soil in readiness for this project. The Center for Soil Research will convert this land into a permanent research station and has decided to take advantage of the necessary land clearing operations and will use them to answer questions on land clearing. This parcel of land located on the dissected peneplain and occupied mainly by Oxisols and Ultisols has been selected to represent the full soil and topographic range in

the region. About a third of the area is relatively flat and the remainder varies in steepness.

During the workshop on land clearing scheduled for August 1985, IBSRAM intends to develop a network of landclearing projects to answer a broader spectrum of questions including long term environmental effects of deforestation. Dr. Rattan Lal of the International Institute of Tropical Agriculture is organizing the workshop program to ensure that Africa, South and Central America and Asia are included in the network. The Sitiung TropSoils land clearing project will be the first member to be identified in the Network.

Duration: October 1984 to September 1989.

Management Entity Comment:

The project is to be rewritten following the IBSTRAM workshop on land clearing to provide more sharply focused objectives and experimental plan. The revised project is to elaborate on the economic component identified under objective "D," but currently lacking in specificity on means of accomplishment.

The Role of Soil Physical Properties on Land Quality
for Sustained Agricultural Production on Land Cleared
by Heavy Equipment
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	22	25	28	29	31	135
Fringe Benefits	9	10	11	12	13	55
Supplies	12	10	10	10	10	52
Equipment	12	6	9	1	1	29
Travel	40	6	8	9	10	73
Allowances	3	4	4	4	4	19
Other Direct Costs	6	4	4	3	4	21
Indirect Costs	27	19	21	23	24	114
TOTAL	131	84	95	91	97	498

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.10	0.10	0.10	0.10	0.10	0.00	0.50
Field Based Scientist	0.50	0.50	0.60	0.60	0.60	2.80	0.00
Graduate Student	1.00	1.00	1.00	1.00	1.00	5.00	0.00
TOTAL	1.00	1.00	1.70	1.70	1.70	7.80	0.50

Program: Humid Tropics

Research Topic

Title: Land Reclamation: Land Clearing and Soil Conservation

Goal: Select suitable forage crops to plant on cleared lands for livestock

Project

Title: Pasture Grass and Legumes for the Humid Tropics

Objectives: To find forage crops adapted to a range of environments representative of the humid tropics and to identify suitable cover crops to reclaim and protect eroded lands.

Project Leader: John Thompson, University of Hawaii

Collaborating Scientists: D. S. Gunawan, Center for Soil Research

Reasons for the Investigation:

Ground cover is a logical and sound way to protect cleared land, reclaim eroded soil, provide feed for livestock and serve as green manure for the resource-poor farmers of Sitiung and the humid tropics. Pasture grass and legume species that perform well and serve multiple uses can become permanent and inexpensive components of the farming system. The varietal testing also serves to illustrate genotype-environment interactions and the principles of matching crop requirements to land characteristics. The multiple uses of grasses and legumes in the farming system provide the basis for systems thinking in soil management research. This project is designed to match the environmental requirements of pasture grass and legumes to (1) the environmental characteristics of the land and (2) the resource characteristics and preference of the farmer.

Relevance to Other Programs:

Carol Colfer has discovered from her time allocation studies that Sitiung families require considerable time to cut forage from roadside and abandoned fields for their farm animals. The quality of the feed is very poor and the CIAT collection has the potential to significantly reduce the time needed to harvest forage and measurably improve quality of the harvested feed.

This work also has relevance to the small ruminant CRSP which is active in the country. It is highly likely that future tests of CIAT's

pasture grass and legume collection will uncover many more high performance species that will serve as ground cover to protect soil from erosion, green manure, forage for farm animals and a land reclamation cover crop.

Generalized Procedures:

CIAT has a collection of pasture grass and legume germplasm ready for testing. These cultivars will be tested in Sitiung under minimum input situations. Cultivars will be selected for vigor, growth rate, pest resistance, palatibility, productivity and survivability.

Pasture grasses and legumes are important elements in erosion control, green manuring, biological nitrogen fixation, ecology of mycorrhize, animal feeding, land reclamation and ground cover for rubber plantings.

Principal Site for Experimentation: Sumatra, Indonesia

Duration: October 1984 to September 1989

Management Entity Comment:

A critical review of the project will be conducted prior to the end of year five and subsequent funding decided upon following the review.

Pasture Grass and Legumes for the Humid Tropics
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Fringe Benefits	6	7	7	8	8	36
Supplies	2	2	2	2	2	10
Equipment	2	0	6	0	0	8
Travel	4	3	2	3	3	15
Allowances	2	2	2	2	2	10
Other Direct Costs	1	1	1	1	1	5
Indirect Costs	5	5	5	5	5	25
TOTAL	22	20	25	21	21	109

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.10	0.10	0.10	0.10	0.10	0.50	0.00
Field Based Scientist	0.30	0.30	0.30	0.30	0.30	0.00	1.50
TOTAL	0.40	0.40	0.40	0.40	0.40	0.50	1.50

Program: Humid Tropics

Research Topic

Title: Land Reclamation: Land Clearing and Soil Conservation

Goal: Management of Organic Matter in Indonesian Farming Systems

Project

Title: Management of Organic Matter in Indonesian Farming Systems

Objectives:

(A) To enable farmers to use soil organic matter as a source of plant nutrients

(B) To incorporate the production, handling and use of organic matter into the farming system.

Project Leader: Carl Evensen, University of Hawaii

Collaborating Scientists: Russell Yost, University of Hawaii
John Thompson, University of Hawaii

Reasons for the Investigation:

Organic matter is an important soil component, especially in highly leached and weathered tropical soils. Soil organic matter is associated with increased CEC, improved soil structure, and provides the major source of many plant nutrients. The soils in much of the Sitiung area developed under rain forests, which as a rule, maintain a tight nutrient cycle between litter decay, root uptake, and plant growth. The clearing of rain forests breaks this cycle and often leads to soil degradation through increased organic matter decomposition, leaching of nutrients, soil compaction, and erosion.

Sustainable, low-input farming systems in Sitiung must provide for maintenance of soil organic matter. This project is designed to compare farming system technologies in terms of inputs and persistence of organic matter and their feasibility and attractiveness to subsistence level farmers. An assumption to be tested is that a permanent soil cover of vegetation or mulch will best protect the soil and create a stable equilibrium between organic matter deposition and decomposition. Hedges of legume trees cut frequently to provide mulch and legume cover crops providing vegetative soil cover will be assessed in intercropping with food crops.

Relevance to Other Programs:

Organic matter is expected to be an important soil component in other transmigration sites with highly leached and weathered soils. Findings from these studies in Sitiung should contribute to better management of soil or matter in similar sites. Of particular interest will be the identification useful tree and cover crop species and determination of their interactions with intercropped food crops.

Generalized Procedures:

The research is proposed to consist of two major phases. The first phase will involve tree and cover crop species selection, determination of lime and fertilizer requirements, and observation of interactions between food crops and organic matter producing plants. In the second phase, promising tree or cover crop, fertilizer, and food crop combinations will be tested in farmer managed trials to determine farmer acceptance. Since this research will be conducted as part of a farming systems project, the trials will be open to adaptation as the research needs and farmer situation in Sitiung are better understood.

Principal Site for Experimentation: Sumatra, Indonesia

Duration: October, 1984 to March, 1987

Management Entity Comment:

Project to be rewritten prior to the end of year four with emphasis on clearly defined and focused objectives that will contribute to the SM-CRSP goal. An intensive review of the project will be conducted prior to the end of year five and subsequent funding decided upon following the review.

Management of Organic Matter in
Indonesian Farming Systems
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	14	15	16	0	0	45
Fringe Benefits	4	5	5	1	1	16
Supplies	5	4	3	0	0	12
Equipment	5	0	0	0	0	5
Travel	6	5	6	0	0	17
Allowances	5	5	5	1	1	17
Other Direct Costs	2	1	1	0	0	4
Indirect Costs	10	9	11	1	1	32
TOTAL	51	44	47	3	3	148

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.10	0.10	0.10	0.00	0.00	0.00	0.30
Field Based Scientist	1.10	1.10	1.10	1.00	1.00	5.00	0.30
TOTAL	1.20	1.20	1.20	1.00	1.00	5.00	0.60

Program: Humid Tropics

Research Topic

Title: Land Reclamation: Soil and Water Conservation

Goals: Improve and stablize land productivity through reduced soil erosion and enhanced conservation of soil and water resources

Project

Title: Conservation-Effective Rainfed Farming Systems for the Sitiung Area, West Sumatra

Objectives:

(A) Quantify the rainfall erosion potential for major agroenvironments in the area

(B) Evaluate the effectiveness of alternative cropping systems and land management practices for controlling the erosional losses of soil and water resources

(C) Integrate the above with other agroeconomic and socio-economic information for use in developing productive and stable watershed-based farming systems for the humid tropics.

Project Leader: Samir A. El-Swaify, University of Hawaii

Collaborating Scientists: Soleh Sukmana, Center for Soil Research
Land Clearing Specialist
John R. Thompson, University of Hawaii
Carol Colfer, University of Hawaii

Reasons for the Investigation:

Emotional environmental appeals aside, recent research shows a convincing cyclic interrelationship between sustained farm productivity and the effective, conservation-minded, utilization of soil and water resources. In the humid tropics, the potential rainfall erosion hazard is so high that, if manifested, it can result in the rapid decline of productivity and, eventually in irreversible land degradation. Nowhere is this threat more true than for the land just cleared from forest for use in conventional cropping. For the resource-poor farmer in these regions, the impacts of erosional damage are considerably more, both in the short- and long-term, than for his Western counterpart. This is because he cannot easily or fully afford to replenish lost crop

nutrients or the other inputs necessary for restoring soil productivity. Furthermore, excess soil erosion and runoff degrade the hydrologic performance of the watershed as a whole. Examples of these problems abound in Indonesia and many other countries in the tropics. Therefore, the formulation of a farming system which is conservation-effective is necessary for sustaining high productivity and insuring the overall stability of the resource base.

Relevance to other programs:

Soil and water conservation is a critical component of successful rain-fed farming systems in all agroecological zones. A systematic project as outlined below is a logical one for networking. We, therefore, propose that similar collaborative activities be started in due course in the semi-arid and acid Savannah zones. A number of related activities have already been initiaited in Hawaii and at ICRISAT.

Generalized Procedures:

A. Climatic, soil, and topographic parameters which control runoff and erosional processes will be derived from data on existing or newly designed standard runoff plots. Rainfall variability, soil charactersitics and slope classes will be utilized to determine the minimum number of required experimental locations.

B. Biological and physical management options will be evaluated on plot and small farm scale to quantify their ability to effectively control runoff and erosion. Primary biological components will be (a) the canopy characteristics of important crops or intercrops in the cropping system in addition to the legumes and grasses that are candidates for soil protection and stabilizers for banks or waterways or as ground covers, (b) residue management by mulching or incorporation during the cropping cycle and (c) other crop management options such as cultivar selections, planting density and geometry. Since there are limits, mostly topographic, which prevent sole reliance on biological erosion control measures, it is also critical to determine the need for complementary land management and shaping operations. Among the physical components to be investigated will be (a) bunding systems, (b) terracing systems, (c) inter-terrace land configurations and alternative tillage systems (including conservation tillage) and (d) the interactions between these and slope length and gradient for effective runoff disposal with minimal soil losses. Many of the management options to be considered here must be applied before or during land clearing. Therefore some of the above parameters will be quantified for the land clearance site as well.

C. This interdisciplinary effort will be based primarily in fields selected to form a number of clearly delineated cachments or small watersheds. Each will be instrumented for runoff measurements and

sampling for erosion assessment in complement with crop performance observations. Here the most promising treatments based on findings from objectives A and B will be combined with those resulting from ongoing agronomic trials with participation from the socio-economists and engineers to test the overall productivity and conservation-effectiveness of the farming systems at a realistic, operational scale. It is critical that the selection of catchments include farms on which "traditional" farmer practices prevail to allow systematic evaluation of benefits which may result from newly introduced design features. The latter will include not only crop- and soil-based improvements, terrace and inter-terrace measures, but also drainage waterways for safe carrying and disposal of runoff. The possible storage and utilization of excess runoff is an important feature of watershed-based planning which can add significant benefits to the overall farming systems. Such water may be utilized for supplemental irrigation, meeting livestock requirements or, as is desirable in central Java, fish ponds. It is also critical that selected catchments include appropriate "controls" to allow valid comparisons between soil loss and runoff trends for developed and uncleared forest areas. Comparisons of land clearing techniques, land surface shaping methods and associated soil disturbance must be made to aid in setting a proper strategy for overall land development schemes in these and other humid tropics.

Principal site for experimentation: Sumatra, Indonesia

Duration: This should be considered a long-term project with an intended duration of 10 years.

Conservation Effective Rainfed Farming System
for the Sitiung Area, West Sumatra
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	30	33	37	40	43	183
Fringe Benefits	6	6	7	7	9	35
Supplies	5	10	10	3	2	30
Equipment	5	20	5	0	0	30
Travel	11	11	8	11	10	51
Allowances	6	7	7	8	8	36
Other Direct Costs	12	9	10	7	7	45
Indirect Costs	22	24	26	26	27	125
TOTAL	97	120	110	102	106	535

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.20	0.20	0.20	0.20	0.20	0.00	1.00
Field Based Scientist	0.70	0.70	0.80	0.80	0.80	3.30	0.50
Graduate Student	1.00	1.00	1.00	1.00	1.00	5.00	0.00
Other	0.50	0.50	0.50	0.50	0.50	2.50	0.00
TOTAL	2.40	2.40	2.50	2.50	2.50	10.80	1.50

Program Backstopping Support
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	58	62	77	79	85	361
Fringe Benefits	13	14	16	17	17	77
Other Direct Costs	6	7	6	7	7	33
Indirect Costs	31	33	40	41	44	189
TOTAL	108	116	139	144	153	660

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	1.00	1.00	1.00	1.00	1.00	5.00	0.00
Other	5.00	5.00	5.00	5.00	5.00	25.00	0.00
TOTAL	6.00	6.00	6.00	6.00	6.00	30.00	0.00

HUMID TROPICS PROGRAM

NORTH CAROLINA STATE UNIVERSITY

Humid Tropics Research Program Proposal

North Carolina State University

Synopsis

The proposal for extension of funding through years six to eight and a plan of work for years four to eight under the Soil Management CRSP are described in this document. The proposal was developed after a review of North Carolina State University's TropSoils activities in Peru, Indonesia, Brazil and Raleigh by the External Evaluation Panel. Subsequent planning by NCSU and collaborating country scientists followed. In the case of our primary research site, the planning process culminated by the formal approval of the TropSoils-Peru Committee that met at INIPA on September 22, 1984. The first version was presented at the TropSoils Board of Directors on November 14, 1984. This revised version incorporates many of the suggestions received during that meeting.

The Plan of work continues to be aimed at developing agronomically, economically and ecologically sound soil management options for different soil, landscape and socioeconomic conditions of the humid tropics. All work is carried in close collaboration with INIPA in Peru, EMBRAPA in Brazil and CSR in Indonesia. Field research is planned for sites in Peru, Indonesia and Brazil. Activities in at least four humid tropical countries are envisioned through a research network. First priority is given to generating new soil management technology while the validation of such technology through research support is a second priority.

A total of 11 projects are included in the proposal. Six projects constitute the generation of soil management technology: low-input cropping systems, agroforestry systems, conservation tillage, fertility management, legume-based pastures and soil erosion. Five other projects constitute technology validation and research support: soil characterization, research support in Sumatra, Manaus, Brasilia and the research network.

The 11 projects are subdivided into 46 subprojects for which CRSP funding is sought. Proposed staffing from NCSU includes an average of 5 FTE of senior scientists and 15 FTE of junior scientists and support staff for the five-year period. Total budget request from CRSP amounts to $5.4 million for the five-year period. These funds are matched by counterpart funds from Peru, Brazil and Indonesia and other international donors on a 50:50 basis.

Summary of Budget for Proposed Program

North Carolina State University

Short Title	Year 4	5	6	7	8	Total
			x $1000			
Continuous Cropping Conservation	109	105	112	107	91	524
Continuous Cropping - Fertility	91	102	90	93	92	468
Low Input Cropping Systems	118	124	133	122	98	595
Legume-Based Pastures	57	55	50	0	0	162
Agroforestry Systems	135	128	138	127	95	623
Characterization and Classification	49	44	41	54	44	232
Research Network	99	104	107	66	66	442
Soil Erosion and Reclamation	36	34	21	26	33	150
Soil Management of Oxisols	7	73	79	0	0	159
Soil Management in Sumatra	144	135	135	146	137	697
Texture and Liming on P and Zn	11	11	12	12	12	58
Backstopping	172	174	185	192	203	926
TOTAL	1028	1089	1103	945	871	5036

Summary of the Budget by Object Items and the
Staffing Plan for the Humid Tropics Program
North Carolina State University

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	360	400	411	357	341	1869
Fringe Benefits	42	48	52	43	43	228
Supplies	76	75	77	59	59	346
Equipment	50	45	30	61	24	210
Travel	126	124	129	105	101	585
Allowances	65	72	69	53	55	314
Other Direct Costs	133	142	148	107	91	621
Indirect Costs	176	183	187	160	157	863
Total	1028	1089	1103	945	871	5036

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	2.10	3.20	3.20	3.20	3.20	7.90	7.00
Field Based Scientist	3.40	4.30	4.30	3.30	3.00	18.30	0.00
Graduate Student	12.00	11.00	11.00	9.00	9.00	47.00	5.00
Other	11.70	10.80	9.80	8.80	8.80	20.00	29.90
Total	29.20	29.30	28.30	24.30	24.00	93.20	41.90

Humid Tropics Research Program Proposal

Submitted by

North Carolina State University

Pedro A. Sanchez

Program Coordinator

Objective

The objective of NCSU's TropSoils Program continues to be to develop and transfer, together with national institutions and other TropSoils universities, improved soil management technologies for productive and sustained farming systems in the humid tropics and acid savannas on an agronomically, economically and ecologically sound basis.

Strategy

The Program's strategy is to continue focusing on different management options for principal soils, landscape positions and levels of infrastructure development in the humid tropics. Instead of advocating a solution for the humid tropics, the Program aims to provide a series of options to farmers in the process of transition from shifting cultivation to settled agriculture. Together with support from other disciplines, these options can become components of improved farming systems.

The principal management options are directed toward various soils and landscape positions that occur in the humid tropics on a worldwide basis.

In addition, the Program proposes continuation of research on soil classification and interpretation and in the establishment of a research network to foster the validation of research results in other regions of the humid tropics.

Philosophy

The Program strategy is deeply rooted on the premise that without technology, agricultural development in the humid tropics will be an economic and ecological disaster of worldwide dimensions. With appropriate technology, however, development cannot only be successful but will lead to conserving vast areas of the humid tropics in its natural state. Pressures for indiscriminate deforestation subside when farmers realize that they can produce more on a hectare of appropriately and continuously managed soils than by clearing and abandoning several

hectares every year. The focus concentrates on secondary forest fallows or degraded pastures rather than on primary forest areas, in an attempt to utilize first land that has been previously cleared.

The Planning Process

Following the May review by the External Evaluation Panel, the Principal Investigator requested the inputs of NCSU, INIPA and USAID staff members about the nature of the five-year plan. Many discussions were held between June and September, including staff stationed in Indonesia and Brazil. A draft proposal was presented to the TropSoils-Peru Committee in Lima on September 21), was unanimously approved and constitutes the basis for this proposal.

Priorities

The fundamental priority issue is one of balance between the generation of new soil management technology and the testing and validation of such technology in other humid tropical areas. The External Evaluation Panel report on Peru clearly suggests that the first priority for CRSP resources is to provide the lead role in generating new technology for the humid tropics and that the second is to provide a research support role to other locations in the Selva of Peru as well as in other humid tropical countries. A minimum core program would be the first priority and our networking activities, the second. Priorities between these two categories have also been discussed with our team and have been defined. The results are as follows:

Priority 1. Generation of New Technology for the Humid Tropics

- 1.1 Low-input cropping systems
- 1.2 Agroforestry systems
- 1.3 Conservation tillage, fertility management
- 1.4 Legume-based pastures
- 1.5 Soil erosion

Priority 2. Technology Validation and Research Support

- 2.1 Soil characterization and classification
- 2.2 Sumatra research support
- 2.3 Manaus research support
- 2.4 Research network
- 2.5 Brasilia research support

Sites

Prior to CRSP support, NCSU activities in the humid tropics were mainly confined to the Yurimaguas Experiment Station. With CRSP support, these activities have expanded to Indonesia. We propose the incorporation of additional collaborative sites in Manaus, Brazil which represent an intermediate situation between the loamy Ultisols and weak

dry season environment in Yurimaguas and the clayey Oxisols with strong dry season typical of the acid savannas. Additional collaborative sites have been established in Peru with counterpart funds, including a periodic regime at Pichis-Palcazu (3400 mm rainfall, Ultisols and Dystropepts) and a near ustic soil moisture regime in Pucallpa (1500 mm).

Through the establishment of a modest research network, we believe collaborative activities can expand to at least four other countries in the humid tropics, without stationing NCSU scientists in them. The selection of countries will be done in consultation with the Latin American and Caribbean, African and Asian Bureaus of AID. The LAC Bureau has expressed strong interest in this possibility.

Major Developments in Peru

INIPA has taken the following actions which have a significant impact on the TropSoils program in that country.

1. Appointed a "Comite Coordinador del Proyecto Suelos Tropicales." It is composed of INIPA's Executive Director for Research, Director for Crops Research, Director of the Yurimaguas Station, and Director of Studies and Projects. NCSU is represented in the Committee by its Chief of Mission in Peru, the TropSoils project leader and the TropSoils Principal Investigator.
2. Established the National Selva Program. TropSoils becomes a component of the Selva Program. This provides a direct link with approximately 200 research and extension workers stationed throughout the Selva of Peru.
3. Established several new positions to serve as counterparts for NCSU junior scientists stationed in Peru.

Backstopping

Backstopping consists of administrative, laboratory and data processing support for the entire program. Operations take place at the Tropical Soils Program office on campus, at the NCSU Mission to Peru Offices at INIPA headquarters in Lima and at the Yurimaguas Experiment Station. IICA provides backstopping to the Manaus operations in Brazil and the University of Hawaii team leader in Sumatra serves that function. Approximately one-half the cost is for administrative functions and one-half is for laboratory and data support.

Program: Humid Tropics

Research Project:

Title: Continuous Cropping Systems: Conservation Tillage

Objectives: To develop proper soil management practices for the maintenance of soil physical properties for sustained fertilizer-based continuous crop production systems in humid tropical areas with favorable infrastructure development.

Project Leader: J. C. Alegre, North Carolina State University

Principal Collaborators: D. K. Cassel, G. C. Naderman, A. Aznaran, M. Villavicencio

Rationale:

The potential for soil erosion is high in continuously cultivated Ultisols of the humid tropics because much of the rainfall occurs during brief intense storms. In spite of the high annual rainfall levels, crops often suffer from severe moisture stress during rainless periods of two or more weeks. The management of excess water as well as soil moisture shortages are important considerations for successful settled agriculture.

Conservation tillage, reduced tillage, minimum tillage, no-till have been suggested and are currently in use in many parts of the world as management practices that could be adapted to the Amazon in order to reduce soil erosion and conserve water while increasing crop yields. The term "conservation tillage" will be used in the remainder of this proposal as any form of tillage which conserves natural resources such as soil, water or energy.

When conservation tillage practices of any kind are imposed on cropland, some change in the soil water balance or moisture regime occurs. For example, some forms of conservation tillage leave crop residue from the previous harvest on the soil surface. The presence of this residue will likely change the moisture regime compared to a form of tillage where residue is incorporated into the plowed layer. Crop residue on the surface will reduce or eliminate the impact of falling raindrops on the soil surface, increase the infiltration rate, reduce surface runoff, increase the amount of water being stored in the soil profile, and possibly lead to greater amounts of water percolating out of the plant rooting zone. More percolating water may give rise to greater downward transport of calcium and magnesium from lime sources but may also leach more plant nutrients out of the root zone.

In addition to changes in moisture regime, conservation tillage is also expected to alter soil physical and chemical properties. Many forms of conservation tillage minimize mixing of the surface soil; hence, lime and fertilizers are often added to the soil surface or, during the planting operations are placed in the soil at 3 to 5 cm depth in bands close to the seeds. These chemicals are not mixed throughout the topsoil as is common in conventional tillage. Some soil physical properties that are altered to some degree by various tillage regimes are bulk density, mechanical impedance, the aeration regime and soil temperature regime. The magnitude that these properties will change will vary with time and depend upon the particular conservation and conventional tillage systems being compared.

Changes in the soil moisture balance and other physical properties affected by various conservation tillage regimes are expected to have a pronounced effect on soil trafficability. The range in soil water contents over which the soil may be affected by tractor drawn machinery, man-operated equipment, and foot traffic may be altered. Certainly the number of days during the year when the soil can be tilled without inflicting damage to soil physical properties will vary with different tillage regimes.

The combined results of all of the above changes by imposing conservation tillage practices will certainly have an effect on both short- and long-term crop production. We anticipate success in obtaining higher crop yields by adoption of conservation tillage practices if chemical weed control can be maintained.

Relevance to Other Activities:

Conservation tillage is increasing in popularity in many parts of the United States, the world, and even in some areas in the humid tropics. For example, Rattan Lal at IITA has conducted extensive research on the effects of conservation tillage in Alfisols of West Africa. One concern expressed by the May 1984 review at Yurimaguas was that no systematic consideration was being given toward conservation tillage. One reason this topic arose was that visible evidence of erosion was on land with 2 to 4% slope at one or two locations on the station. In our opinion, erosion in these spots was not worthy of major concern. Grass strips surrounded all of these sites, thus trapping any sediment transported from the field. Maximum soil transport would have been less than 50 m.

On the other hand, because droughts of two weeks or longer are common in Yurimaguas, conservation tillage may have considerable merit in altering the soil moisture regime by storing more water in the soil profile for subsequent crop use. Then, too, as mechanization of agricultural practices proceeds at Yurimaguas, it behooves us to develop tillage practices which are efficient from the standpoint of labor, the number of passes over the field, and the amount of energy or fuel con-

sumed. Finally, even though we feel that erosion is not a problem at the Yurimaguas station, much of the land that will be brought into cultivation in the humid tropics itself, will be on land with slopes greater than 2 to 4% and erosion will be a serious problem.

Information obtained during the first two to three years of this project will be utilized in developing the management practices to install on the proposed watershed erosion project Y-810.

Generalized Procedures:

Conservation tillage systems will be evaluated for mechanized farming and for low input systems. All land will be intensively cropped. The soil moisture balance for each tillage system will be evaluated; rainfall will be measured and soil water content will be monitored using a neutron probe and tensiometers. Soil physical property measurements will be evaluated before the study begins and at selected intervals throughout the investigation. Plant measurements such as plant height and biomass will be periodically monitored. Final yield and water use efficiency for each treatment will be evaluated.

Scope of Work:

This project consists of four experiments: Conservation tillage (Y-113), water balance (Y-112), soil trafficability (Y-111) and the central continuous cropping experiment (Y-101).

Conservation Tillage Experiment (Y-113)

This study will have two major portions: high input and low input.

High input. The high input study will be a complete randomized block design with four replications. Tillage treatments may include, but are not limited to the following:

A. No till. Chop residue with bush-hog, plant with no till planter, herbicide weed control.

B. Minimum till-bush-hog, disk harrow once per year to incorporate lime and P fertilizer, plant with no-till planter, herbicides weed control.

C. Conventional tillage like treatment #1. Bush-hog, disk-harrow before planting each crop, plant with row planter, cultivate row crops.

D. Conventional tillage like treatment #2. Bush-hog, moldboard plow, disk-harrow, cultivate row crops.

E. Subsoil-minimum till-Bush-hog, subsoil-bed-plant in same operation, chemical weed control.

Prior to installing the experiment, the 1.5 hectare site will be intensively sampled to determine the spatial variability of the following physical properties; bulk density, mechanical impedance, *in situ* field capacity, saturation, hydraulic conductivity, and infiltration rate. Corn, peanuts and soybeans will be cropped. Plot size will be 50 x 10 m. Soil moisture will be monitored during the study using the neutron probe and tensiometers. Soil temperature will be monitored at selected depths in each treatment. Runoff plots will be established at the lower end of each treatment to evaluate both surface runoff, sediment removal, and nutrient loss. The soil physical properties measured initially will be periodically evaluated during the 5-year study.

Low input. The experimental design and methodology are identical to the high input study, except for plot size which is 5 x 1.6 m and treatments which are listed below:

A. Zero tillage, residue left on surface plant with a no-till planter pulled by a 14 HP tractor, chemical weed control.

B. Minimum tillage, slash by hand, disk with 14 HP tractor once per year, plant with injector planter or small drill, weed with rolling weeder.

C. Conventional tillage like #1, disk with 16 HP tractor for each crop, plant with injector planter or small drill, weed by cultivation.

D. Conventional tillage like #2, moldboard plowing or soil loosening with 14 HP tractor for each crop) plant with injector planter or small drill, weed by cultivation.

Water Balance Experiment (Y-112)

A detailed water balance will be developed for several of the tillage systems described in Y-113. Precipitation will be measured with a rain gauge. Surface runoff data will be available from experiment Y-113. Soil water content at 10 to 15 cm depth intervals in the crop rooting zone will be monitored periodically during the growing season. Tensiometers located at two arbitrary depths below the rooting zone will monitor the hydraulic gradient which will indicate if water is flowing downward out of the root zone or upward into the root zone from the soil below. The *in situ* unsaturated hydraulic condcutivity for these soils will be measured using the instantaneous profile method. The flux of solutes below the soil root zone will also be monitored using suction lysimeters.

Soil Trafficability (Y-111)

This study will have a two-pronged approach. The first part of the study is designed to determine the probability of having soil that is trafficable for a given number of days per year. The rainfall data from

Yurimaguas and several other sites having longer term rainfall records will be accumulated. Soil samples from each area will be collected and the Atterberg limits established. Using soil and rainfall data, a series of probability functions will be developed to determine those periods when one has the greatest probability of performing tillage operations for the particular soils-rainfall pattern at each site.

A field study to evaluate the trafficability of some of the treatments established in experiment Y-113 will be conducted. After certain rainfall events, the soil water content and the penetrometer resistance of the upper 45 cm of soil will be measured. Comparison of the soil water content with the Atterberg limits will indicate if the soil is trafficable. These water contents and penetrometer measurements will be repeated two or three times daily until the tillage regimes become trafficable.

In addition to the above approach, a field test of trafficability will be conducted. Based upon the results of the water content measurements above, an attempt to drive a tractor with attached equipment across each plot will be made. Differences in soil moisture regime as affected by tillage treatment are expected to cause differences in trafficability. Trafficability is very important for conservation tillage because herbicides and insecticides must be applied when they are needed. Details for this study will be formulated based upon the amount of land available.

Central Continuous Croping Experiment (Y-101)

The historical plots in Chacras I and III were designed for small hand tractors. Hand weeding and its deposition on alleyways have caused a gradual buildup that affected surface water movement. The bulk of these chacras, however, were used for other experiments that were terminated. This resulted in a significant heterogeneity in soil physical and chemical properties. The purpose of this work is to determine how this variability can be alleviated or eliminated by introducing the practices arising out of experiments Y-111, Y-112 and Y-113. Grass waterways will also be introduced. The areas will then serve mainly as a demonstration of continuous cultivation with sound physical soil management, while allowing continuity in monitoring the historical long-term plots. The seven treatments in the long-term plots will be modified but will include checks, completely fertilized treatments with proper conservation tillage. New treatments that may be introduced are related to the frequency of fertilization in relation to the newly developed conservation tillage practices. Three of the four replicates will be maintained in Chacra I. Two crops per year will be grown, alternating a cereal (corn or grain sorghum) with a grain legume (soybean or peanut). Unless price advantages dictate otherwise, species that have Al-tolerant varieties (upland rice and cowpeas) will be excluded from this trial, because liming and fertilization are supposed to largely eliminate fertility constraints.

Principal Research Site: Yurimaguas Experiment Station

Duration: Five years

Continuous Cropping Systems: Conservation Tillage
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	28	28	37	40	34	167
Fringe Benefits	3	3	4	4	4	18
Supplies	8	8	9	7	6	38
Equipment	12	6	2	10	2	32
Travel	11	13	14	11	10	59
Allowances	9	8	7	7	8	39
Other Direct Costs	21	22	22	11	11	87
Indirect Costs	17	17	17	17	16	84
TOTAL	109	105	112	107	91	524

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.20	0.20	0.20	0.20	0.20	0.00	1.00
Field Based Scientist	0.70	0.70	0.70	0.70	0.70	3.50	0.00
Graduate Student	1.00	1.00	1.00	1.00	1.00	5.00	0.00
TOTAL	1.90	1.90	1.90	1.90	1.90	8.50	1.00

Program: Humid Tropics

Research Project

Title: Continuous Cropping Systems: Fertility Management

Objectives: To improve the efficiency of nitrogen, phosphorus, potassium and zinc applications and weed control in fertilizer-based continuous cropping systems and to determine more precisely the residual effects of lime and phosphorus applications.

Project Leader: R. E. McCollum, North Carolina State University

Principal Collaborators: J. Mt. Pleasant, J. R. Benites, F. R. Cox, L. Arevalo, M. Villavicencio

Rationale:

The long-term continuous cropping experiment (Y-101) showed that high crop yields can be obtained on a sustained basis provided the fertility limitations are corrected by lime and fertilization based on soil tests. This methodology produced harvests of 28 consecutive crops of upland rice-corn-soybeans or peanuts grown in rotation. After eight years of continuous cropping, soil chemical properties had actually improved while no detrimental effects on soil physical properties were detected, provided vigorous crop growth was insured by adequate fertilization.

Relatively little research has been done on how to improve the efficiency of fertilizer applications for this management option. It has become increasingly apparent that farmers likely to use this technology will do it in a mechanized fashion rather than depending exclusively on hand labor. The introduction of mechanized land preparation, either with conventional or conservation tillage will affect fertilizer management. For example, deeper tillage with a moldboard plow has effectively raised the phosphorus sorption capacity of the plowed layer because the top of the argillic horizon is mixed with the 10 cm thick epipedon. Crop varieties have also changed since the earlier fertility experiments were done in Yurimaguas during the early 1970's. Species with adapted cultivars tolerant to high levels of Al saturation will no longer be included because their place is in the low input system option. Consequently, further work will concentrate on species which so far require liming to produce adequate yields in Yurimaguas: corn, soybeans, peanuts. Grain sorghum is also a possibility for planting during the drier months.

Relevance to Other Programs:

The maintenance of fertility in acid soils of the humid tropics is of worldwide relevance. Results of this project will provide data for comparisons with similar work done in Sitiung, Indonesia and Manaus, Brazil providing a range for edaphic and climatic variability within Oxisols and Ultisols of udic, isohyperthermic regimes.

Scope of Work:

This project consists of six experiments, four supported by the CRSP and two supported by counterpart funds. The four CRSP-supported experiments are: nitrogen carryover in rotations and intercrops (Y-103b), residual effects of phosphorus and zinc (Y-114), potassium fertilization management (Y-103a) and residual effects of liming (Y-102). An additional experiment on weed control currently supported by the CRSP on weed population shifts (Y-109a) and chemical weed control in upland rice (Y-109b) will be taken over by the weed control specialist to be appointed by INIPA. This scientist will be backstopped by NCSU weed specialists as needed.

Generalized Procedures:

A cereal-grain legume rotation will be used with two or three crops a year as appropriate. Some rotations will involve corn-soybeans, corn-peanuts, grain sorghum-peanuts, including the possibility of a ratoon sorghum crop as a third crop during the drier parts of the year. Upland rice will be considered if its price advantage greatly exceeds that of other cereals at a specific planting date.

The field layout of the new experiments of this project will be designed in a way that the identity of the individual plots be preserved for several years under mechanical tillage practices.

Plots are sampled for pH, exchangeable Al, Ca + Mg and Olsen-P prior to each planting. Grain yields are measured and, where appropriate, dry matter samples are analyzed for N, P, K, Ca, Mg and Zn to calculate nutrient extraction. Analysis of the subsoil fertility parameters is done periodically on the potassium and liming experiments.

Nitrogen Carryover in Rotations and Intercrops (Y-103b)

A field experiment was initiated in 1984 to test the potential carryover effect of nitrogen fixed by a grain legume crop to a subsequent crop of corn. Corn and peanuts are planted as sole continuous crops, in row intercrops and in a double rotation, where corn is planted where peanuts were just harvested and vice versa. These four treatments form main plots with N fertilizer rates for corn as subplots, with three replications. The hypothesis is that planting corn after peanuts will

decrease the fertilizer nitrogen requirements of corn, while the effect of row intercropping will be less.

Phosphorus and Zinc Fertilization Experiments (Y-114)

Previous research in Yurimaguas has demonstrated the value of phosphate rock and the generally short residuals effect of P applications. This effect is partly due to the relatively low P sorption capacity of the sandy topsoils and consequent low required rates of P. The introduction of mechanical tillage operations has effectively increased the P sorption capacity of the plowed layer as previously mentioned. It also has triggered Zn deficiencies in corn when P fertilizers are band-placed. The introduction of conservation tillage, particularly no-till may further affect phosphorus management. An experiment or group of experiments is in process of being designed to test the following hypotheses and perhaps others:

A. What is the long-term residual effect of broadcast or banded P applications or a combination of both under several kinds of conservation tillage practices?

B. Is there a potential advantage of the high reactivity Bayovar rock phosphate over superphosphate in cropping systems that require liming to pH 5.5?

C. Is there a negative P-Zn interaction and if so, how could it be prevented or overcome?

D. What are the most effective systems of P fertilization for specific conservation tillage practices?

Potassium Fertilization Experiments (Y-103a)

Potassium is the fertilizer element required in largest quantities in Yurimaguas. Little is known about its dynamics under continuous cropping, particularly in relation to liming. Two experiments were planted in 1984 to determine 1) effects of K rates at three levels of base saturation on the yield and uptake of basic cations of a corn-grain cropping sequence; 2) the effects of the above treatments on the retention and leaching of potassium in Ultisols of different textures.

The experiments were installed in adjacent previously bulldozed sites. The soils represent the range in texture of Udults found in Yurimaguas. Site A has a sandy topsoil over a sandy loam subsoil while Site B has clayey texture throughout. Five rates of K required to increase exchangeable K levels to 0.05, 0.10, 0.15 and 0.20 meq K/100 g were applied in a factorial design with three levels of lime (0, 0.5 and 1.0 times the exchangeable Al) in Site A and two levels in Site B. Crop yields, uptake of basic cations and exchangeable bases in the profile will be monitored.

Liming of Continuously Cropped Land (Y-102)

Basic data on lime rates and depth of incorporation were obtained for four years in an experiment initiated in 1978. Additional information is needed on 1) the long-term residual effects and changes in subsoil chemical properties; 2) the timing, placement and rates of lime applications under conservation tillage.

The first item is to be answered by continuing sampling the old plots for residual effects. A new trial will be designed to tackle the issue of liming under conservation tillage that involves minimum soil disturbance. Experience in Ultisols of Southeastern United States indicates that liming is a more complicated issue under no-till farming. The second trial will not be initiated until the results of the conservation tillage experiment (Y-113) are sufficiently advanced to determine the most promising tillage methods.

Principal Research Site: Yurimaguas Experiment Station

Duration: Five years

Management Entity Comment:

This project will be assessed in depth during the fourth year and the extent and value of new information likely to be obtained will be considered. Funding beyond year four will be influenced materially by this evaluation.

Continuous Cropping Systems: Fertility Management
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	32	36	36	37	37	178
Fringe Benefits	3	4	4	4	4	19
Supplies	5	4	5	4	5	23
Equipment	2	16	2	2	2	24
Travel	13	9	6	9	6	43
Allowances	10	8	9	9	10	46
Other Direct Costs	12	10	12	12	12	58
Indirect Costs	14	15	16	16	16	77
TOTAL	91	102	90	93	92	468

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.10	0.40	0.40	0.40	0.40	1.20	0.50
Field Based Scientist	0.50	0.50	0.50	0.50	0.50	2.50	0.00
Graduate Student	1.00	1.00	1.00	1.00	1.00	5.00	0.00
TOTAL	1.60	1.90	1.90	1.90	1.90	8.70	0.50

Program: Humid Tropics

Research Project:

Title: Low-Input Crop Production Systems for Acid Soils in the Humid Tropics

Objectives: To continue developing components of low-input soil management technology for areas with limited infrastructure, as a transition phase between shifting cultivation and settled farming systems.

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

Principal Collaborators: J. Mt. Pleasant, M. P. Gichuru, J. R. Benites, J. C. Alegre, G. C. Naderman, A. G. Wollum M. Villavicencio, A. Rachumi, J. Lopez, W. Guillen

Rationale

The vast majority of shifting cultivators in the humid tropics is unlikely to rapidly adopt continuous cultivation technologies based on the intensive use of fertilizers, lime and farm machinery. Experience in frontier development indicates that farmers are reticent to make major investments in fertilizers and machinery until the level of regional development assures the transportation of purchased inputs and a reasonable market for their crops. Several humid tropical areas have reached this state, land values have subsequently increased, and farmers are willing to make lasting investments in their farms. Key soils research questions for such conditions are addressed in the two previous project proposals. This proposal focuses on a transition crop production technology that may be readily adopted by farmers who want to increase their production but are unable or unwilling to jump to fertilizer-based continuous crop production. We call it low-input technology to reflect the low (but not zero) levels of purchased energy inputs, be it in the form of fertilizers and herbicides or in terms of fossil fuel consumption. This technology is not necessarily low in family labor input, or in the applications of latest technology such as improved germplasm. Its basic premise is to adapt plants to the soil constraints, rather than correcting soil constraints to meet the plant's demands. Low-input technology is not a matter of applying less fertilizer than high input technologies. It is a different way of managing the soil.

In 1981, a low input technology strategy was designed, based on the premise of introducing gradual changes in traditional shifting cultivation. Farmer interviews indicated that weed invasion rather than fertility decline is perceived as the main constraint for prolonging the

cropping period. Our approach is to begin just like the shifting cultivators, but gradually introducing innovations at the time farmers normally abandon their fields to forest fallow regrowth. Research at Yurimaguas has shown that low input systems include the following components: (1) Slash and burn clearing, leaving stumps in place; (2) Use of crop varieties that can yield well at Al saturation levels of 80%, thereby eliminating the need of lime to neutralize toxic levels of aluminum; (3) A rotation of upland rice with cowpeas; (4) Zero or minimum tillage, tacarpo (stick) planting; (5) Chemical weed control; (6) Modest rates of N, P and K applied to the cereal crop only. In Yurimaguas, the rates are 60 kg N/ha, 50 kg P_2O_5 and 60 kg K_2O/ha; (7) Leaving all crop residues deliberately in place and redistributed in the field, if necessary; (8) Managed fallows may be planted if the farmer decides to cease cultivation.

Such a system is considered transitory because fertility depletion is expected to produce a crop yield decline with time. At a certain point, the farmer may have to pursue other options such as land abandonment, managed fallows, fertilizer-based continuous cropping, grass-legume pastures or agroforestry. A replicated, farm level low input trial (Y-210) is showing that the system is lasting considerably longer than expected. Five crops, three of upland rice and two of cowpeas, have been harvested in two years yielding a total 8.2 tons/ha of rice and 2.1 tons/ha of cowpeas without any fertilizer applications. This is totally different from our experience in many experiments with the continuous cropping option where crop yields declined to virtually zero after the second or third crop without fertilization. The reasons for the differences are not understood. This project proposes to achieve a better understanding of how low input systems operate, continue improving the individual components and study some new ones such as organic manures, slash and mulch, and growing a fallow before beginning cultivation.

Relevance to Other Programs:

Results so far show much promise for the low input strategy as a totally different option for acid soils in the humid tropics from that of fertilizer-based continuous cultivation. The low input option is likely to have a wider immediate applicability, because of its lower risk, less demanding market infrastructure requirements. This transition technology is likely to be widely applicable throughout the humid tropics. The use of managed fallows after cropping provides an excellent cover for protection against soil erosion.

Scope of Work:

This project consists of 10 experiments, six of which are to be supported by the CRSP and the rest by INIPA's national programs. All research on screening crop varieties for Al tolerance (Y-203), high yields and other desirable agronomic characters (Y-204) is already

transferred to INIPA's national crop programs. Ongoing research on minimum tillage, crop residue incorporation and interactions with K, P, Ca and Mg (Y-206 and Y-207) are scheduled for completion in 1985. The trial on downward movement of Ca and Mg (Y-208) is also scheduled for completion in 1985, but may be extended if the data so suggest. Research on weed control in low input systems (Y-209), and the central low input experiment (Y-210) are expected to continue. New experiments are planned on soil fertility dynamics (Y-215), improving seed and fertilizer placement with tacarpo (Y-217), burning and immediate fallows (Y-216) and manure and animal traction (Y-211).

Generalized Procedures:

Secondary forest fallows are cleared by slash and burn, removing logs but leaving stumps in place. A rotation of upland rice-upland rice-cowpeas is established with a planting stick (tacarpo) and appropriate fertilizer rates are applied, but no lime. Herbicides are used to control weeds and kill live crop residues if necessary. Land in completed experiments will be planted to a managed legume fallow. Soil dynamics and agronomy will be followed in a similar manner to Project #2.

Germplasm Screening for Aluminum Tolerance (Y-203)

Screening of varieties or breeding lines for tolerance to 70-80% Al saturation in the topsoil will continue, following the methodology developed by Piha and Nicholaides. These projects are now the responsibility of INIPA National Programs and will be managed by three specialists on-site and supervised by the Program Coleaders. Yurimaguas is the National Rice Program's primary screening site for acid tolerance in upland rice. Breeding lines as early as F_2, produced at CIAT's Villavicencio Station in Colombia are first screened for blast tolerance in Alto Mayo and the survivors then tested for Al tolerance in Yurimaguas. This is an essential component of this strategy, as the leading variety "Africano Desconocido" is showing inferior grain milling qualities.

Researchers from the National Corn Program are screening both corn and grain sorghum germplasm from material gathered by CIMMYT and INTSORMIL, respectively. The National Grain Legume Program will similarly screen soybean, cowpea and peanut cultivars. Screening of sweet potato cultivars will be taken over by the International Potato Center as part of the extension of their mandate to this crop.

Weed Control Measures for Low-Input Management Systems (Y-209)

Objective. To develop low-chemical input management methodologies for controlling weeds on recently cleared land.

Procedure. An experiment was initiated in August 1983 using the upland rice-upland rice-cowpea rotation subjected to the following

variables: tillage (some vs. none), residue management (incorporated vs. surface mulches), two plant densities and several weed control methods. The first phase of this experiment (6 crops) is expected to conclude in August 1985. The second phase will examine the long-term effects of imposed treatments on weed population shifts. Results so far indicate that several Cyperaceae species become the most prevalent weeds in low input systems.

Soil Dynamics in Low Input Systems (Y-215)

Objective. To establish the pattern of soil fertility decline and fertilizer response of low input systems, which is apparently quite different from the established pattern under high input systems involving conventional tillage.

Procedure. The "chronologic" design developed by Smyth and Bandy and implemented in Manaus will be imposed on a newly cleared and burned chacra in Yurimaguas. Design consists of 35 treatments with 4 replications in 80 m^2 plots. Total area = 1.12 hectares. For details see experiment M-901 under the Manaus project.

Improved Tacarpo and Fertilizer Placement (Y-217)

Objective. To improve seed germination, emergence and fertilizer placement by improving the use of the tacarpo (planting stick) in zero tillage system.

Justification. The tacarpo is likely to remain the primary planting tool for low input systems. The advantages of point tillage are often outweighed by uneven seed germination. Fertilizer placement under these conditions has not been properly investigated. Jabbers and other mechanical adaptations of tacarpo (including a double one for seed and fertilizer placement) imported from U.S. and Brazil only work well when the land has been tilled. Rotary injection planters have shown promise at IITA, but their performance on fields riddled with stumps and ample crop residues has to be determined.

Procedure. An experiment will be designed to test potentially improved tools both of planting stick and rotary injection planters that could provide a better seed germination and superior placement of fertilizer. The actual treatments are to be developed in late 1985 and the trial is to be initiated in 1986.

Burning and Immediate Fallow Planting (Y-216)

Objectives. 1) To test the value of burning felled secondary forest vegetation vs. slashing it; 2) To determine the potential for immediate planting of a managed fallow prior to growing crops.

Justification. The value of burning is seldom questioned as a means for adding a surge of nutrients to acid infertile soils and providing a

good start for crops. It is also an effective way to clear debris and facilitate planting. Burning is also known to cause considerable losses of nitrogen and sulfur to the atmosphere. Slash and mulch is only practiced in perudic areas where the high and well distributed rainfall prevents effective burning. Slash and mulch would presumably reduce N and S losses and allow a slower release of nutrients to the soil. One negative aspect would be the difficulty in planting, although additional slashing with machete may alleviate this problem. It is not known whether the absence of burning will increase or decrease the rate of resprouting from felled trees. When aluminum-tolerant crops are grown, it is questionable whether the rapid but short-lived increase in nutrient availability is better than a slower release pattern. A preliminary comparison of slashing vs. slash and burning a 25-year old secondary fallow in experiment Y-202 indicated somewhat higher crop yields without fertilization in the absence of burning.

Scientists in Southeast Asia are advocating the immediate planting of a kudzu fallow right after burning acid soils of their humid tropics. This possibility suggests positive benefits in immediate recycling of the surge in fertility and allowing time for the stumps to rot. It will also leave the land ready for clearing as our experience indicates that clearing kudzu fallow is a simple and straightforward practice. This practice appears specially advantageous when more land is cleared and burned than the farmers have the capacity to plant, due to seed, labor or fertilizer shortages. The apparent disadvantages are not to be able to grow crops immediately. To our knowledge, the advantages and limitations of this possibility have not been systematically determined. Little is known about the differences between grass and legume fallows in this respect.

Procedure. An experiment is proposed to test the advantage and limitations of these two practices under low input systems. A ten-year old forest fallow already cleared will be used and subjected to the following treatments, with four replications:

1. Slashed and burn-low input cropping;
2. Slash and burn-kudzu fallow;
3. Slashed and burned-Guinea grass fallow;
4. Slashed and mulch-low input cropping;
5. Slashed and mulch-kudzu fallow;
6. Slashed and mulch-Guinea grass fallow.

Plot size will be 500 m^2, requiring a total area of 1.2 hectares. Proposed measurements include monitoring of soil fertility dynamics, organic matter and litter decomposition, above-ground biomass and, after one year, infiltration rates and root development.

Manures and Animal Traction (Y-211)

This experiment, to be conducted with support of the National Selva Program, is at the design stage. The justification is the potential use of water buffaloes for animal traction and the potential utilization of manures gathered from buffalo milking corrals. CORDELOR is introducing these animals into the Selva, primarily to work on paddy rice fields, but potentially for this management option. Work is likely to be initiated in 1986 or 1987.

Central Low Input Experiment (Y-210)

Objective: To integrate the main components that result from other experiments of this project into farm-level alternatives.

Procedure. This trial was initiated in July 1983 and consists of two treatments: with and without fertilization (30 kg N, 50 kg P and 60 kg K/ha/rice crop) replicated twice in a 1 hectare field. It is planted according to the generalized procedures described in this project. Labor and other cost records are kept as well as monitoring crop yields and soil dynamics once a year. As mentioned before, this trial has provided better than expected results in terms of stability of crop yields. How long the system will remain stable is the main justification for maintaining its existence.

Principal Research Site: Yurimaguas Experiment Station

Duration: Five years

Low Input Crop Production Systems for Acid Soils
in the Humid Tropics
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	46	49	57	49	42	243
Fringe Benefits	4	5	5	5	5	24
Supplies	12	12	12	7	6	49
Equipment	3	2	2	18	2	27
Travel	9	9	11	9	9	47
Allowances	10	10	10	7	7	44
Other Direct Costs	15	15	15	9	9	63
Indirect Costs	19	22	21	18	18	98
TOTAL	118	124	133	122	98	595

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.20	0.40	0.40	0.40	0.40	1.30	0.50
Field Based Scientist	0.70	0.70	0.70	0.70	0.70	3.50	0.00
Graduate Student	1.50	1.50	1.50	1.00	1.00	6.50	0.00
TOTAL	2.40	2.60	2.60	2.10	2.10	11.30	0.50

Program: Humid Tropics

Research Topic

Title: Legume-Based Pastures for Acid Soils in the Humid Tropics

Objectives: To continue developing soil management technology components for improved pastures production in acid soils of the humid tropics.

Project Leaders: P. A. Sanchez, North Carolina State University

Collaborating Scientists: M. A. Ara, M. A. Ayarza, R. Schaus, A. G. Wollum
R. Dextre, J. Vela
J. Toledo, E. Pizarro, M. Calderon, J. Lenne

Rationale:

Pasture development for dual purpose (beef-milk) cattle production is a major activity in the Amazon and also a major concern. The high demand for beef, milk, and byproducts and the traditional role of cattle ranching in expanding the agricultural frontier in tropical Latin America are among the main reasons why pasture development is so important in the Amazon. The direct transplanting of Southern Brazilian technology to the Amazon resulted in widespread failures, arousing major ecological concerns about degradation of the environment. Outside of Brazil and Colombia, pasture development in the Amazon occurs mainly in small-scale, mixed farming systems based on shifting cultivation. The traditional technology is based on the expected substitution of the planted grass pasture by "torourco," a mixture of *Paspallum conjugatum* and *Axonopus compressus*. The same mixture, incidentally, has been observed in pastures of many other humid tropical areas, including Sitiung in Indonesia. When grazing pressures become too intense, while cattle numbers remain constant, the pastures degrade. Considerable soil compaction, runoff and erosion occurs, justifying many of the concerns raised by ecologists.

Well-managed pastures, on the other hand, have several positive attributes of relevance to the humid tropics. They keep the soil protected by a plant canopy throughout the year, require low quantities of purchased inputs per hectare, and can make good use of marginal soils unsuitable for crop production. Furthermore, grazing animals have the potential to recycle most of the nutrients they consume back to the soil.

It is clearly acknowledged that the main factor limiting cattle production in the humid tropics is inadequate animal nutrition related

to pasture persistence and quality. These latter factors are directly related to soil management. In 1978, a year after CIAT's Beef Program was reorganized as a Tropical Pastures Program focused on acid, infertile soils, this project was initiated at Yurimaguas in close collaboration with CIAT. Research phases included testing of promising germplasm, pasture fertilization, screening for insect and disease resistance and evaluation of mixed pastures under grazing. Yurimaguas is the oldest site of CIAT's Tropical Pastures Network with a continuous grazing trial with acid-tolerant germplasm in the rainforest ecosystem. Extrapolation to other areas of Peru started within the past two years.

With the advent of the National Selva Program's Tropical Pasture Network, scheduled to begin in 1985, most of the agronomic activities formerly supported by CRSP funds will be transferred to the National Selva Program, allowing CRSP funds to be used for tackling specific soil-plant-animal research problems affecting the quality and.persistence of mixed grass-legume pastures. The main ones center around the relationship between soil fertility, pasture quality and animal intake, soil and grazing management for pasture persistence, nutrient recycling by the grazing animal and the transfer of nitrogen from legumes to grasses.

Relevance to Other Programs:

Most research on soil-plant-animal relationships in the lowland tropics have been conducted in semiarid tropics and savanna ecosystems where pasture productivity during the dry season is the primary concern. Very little work has been done in the udic tropics where pastures grow and remain green throughout the year. Competition between grasses and legumes is quite different from the ustic tropics, where the grass dries out during the dry season while legumes generally remain green. The infinite growing season of the humid tropics raises questions such as the role of legumes that require specific research. Such information would be of value to the humid tropics in general.

Scope of Work:

This project consists of nine experiments, three of which are to be supported by the CRSP and the rest by the National Selva Program. It is closely linked with CIAT, and all NCSU and INIPA personnel involved have either worked at or received training at CIAT. The following experiments of a primarily agronomic nature will be supported by the National Selva Program: Germplasm introduction (Y-301); regeneration of degraded pastures (Y-304); pasture seed production (Y-305); tolerance to diseases and insects (Y-306); and pasture establishment in degraded lands (Y-309). Experiments that include CRSP support are: grass-legume mixtures under grazing (Y-302); nutritional requirements for pasture establishment (Y-303); potassium dynamics and recycling (Y-307); and nitrogen transfer in mixed pastures (Y-308).

Generalized Procedures:

Grass or legume accessions screened for acid tolerance by CIAT are first grown under clipping in Yurimaguas and then mixed in grazing trials. The basic premise is minimum additions of fertilizers, on the order of 50 kg P_2O_5/ha and 50 kg K_2O/ha and 10 kg Mg/ha per year, while maintaining pH values between 4.0 and 4.5 and Al saturation levels between 60 and 95 percent. Conventional pasture establishment normally originates from previously cropped land or degraded pastures with no stumps left. Virgin forests are seldom planted directly to pastures. Disk plowing is used to leave a corrugated soil surface where grass or legume seeds (previously mixed with inoculum) are planted in 50 cm rows. If botanical seed is not available, sprigs are transplanted. Fertilization using ordinary superphosphate, KCl and MgSO, is applied along seed bands. Paddocks are fenced and provided with mineralized salt and drinking water. Nellore or crossbred steers with Zebu blood, of about 150 kg in weight, are brought from Ganadera Amazonas ranches, and will be used until they reach approximately 250 kg weight. Grazing pressure is determined in relation to expected green forage availability. Grazing management is rotational, with the same animals used for all replicates of each treatment. Forage dry matter, botanical composition and nutrient composition (where applicable) are determined prior to each grazing period. Soil dynamics are followed once a year. Liveweight gains are recorded at the end of each grazing period. All grazing trials are considered long-term, because the most relevant data on pasture persistence is gathered from the second to the sixth year.

Grass-Legume Mixtures Under Grazing (Y-302)

Objectives. To estimate pasture persistence of promising mixtures, the changes in soil properties and obtain estimates of animal productivity.

Procedure. Experiment Y-302 was established in July 1980 with five grass-legume mixtures selected from the most promising material from Experiment Y-301 as treatments, and two replications with a plot size of 0.45 ha. Some associations have failed to persist. The surviving ones as of October 1984 are: *Brachiaria decumbens-Desmodium ovalifolium*, *Brachiaria humidicola-Desmodium ovalifolium*, *Andropogon gayanus-Stylosanthes guianensis*, and *Centrosema* hybrid 438. A new mixture of *Andropogon gayanus* with *Centrosema macrocarpon* is scheduled to replace *Panicum maximuim-Pueraria phaseoloides* which failed. Under continuous grazing, imbalances developed in several mixtures which threatened the persistence of the grass species. This was partially corrected by shifting to alternate grazing management and by replanting grass strips in some paddocks. Although annual liveweight gains per hectare are 6 to 8 times that of Torourco pasture, relatively low daily gains per animal suggest a pasture quality problem. Nitrogen, potassium and sulfur are suspected to be the main limitations. The role of tannins

is being studied in Raleigh to determine whether the sulfurtannins relationship observed in acid savannas apply to the humid tropics. After four years, some improvement in topsoil exchangeable Ca and Mg and available P are beginning to be noted. We propose to continue this experiment as the "central" trial of this management option, where soil-plant-animal data continue to be monitored. The next three-year period is considered critical for pasture persistence. Recent decreases in the legume percentage of two mixtures indicate that much needs to be learned to maintain a grass: legume balance in acid soils of the humid tropics.

Nutritional Requirements for Pasture Establishment (Y-303)

Objectives: To establish critical levels of phosphorus, both external and internal, for the establishment phase of eight main tropical pasture species in Yurimaguas.

Procedure. Experiment Y-303 was established in October 1984 to determine the in-situ P critical levels of *Andropogon gayanus*, *Bracharia decumbens*, *Panicum maximum*, the torourco mixture, *Desmodium ovalifolium*, *Stylosanthes guianensis*, *Centrosema pubescens* and *Pueraria phaseoloides*. After running P sorption isotherms, six P rates were determined. The trial is a factorial of 8 species x 6 rates x 4 replications. Available soil P and P in the plant will provide the critical levels. Virtually all information on P critical levels of these species has been developed for high P-fixing Oxisols. We expect higher soil critical levels in low P-fixing Ultisols.

Potassium Dynamics and Recycling (Y-307)

Objectives: 1) To study the effects of potassium fertilization and grazing pressures on forage and litter production of a *Brachiaria decumbens-Desmodium* ovalifolium; 2) to evaluate the importance of plant litter, animal urine and leaching losses for the K-economy in pastures.

Procedure: Three field experiments will be established simultaneously. The grazing experiment is a factorial of three annual rates of K fertilization by two grazing pressures with three repetitions with a total area of 1 hectare. A parallel clipping experiment with the same K levels provides a comparison of the effect of grazing on K dynamics. A bare plot experiment will account for soil chemical and physical properties related to K leaching.

The main parameters to be measured are: available forage before and after grazing, botanical composition, litter dry matter, K content in biomass, K in litter, exchangeable K and other bases in the profile and point samples in excreta areas. Animal liveweight gains will also provide an estimate of K removal. This experiment will be used to study the effect of grazing on other nutrients by INIPA counterparts.

Nitrogen Contribution of Legumes in Mixed Pastures (Y-309)

Objectives. 1) To estimate the N contribution of two adapted legumes that differ in palatability in mixtures with *Brachiaria decumbens*; 2) to evaluate the effect of grazing pressures on the N contribution of *Desmodium ovalifolium* to the grass; 3) to compare N availability to animals in mixed grass-legume pastures with N-fertilized, pure grass pastures. It is hypothesized that, 1) nitrogen transfer through animal excretion is expected to be more important in the more palatable legume, (*Centrosema* hybrid 438) while N release through legume litter may be more important in the less palatable and therefore, less consumed species (*Desmodium ovalifolium*); 2) increasing grazing pressure decreases animal selectivity between grasses and legumes and increases N intake by the animal and decreases litter accumulation.

Two experiments are being installed at IVITA's Pucallpa Station to test the above hypotheses. The grazing experiment consists of six treatments, with three replications with a total area of six hectares. Treatments 1 and 2 consist of the *Bd*/*Do* mixture at a moderate grazing pressure (9 kg available forage dry matter/100 kg animal liveweight) and at a high one (4.5 kg DM/100 kg liveweight). Treatment 3 is *Bd*/*Ch* mixture, and the rest pure *Bd* pasture fertilized at 0, 150 and 300 kg N/ha/yr. The latter four are at the moderate grazing pressure. A parallel clipping experiment includes similar treatments with four replications. Differences between N consumed by the grazing animals between the mixed pastures and the pure grass pastures without N fertilization will provide an overall estimate of N contribution of the legumes. Differences between the grazing and clipping experiments will be used to estimate the N transfer by the grazing animal. Differences between N contributed by litter decomposition vs. decomposition of legume roots and nodules will be estimated through a third experiment in which N^{15}-enriched *Desmodium ovalifolium* litter will be added.

In addition to the generalized procedures, this experiment will measure pasture dry matter and N intake with fistulated animals, faecal output, in-vitro and in-rumen dry matter digestibility. Besides estimating the N contribution of the legume, this experiment will provide a quantitative comparison of grass-legume pastures with nitrogen-fertilized grass pastures. The economic analyses will be undertaken by the National Agroeconomics Program, using data from IVITA's nitrogen-fertilized milk production module in operation at the same location.

Principal Research Sites: Yurimaguas Experiment Station
IVATA Principal Station, Pucallpa,
NCSU Soil Science, Crop Science and
Animal Science Laboratories

Duration: Five years

Legume-Based Pastures for Acid Soils in the Humid Tropics
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	21	19	13	0	0	53
Fringe Benefits	2	2	2	0	0	6
Supplies	4	6	6	0	0	16
Equipment	2	2	2	0	0	6
Travel	7	8	6	0	0	21
Allowances	3	2	3	0	0	8
Other Direct Costs	9	7	9	0	0	25
Indirect Costs	9	9	9	0	0	27
TOTAL	57	55	50	0	0	162

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.10	0.10	0.10	0.10	0.10	0.50	0.00
Field Based Scientist	0.10	0.00	0.00	0.00	0.00	0.10	0.00
Graduate Student	1.00	1.00	1.00	0.00	0.00	3.00	0.00
Other	2.00	2.00	2.00	2.00	2.00	0.00	10.00
TOTAL	3.20	3.10	3.10	2.10	2.10	3.60	10.00

Program: Humid Tropics

Research Topic

Title: Soil Management for Agroforestry Systems in the Humid Tropics

Objectives:

A. To continue developing soil management components for improved agroforestry systems on acid soils of the humid tropics.
B. To determine the value of trees and woody shrubs in producing food or fiber.
C. To determine whether trees improve or stabilize soil properties in the humid tropics.

Project Leader: Charles B. Davey, North Carolina State University

Principal Collaborators: L. T. Szott, C. A. Palm, J. R. Davelouis, J. C. Alegre, P. A. Sanchez, A. G. Wollum, M. A. Villavicencio, B. Pichanasi, R. Coral, J. R. Perez, F. Torres

Rationale:

Shifting cultivation, an ecologically stable system when populations are small, breaks down under increasing population pressure. This is occurring in much of the humid tropics and improvements are needed to increase both the productivity and stability of cultivation systems. Trees are considered the natural "vocation" of the humid tropics as illustrated by the ability of rainforests to grow and accumulate large quantities of biomass on acid soils very low in nutrients. No soil management research program in this ecosystem can be considered complete without bringing trees into them. Agroforestry can be defined as growing trees along with crops or pastures either simultaneously or in sequence. Several agroforestry systems offer opportunities for reaching these goals in low to medium input production systems. Most agroforestry research in the humid tropics, however, has been conducted on high base status soils.

Agroforestry is the fourth soil management option being studied by TropSoils-NCSU in Yurimaguas. This option focuses on acid, well-drained soils that occupy flat to rolling topographies. Little is known quantitatively about soil-tree relationships under these conditions. Our involvement in agroforestry started in 1980 with observational trials with two species, melina (Gmelina arborea) and peach palm (Gulielma gasipaes), otherwise known as pijuayo, pupunha, chontaduro or pejibaye. In 1982, a joint study group composed of scientists from INIPA, ICRAF,

CIAT and NCSU undertook a sondeo-type survey in farms around Yurimaguas and Pucallpa to suggest research priorities for integral agroforestry research. The recommendation was to concentrate on crop-tree systems and secondary forest fallows at Yurimaguas and to focus on pasture-tree systems at Pucallpa. Emphasis on peach palm was recommended because Yurimaguas is one of its centers of origin, because its fruit is considered as very well balanced in terms of carbohydrates, protein, fats and vitamins, and because of the plant's ability to coppice, which enables heart of palm (palmito) production for export without killing the tree. Fast-growing trees for pulp or hardwood production were also considered important. The study of secondary fallows, either with natural or introduced species was also initiated in order to bridge one of the major gaps in our understanding of the shifting cultivation process: how do trees improve soil properties? During 1984, a literature review on this subject provided the basis for new hypotheses that served to formulate parts of this proposal.

The agroforestry option, more than the crops or pasture options, requires extensive efforts in germplasm collection and evaluation. The mechanisms for introducing and screening cultivars of crop or pasture species are genuine soil management tools and are now routine. In agro forestry we are at the initial stages of defining species. We know little about growth habits, phenology and propagation characteristics. Conscious of the need for inputs from other disciplines such as forestry and tree horticulture, a project was jointly submitted by ICRAF and INIPA which culminated in the award of 260,700 Canadian dollars to INIPA for the Yurimaguas Agroforestry Project by the International Development and Research Center. This project complements TropSoils activities and is guided by a Technical Committee of which the TropSoils Principal Investigator is a member. Consequently, this endeavor provides a unique opportunity to generate new information on soil-crop-tree relationships.

Relevance to Other Programs:

To our knowledge, this is the first in-depth soil research project on agroforestry in acid soils of the humid tropics that is integrated with other disciplines and is linked with worldwide agroforestry research through ICRAF. Although several experiments focus on one species, the principles likely to evolve can be of value in other areas where other tree species may be the priority. The findings of these studies may be widely applicable to the 500 million hectares of this ecosystem in Asia, Africa and Latin America.

Scope of Work:

The entire agroforestry project consists of 14 experiments of which eight are proposed for CRSP support and six by the IDRC grant. Five of the eight CRSP-supported experiments are ongoing established trials and three are new. Ongoing experiments include: Nutritional requirements of

Gmelina arborea (Y-403); nutritional requirements of peach palm (Y-404); alley cropping (Y-405); improved fallows (Y-409); forest and soil regeneration (Y-410). Three new ones are proposed: cover crops for peach palm (Y-402); fallows as nutrient accumulators (Y-411); and comparative soil dynamics under different management systems (Y-412). Research supported by the IDRC grant includes: Peach palm cover crops (Y-402); collection and propagation of peach palm ecotypes (Y-406); collection and propagation of agroforestry species (Y-407); collection and propagation of Amazonian native fruit trees (Y-408); management of peach palm for fruit or palmito production (Y-414); multistrata polyculture systems (Y-415); and a market potential study of Amazonian palms (Y-416); the latter in cooperation with INIPA's National Agroeconomics Program.

Cover Crops for Peach Palm Plantations (Y-402)

An observational trial, planted in 1980 provided qualitative information that a kudzu (Pueraria phaseoloides) understory favors the growth and initial fruiting of peach palm. After reviewing the information on interrow legume management of rubber in Malaysia, several ideas came forth, including the use of new legume species. A new cover crop experiment is proposed and will include the following treatments:

1. Weedy cover (no management);
2. Kudzu, no fertilizer;
3. Kudzu and 50 kg P_2O_5. and 60 kg K_2O and 10 kg Mg/ha/year;
4. Desmodium ovalifolium, without fertilization;
5. Desmodium ovalifolium, fertilization as #2;
6. Desmodium heterophyllum, without fertilization;
7. Desmodium heterophyllum, fertilization as #2;
8. Centrosema macrocarpon, without fertilization;
9. Centrosema macrocarpon, fertilization as #2;
10. Calopogonium caeruleum, without fertilization;
11. Colopogonium caeruleum, fertilization as #2;
12. Low input cropping (rice-cowpea) with appropriate fertilization.

Plot size is estimated at 500 m^2 each. A completely randomized design with three replications will require approximately 1.8 hectares. The recommended spacing and management practices for peach palm fruit production will be used.

Main parameters to be measured are: ground cover; understory biomass and N content; N fixation activity estimates; height and diameter of peach palm; and fruit yields from the fourth year on. Dynamics of physical, chemical and biological properties will be monitored at planting and once a year.

Nutritional Requirements of Gmelina arborea (Y-403)

Objective. To determine the response of Gmelina arborea to N, P, K, Mg and lime applications.

Procedure. Seedlings of an improved upright variety from Jari, Brazil were planted in mid-1982 at 3 x 3 m spacing in a previously cultivated Ultisol. Eighteen fertilizer treatments provide for a four point response curve to N, P, K and Mg and to one rate of lime (1 ton/ha), and to Cu + Mo + Zn. The experiment has three replications. Strong responses are evident at one year over the check plots. Height and average diameter at breast height (DBH) are being measured four times a year. The experiment will continue through harvest at 9 years and as a residual for the second rotation.

Nutritional Requirements of Peach Palm (Y-404)

The objective, procedures and experimental design are the same as in Y-403, except for different spacing. Stem height and DBH responses to nitrogen (up to 200 kg N/ha/yr) phosphorus (25 kg P/ha/yr), potassium (75 kg K/ha/yr), magnesium (20 kg Mg/ha/yr) and to 1 ton/ha/yr lime are evident at 18 months after transplanting. The experiment is scheduled to continue for 15 years.

Alley Cropping (Y-405)

Alley cropping is a traditional agroforestry system developed in Java where prunings of Leucaena leucocephala grown in rows are used as mulch and a source of nutrients to annual crops grown between them. The principle behind alley cropping is that trees fix nitrogen and cycle other nutrient elements from the subsoil, providing them to the annual crops. This technique has worked well in Alfisols of West Africa where IITA has improved it. But, will it work in acid soils where Leucaena does not thrive and where the subsoils are depleted of nutrients?

An experiment was initiated in August 1983 to attempt to answer this question, using legume species believed to be acid-tolerant. A split plot design was used to study six tree species, six spacings between alleys and three fertilization levels in the tree rows, with four replications. The alley species are: Pigeon pea (Cajanus cajan), guava (Inga edulis), amaciza (Erythrina spp.), tornillo (Cedrelinga catenaeformis), Leucaena diversifolia, believed to be acid-tolerant, and Leucaena leucocephala as a check. Spacing between tree rows ranged from 2 to 4.5 m in 0.5 m increments. Fertilty treatments applied to the tree rows were: none, 2 ton/ha of lime and 2 ton/ha of lime plus 100 kg P/ha as single superphosphate. Food crops were grown under constant spacing and without fertilizer additions. Two additional treatments with sole crops with and without recommended fertilization are used as checks. The first prunings were added to the first crop (corn) in Feburary 1984. The second crop (cowpea) is about ready for harvest.

Soil chemical and physical properties are being monitored. The contribution of nutrients added to the system in the prunings is also being analyzed.

Collection and Propagation of Peach Palm (Y-406)

Yurimaguas is one of the centers of origin of peach palm. Many ecotypes grown in native communities differ greatly in trunk spininess and fruit appearance. A collection effort was initiated in 1981 by Jorge Perez as part of his thesis for the ingeniero forestal degree at the University of Iquitos. About 70 ecotypes have been collected and characterized for fruit properties. Great variability was observed in protein, vitamins, fat contents, mesocarp color and other properties. Several ecotypes are planted in the field to maintain a collection. A major limiting factor is the outcrossing habit of peach palm. Continuation of this work is in progress and is to be supported by counterpart funds.

Collection and Propagation of Agroforestry Species (Y-407)

Trees and woody shrub species for alley cropping, improved fallows and timber production need to be collected from the vast germplasm resources of the Amazon and elsewhere. The failure of Leucaena leucocephala as an alley crop on acid soils (experiment Y-405) underscores the need for selecting species that are naturally adapted to acid soils. Examples of promising genera are Parkia, Schyzolobium, Erythrina, and Calliandra. Collection of species for improved fallows or timber production is also needed. Examples of promising species are anayocaspi (Callyphillum sprucianum), cetico (Cecropia sp.), cituye (Heliconia sp.). Introduction of species considered useful in Africa and Asia is also desirable. Examples of germplasm obtained from IITA and the Niftal Project include Acioa barteri, Albizia falcataria and several others. The proposed work includes:

1. Collect seed of candidate trees and woody shrubs (both N-fixing and non-fixing) and determine whether they can be direct seeded in the field or need to be germinated and raised in the nursery and transplanted to the field.

2. Determine best spacing for the trees/bushes within rows, among rows.

3. Determine their response to pruning and their ability to produce viable seed or multiply by vegetative propagation.

Preliminary contact have been established with Dr. Roger Leakey of the Institute of Terrestrial Ecology in Scotland for collaborative work in studying vegetative propagation methods of these species. Cooperation with the Von Humboldt Station of INFOR at Pucallpa is also envisioned. This work is to be supported by counterpart funds, including additional staff to be hired.

Collection and Propagation of Native Fruit Trees (Y-408)

The Amazon has a considerable number of fruit species that appear well adapted to acid soils and that are virtually unknown outside the region. Their fruits are sources of food, juices, spices or edible oils. We propose similar collection and propagation of fruit tree species considered as having promising agroindustrial potential in the Amazon. The species selected, apart from peach palm are: araza (Eugenia stipata), guarana (Paulina cupana), camu-camu (Myrciaria dubia), ungurahui (Jessenia polycarpa), copoazu (Theoboma grandifolium), achiote (Bixa orellana) and guava (Inga edulis and Inga spectabilis). Collections will be conducted in cooperation with INIPA's San Roque Station at Iquitos. Work is to be supported by IDRC grant funds and will be led by the horticulturalist to be hired with those funds.

Improved Fallows (Y-409)

The purpose of this experiment is to determine whether the rate of improvement in soil properties after the cropping phase of shifting cultivation can be accelerated by improved fallows in comparison with natural forest fallow regrowth. The experiment is expected to broaden the inquiry started by the kudzu fallow experiment (Y-202), now terminated.

A one-hectare mature secondary forest fallow was slashed, burned and planted to upland rice without fertilization in August 1983. After the rice harvest, the following treatments were installed in 100 m^2 plots with four replications, arranged in a randomized complete block design:

Natural fallow regrowth
Cajanus cajan
Inga edulis
Stylosanthes guianensis 136
Centrosema hybrid 438
Desmodium ovalifolium 350
Pueraria phaseoloides
High input cropping check
Low input cropping check

Above-ground biomass is sampled every four months. Soil fertility dynamics and certain physical properties such as infiltration rates and bulk density are periodically sampled. Botanical composition and the structure of the fallows are also monitored. Litter quality and organic matter decomposition will begin to be monitored after the second year. No weeding will be done, allowing competition between the planted species and spontaneous ones. After four years, the fallows will be cut, burned and planted to low input crop rotations.

Forest and Soil Regeneration (Y-410)

Information about the natural processes involved in the regeneration of favorable soil properties by secondary forest fallows is critical to our understanding of shifting cultivation and hence, for designing improved systems. This experiment represents an attempt to quantify soil dynamics through the study and manipulation of fallows of various ages. The following objectives are attempted in this study:

1. To observe the changes in soil properties associated with natural secondary vegetation (purma) of different ages growing on similar Udults;

2. To quantify the potential or actual nutrient contributions from various sources in an abandoned agricultural field and to estimate leaching losses;

3. To experimentally investigate the effects of soil physical and chemical properties on secondary succession by manipulating soil fertility levels and residue input;

Objective 1 is to be accomplished by selecting purmas of known age, growing on Paledults with similar color and textural gradients and located on similar slopes around the Yurimaguas station. An attempt will be made to identify indicator species that correlate with age of fallow.

Objectives 2 and 3 are expected to be accomplishing in a 3-hectare plot cleared of tall secondary fallow, cropped and just abandoned by a farmer near the Yurimaguas station. The land was rented from the farmer in February 1984 and has been divided into four treatments, arranged in a completely randomized design with four replications. The treatments are:

1. Removal of all plant residues;

2. Plant residue left in place;

3. Double the amount of plant residue;

4. Fertilization in kg/ha/yr: 100 N, 100 P and 120 K.

Measurements taken include rainfall and its chemical compostion, biomass, its structure and nutritional composition two times a year, soil dynamics with time, infiltration and bulk density, leaching through zerotension lysimeters and root distribution in the top 50 cm. Total elemental analysis to 1 meter depth was also performed. Soil respiration was measured by CO_2 entrapment field techniques once during the first year. If continued for about 15 years, this experiment will provide a sound basis for understanding the process of soil productivity regeneration under fallows.

Fallows as Nutrient Accumulators (Y-411)

Two functions commonly ascribed to the fallow phase of shifting cultivation are: 1) to accumulate and conserve nutrients in the vegetation, protecting them from leaching, and 2) to increase the organic matter of the topsoil thereby increasing the cation exchange capacity and hence, the total nutrient availability of the soil. The generally long fallow periods required to restore fertility make shifting cultivation an extensive form of land use, approximately 80% of the land being in fallow at any one time. An ideal fallow would be one that takes up available nutrients and recycles them efficiently within the system, shortening the time required to restore fertility. Plant species differ in their nutrient uptake capacities, due both to different uptake kinetics and distribution of roots in the soil. One might expect, therefore, certain plants to be better suited for nutrient accumulation and recycling. Data on Gmelina arborea from Brazil and Nigeria indicate this fast-growing tree is a Ca, and perhaps Mg, accumulator. The soils under these trees have several times the exchangeable Ca as the soil under rainforest. Certain bamboo and other grasses, on the other hand, accumulate K in the plant tissue and the K-enriched litter increases the soil exchangeable K. There are also reports that Cecropia sp. are K accumulators. Tergas and Popenoe found in Guatemala that soils under pure stands of Heliconia sp. had 3-4 times the available P as mixed species fallows of the same age. And, it is well known that nitrogen-fixing legumes enrich surface soils with available N. One would predict that fallows planted or enriched with such species would restore soil fertility faster than natural fallows.

Fertility improvement can be of two kinds: 1) increasing soil nutrient availability during the fallow period itself, rendering the soil indeed more fertile before reclearing, or 2) immobilizing increased quantities of nutrients in the fallow biomass which would be rapidly released upon clearing and burning. We are interested primarily in the first kind, although the development of ash with higher nutrient contents would also be advantageous.

The purpose of this new experiment, therefore, is to determine if fallows planted with species known or reported to be nutrient accumulators take up and recycle nutrients more efficiently than natural fallows, thereby restoring fertility more quickly and reducing the time required for the fallow phase.

A two-phase approach is proposed. Phase I consists of sampling otherwise identical soils in fallows with or without the candidate species for nutrient accumulators. This includes Heliconia spp. and Cecropia spp. both of which readily invade abandoned fields. Preliminary results from fallows sampled in Ultisols of Costa Rica do in fact corroborate the findings of Tergas and Popenoe that soils under Heliconia are higher in available P. Further spot testing is currently underway in Yurimaguas on soils and plant tissue of Heliconia and Cecropia stands and in Gmelina arborea plots with and without lime in experiment Y-403.

If the results of Phase I provide strong leads, an experiment will be designed that will include these and other fallows in previously fertilized and/or not fertilized plots. In addition to differences in available and exchangeable nutrients under different planted fallows, changes in the quantity and composition of soil organic matter and cation exchange capacity might result from differences in the quality and quantity of litter produced. Some types of litter are readily decomposed making nutrients readily available to plants. Other types are not easily decomposed and lead to the formation of humus and potential changes in the cation exchange capacity of the soil. Both types of litter would be desirable for maximum nutrient availability and retention.

Comparative Soil Dynamics Under Different Management Options (Y-412)

The potential effects of different farming systems on soil properties in rainforest regions are frequently mentioned in both the scientific and popular press. Statements such as "pastures degrade tropical soils," "trees improve soil properties," "arable crops are erosive," abound. Such questions are of fundamental importance to guide the development of marginal lands in the humid tropics. There are no studies where the effects of different management systems on soil properties can be determined in a rigorous way. The purpose of this proposal is to compare systematically the effect of different management options on well-drained Ultisols. It brings together what we have learned as promising options in 12 years of research at Yurimaguas and places the options in a way they can be compared.

An 8-hectare field of Typic Paleudult soils located on 0-4% slopes was selected on an area newly incorporated into the Yurimaguas Experiment Station. The vegetation is a 10-12 year old secondary forest fallow, typical of the target area of the Program. The field will be divided into 24 plots by transects before clearing it July 1985. Each plot will be placed in a manner that includes the topographical variability, including the small percentage of wet spots (tahuampas) typical of this landscape. The experiment will consist of eight management options as treatments with three replications arranged in a randomized complete block design. Land clearing will be by slash and burn unless otherwise specified. The treatments developed together by the INIPA and NCSU resident staff in Yurimaguas are:

1. Shifting cultivation (0.36 ha per plot). Land will be planted to the traditional upland rice variety intercropped with cassava. After the cassava harvest, the plots will be allowed to revert to fallow, thus permitting the study of the fallow regeneration process. These plots will be contracted out to farmers who will clear and manage them.

2. Mechanized continuous cropping (0.36 ha per plot). Land will be cleared with a tractor equipped with a KG blade, burned, disked, limed and fertilized according to soil test recommendations and planted to a

corn-peanut-soybean rotation. Grass waterways to dispose of excess water will be established as needed. Ample room for turning tractors will also be provided. Conservation tillage will be practiced after lime and phosphorus are properly incorporated into the subsoil.

3. Transition technology (0.36 ha per plot). Plots will be cleared by slash and burn, withdrawing logs for firewood but leaving stumps in place. Low input technology with an upland rice-cowpea rotation will be planted, fertilized and managed according to the practices developed in Experiment Y-210. After three years, when most stumps have rotted out, the land will be plowed, limed, fertilized and treated like treatment #2.

4. Low input technology with managed fallow (0.36 ha per plot). As treatment #3 except that the upland rice-cowpea rotation will continue until the yield declines become serious. Then it will be planted to kudzu or another managed fallow, rested for two years, burned and planted again to the low-input technology system.

5. Tree crop production (0.5 ha per plot). Land will be planted to low input technology crops but interplanted to one species of value to the plywood industry developing near Yurimaguas. Candidate species are ishpingo (*Amburana searensis*), anayocaspi (*Cordia alliodora*), capirona (*Callyphillum sprucianum*) or tornillo (*Cedrelinga catenaeformis*).

6. Peach palm production (0.5 ha per plot). Land will be planted with peach palm spaced at 5 x 5 m with kudzu interrows fertilized according to the soil test critical levels arising out of experiment Y-403. No initial production of palmito is contemplated.

7. Multistrata system (0.5 ha per plot). A traditional system developed by Bora natives north of Iquitos, modified in relation to Yurimaguas conditions will be tested as an option that reflects traditional management. Plots will be cleared and planted to low input technolgy crops. Interspersed among them araza (*Eugenia stipata*) seedlings will be planted at 3 x 3 m spacing forming a second stratum. The third stratum will be composed of hardwood trees planted also at the same time but at 5 x 5 m spacing. Candidate species are mahogany (*Swetania macrophyla*), ishpingo (*Amburana searensis*) and *Cordia alliodora*. The annual crop stratum will gradually be shaded out by the tree strata.

8. Forest fallow check (0.5 ha each). Plots will be left untouched to serve as a check against other treatments.

Additional treatments involving legume-based pastures under grazing were considered highly desirable but not feasible within the space available. Two treatments (traditional vs. improved pastures) would add an additional 6 hectares of land to this experiment.

Forest biomass and nutrient composition will be estimated prior to clearing. Rainfall records will be kept and rainfall chemical composition analyzed.

The fertility-related parameters to be measured include chemical composition of the ash and periodic soil samplings at depths of 0-15, 15-30, 30-50 and 50-100 cm at the following months after burning: 0, 3, 6, 12, 18, 24, 36, 48, 60, 72, 84, 96, 108 and 120. Total composite soil samples per sampling period will be 96. Soil samples will be analyzed for pH (1:1 H_2O), organic C, total N, 1N KCl-extractable acidity, Ca, Mg and inorganic ^{2}N. Exchangeable K and available P, Zn, Fe, Mn and Cu will be determined by the modified Olsen extraction. 1N $CuCl_2$-extractable Al will also be determined. Micronutrient determinations will be limited to the 0-15 cm layer. Effective CEC and Al saturation will be calculated.

Soil physical parameters will include penetrometer resistance, bulk density and water infiltration rates once a year. Biological parameters will include litter quality indicators, estimates of N_2-fixation, and mycorrhizae populations with emphasis on the topsoil layer and the litter layer, if present.

Agronomic parameters include yield determinations and growth of tree crops. Estimates of total biomass will be done by appropriate techniques. Estimates of nutrient uptake will also be done, with emphasis on the portions removed from the field.

The representative of the National Agroeconomics Program stationed in Yurimaguas will monitor labor inputs and production costs and returns.

Principal Research Site: Yurimaguas Experiment Station

Duration: Five years

Soil Management for Agroforestry Systems in the Humid Tropics
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	45	49	54	35	30	213
Fringe Benefits	4	4	5	3	3	19
Supplies	9	8	8	7	6	38
Equipment	10	2	3	20	2	37
Travel	12	12	12	12	12	60
Allowances	11	12	13	12	12	60
Other Direct Costs	18	21	21	17	15	92
Indirect Costs	26	20	22	21	15	104
TOTAL	135	128	138	127	95	623

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.20	0.20	0.20	0.20	0.20	0.50	0.50
Field Based Scientist	0.10	0.10	0.10	0.10	0.10	0.50	0.00
Graduate Student	2.50	2.50	2.50	2.00	2.00	11.50	0.00
Other	1.00	1.00	1.00	0.00	0.00	0.00	3.00
TOTAL	3.80	3.80	3.80	2.30	2.30	12.50	3.50

Program: Humid Tropics

Research Topic

Title: Characterization, Classification and Interpretation of Soils of the Humid Tropics

Objectives:

1. To increase knowledge of soils and soil properties in the humid tropics.
2. To characterize potential network sites to aid in proper site selection of extrapolation work.
3. To improve the interpretation of Soil Taxonomy in agronomic terms through the Fertility Capability Classification System.

Project Leader: S. W. Buol

Principal Collaborators: L. R. Newman, R. Hoag, P. A. Sanchez
R. Chumbimune, H. Subagjo, H. Eswaran

Rationale:

Knowledge of the properties and distribution of soils of the humid tropics serves as the basis for soil management. The link between the subdisciplines of soil classification and soil fertility have always been strong in TropSoils-NCSU. Proper selection of sites for extrapolation work requires good soil characterization, classification via Soil Taxonomy and interpretation in practical agronomic terms. This project proposes continuation of these activities, several of which are outlined as subprojects here and others which may arise in the course of the 1985-89 quinquennium.

Relevance to Other Programs:

Increased knowledge about properties of humid tropical soils will provide feedback for improving Soil Taxonomy and other natural classification systems. Membership of NCSU faculty involved in this project on international committees of the Soil Management Support Service provides such a link. Participatiion in the following committees is ongoing at present: ICOMLAC (low activity clays), ICOMOX (Oxisols), ICOMAND (Andisols) and ICOMAQ (aquic soils). SMSS covers direct costs. Our research will also relate to the FAO-led soil reference base and framework on land evaluation.

Scope of Work:

This project consists of six subprojects all supported either partially or totally by the Soil Management CRSP: characterization of network sites (Y-605); maximum nutrient potential of principal soil areas of the Amazon (Y-606); influence of volcanic ash in transmigration areas in Sumatra (Y-608); FCC refinement and testing (Y-601); FCC map of the developing world (Y-602); and soil taxonomy and FCC software for microcomputers (Y-607). Two additional subprojects, characterization of alluvial soils of the Amazon (Y-603) and characterization of Puerto Maldonado Experiment Station (Y-604) are scheduled for completion in 1985 and are not described in this proposal.

Characterization of Network Sites in the Humid Tropics (Y-605)

Objectives. Describe, sample, characterize and classify representative soils in the humid tropics where agronomic research is to be conducted or transferred by TropSoils collaborators.

Justification. Soil properties such as texture, depth, mineralogy, structure and base saturation affect the responses obtained when management practices are implemented. As management practices develop, researchers and extension specialists need to evaluate other locations where the technology is applicable. This subproject will provide soil property data needed to base technology transfer judgments. In addition, it provides data to classify the soil used in any of the agronomic research.

Generalized procedures. Sites on existing experiment stations are sampled by natural horizon thickness to a depth of 2 meters. Profile descriptions are prepared in the field either by excavating a pit or from auger samples. The profile description includes horizon thickness, color, texture, structure, and consistence information. Samples of each horizon are taken and chemical and/or mineralogical analyses are conducted as needed to properly classify the soil. At locations remote from the established experimentation site, similar descriptions and samples are obtained. These sites are selected in response to requests by project researchers and/or collaborators who want to establish new research sites and/or farmer demonstration trials. Sites are visited by experienced soil survey personnel who make the final site selection, prepare the profile descriptions, and are involved in the sampling. Soil erodibility (K) factors will be determined to evaluate sensitivity to erosion.

Maximum Nutrient Potential of Principal Soil Areas in the Amazon Basin (Y-606)

Objective. Determine the quantity and composition of primary minerals in the silt and sand fractions of areally extensive soils in the Amazon Basin.

Justification. Every soil has a measurable reserve of relatively plant unavailable nutrients. These nutrients, such as Ca, Mg, K, P and certain micronutrients, are slowly available as the coarser particles weather. Collectively they are referred to as weatherable minerals when used as soil classification criteria. Their quality and quantity are a basis for predicting in what areas, i.e., parent material sectors, of the basin are most probably going to experience deficiencies in certain plant nutrients under cropping.

This subproject is an interface between soil survey and soil testing. Whereas soil test techniques attempt to measure the amount of a plant nutrient that is available to a crop because it appears in the soil in an available form, this project attempts to determine the ultimate potential source of the plant nutrients in geologically defined parts of the basin. In brief, it attempts to evaluate the potential of different soils to resupply the available forms of plant nutrients removed by crop harvest.

Generalized procedures. Five regional areas within the Amazon Basin will be selected on the basis of the geologic origin of the parent material. They are materials from: 1) sedimentary Andean source areas; 2) metamorphic (felsic) Andean source areas; 3) volcanic Andean areas 4) sedimentary (sandy) Guayanan highlands source area; 5) Brazilian shield areas.

Paired sites of upland (well drained) and lowland (poorly drained) soils will be sampled, by horizon, to a 2 m depth. Profile descriptions will be prepared at each site. Characterization data, as needed for proper classification, will be obtained on the samples. Samples from three major horizons in each soil will be subjected to optical mineralogical determinations of the sand fraction and total elemental analyses of the sand fractions will also be made.

Survey of Volanic Ash Influence on Transmigration Areas in Sumatra (Y-608)

Objective. Determine the amount, thickness, and present composition of amorphous material in the major soil and geographic areas of Sumatra.

Justification. Amorphous material weathered from volcanic material in udic soil moisture regimes has significant influence on P reactions in soils. The volcanic areas in Sumatra are on the southern coast of the island but ash deposits extend over other geologic areas to the north of the source area. Although the mantle of ash may no longer be recognized because of weathering and pedoturbation processes, it may be detectable and spatially predictable in the surface horizons of otherwise contrasting soils. Landscape evolution may have produced micro variability with more amorphous material on the stable landscape positions than on the hillslopes.

Correction of P deficiencies through fertilization is a major concern to other projects in this program. From results in other areas of the world, it is known that P fixation by amorphous Al cannot be managed the same as P fixation by iron. Soils in some of the transmigration areas are classified as Oxisols and thus, the initial hypothesis is that the technology previously developed in Brasilia by our earlier project will transfer. However, Brasilia has no known potential amorphous material source such as volcanic ash. Also, if the natural geomorphic activity has unevenly eroded the surface layers, local variability related to landscape position may significantly influence results from fertilization application.

Generalized procedures. Sample sites on paired stable and sideslope positions will be located on North-South transects across Sumatra. Profile descriptions and samples to a depth of 2 m will be made at each site. Sampling will be conducted by soil horizon but any horizon over 20 cm thick will be subdivided. The samples will be subjected to NaF pH value determination in the field and laboratory. The samples, total and sizefractionated subsamples, will be analyzed by DTA to determine kaolin and gibbsite content. Total amorphous material will be determined by KOH extraction and the remainder of each sample again subjected to DTA. Total amorphous material minus gibbsite and kaolin loss during KOH treatment is a reliable measure of "true" amorphous material present. The Si/Al ratios, an indicator of P fixation potential, of the amorphous material will be determined. Also, oxalate extractable Al will be determined as a sensitive P fixation indicator. Appropriate P-fixation values will be determined on selected samples.

Fertility Capability Classification: Refinement and Testing (Y-601)

Objectives. Further evaluate both existing and new data and experience to formulate the best interpretation packages for each FCC group and to develop systematic methodology for utilizing these packages within information delivery systems such as an agricultural extension service.

Justification. FCC groups are being used as a basis for research planning and technology transfer in many areas of the world. Modifications have been made to utilize new research findings. Further modifications are probable; however, they are expected to be minimal in concept.

Until now most attention has been given to developing criteria for creating and placing kinds of soil into FCC groups. Little attention has been given to systematic methods of presenting management recommendations associated with each group. Whereas each FCC group outlines physical and chemical constraints in the soil, there are several technologies available to cope with each constraint. There is a need to organize and present packages of technological alternatives of soil management that are most compatible with the infrastructure constraints in various areas of the humid tropics.

This subproject involves reviewing experimental and demonstrational results in this and other projects in the tropics as well as farmer results obtained on known kinds of soil as grouped by FCC criteria. These findings are to be assembled into packages of soil management suggestions to guide extension workers charged with the transfer of technology to the farmer fields. In brief, the subproject will attempt to create a delivery mechanism by which current research information can be transmitted to the farmer in a rapid and systematic fashion.

Generalized Procedures. It is apparent that many of the constraints identified by FCC groups can be and are presently being overcome by different maragement techniques. The method selected depends upon the economic and social status of the farmer as well as his perception of the risks involved. Research results have demonstrated that both higher fertilizer input technologies and low fertilizer input technologies are effective in overcoming many fertility constraints. Local farmers and extension specialists are often not appraised of these alternative scenarios of management practices on FCC groups will be assembled into systematic packages for the extension specialist to study and make further adaptations as he attempts to aid the farmer in management decision-making relative to the particular soil constraints on his farm. The project personnel will review existing farm practices and research results on FCC identified groups of soils and assemble the management alternatives in a form compatible with the operations of technology transfer delivery systems in developing countries in the humid tropics. Close working relationships with host country extension specialists will be developed.

Continuation of the FCC adaptation to wetland soils will continue at the request of INSFFER (International Network for Soil Fertility and Fertilizer Evaluation on Rice) co-sponsored by IRRI and IFDC, at its April 1984 meeting. Through this network, FCC is being tested in rice fields of Burma, China, India, Indonesia, Malaysia, Pakistan, Philippines, Sri Lanka, Thailand, Nigeria, Zambia and other countries.

Soil Constraints Map of the Developing World (Y-602)

Objective. Interpret the World Soil Map and other information generated by soil survey projects in terms of fertility and management constraints.

Justification. A vast amount of data has been obtained by soil survey projects in many areas of the developing world. This data is most often presented in terms of natural soil classification terminology, such as the World Soil Map legend, Soil Taxonomy, or national soil classification nomenclature. These nomenclatures deal with physical, chemical, and mineralogical compositions of the soils and can serve as the basis for the planning of long range activities, such as fertilizer manufacturing and distribution, irrigation and drainge projects, and other agro-business development projects. Technical interpretations of

natural soil classification terminology are needed to make this information more understandable and usable to soil management, agro-business, and developent specialists.

This subproject is an extension of previous ones, but on a larger scale. It attempts to generalize information determined at many research sites and observed in many farming situations, to the soil data presented on existing small scale maps via a series of technically specific maps and reports.

Generalized Procedures. Existing soil maps of countries will be digitized for computer manipulation. Soil map information will be interpreted in terms of FCC groups and where needed other soil management constraint information will be used. The output maps will identify areas, at a small scale, that have severe soil acidity problems, potential major plant nutrient problems, and specific soil conservation problems to name a few of the specific interpretations.

Soil Taxonomy and FCC Software for Microcomputers (Y-607)

Objective. To develop microcomputer software to aid in the teaching and use of soil classification, both natural systems and technical systems such as the FCC.

Justification. Present soil classification systems, when written in key form, are bulky and cumbersome to use. Interactive microcomputer programs have demonstrated that a great deal of the key sequence can be bypassed. Their use in developing countries is mushrooming. Also, the programs permit students and relatively inexperienced scientists to input data from soil at their experimental site and properly classify soils into Soil Taxonomy and/or FCC. Another advantage is the relative ease of incorporating changes in classification criteria on a new or revised disk, thus speeding the time of communication in the correlation process.

Generalized Procedures. Initial programs have been written in BASIC for Apple and IBM microcomputers. The procedure is to program the classification keys from Soil Taxonomy and FCC with appropriate modifications in the wording needed to fit the constraints of the microcomputer hardware. Both video and printer outputs can be made available to interested users.

Principal Research Sites: North Carolina State University, field research sites in several tropical countries

Duration: Five years

Characterization, Classification and Interpretation
of Soils of the Humid Tropics
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	18	12	12	13	13	68
Fringe Benefits	2	1	1	1	1	6
Supplies	3	4	3	4	3	17
Equipment	1	1	1	1	1	5
Travel	10	12	10	12	10	54
Other Direct Costs	7	7	7	16	9	46
Indirect Costs	8	7	7	7	7	36
TOTAL	49	44	41	54	44	232

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.30	0.40	0.40	0.40	0.40	0.40	1.50
Graduate Student	2.00	1.00	1.00	1.00	1.00	6.00	0.00
Other	1.00	1.00	1.00	1.00	1.00	0.00	5.00
TOTAL	3.30	2.40	2.40	2.40	2.40	6.40	6.50

Program: Humid Tropics

Research Project:

Title: Soil Management Research Network for the Humid Tropics

Objectives:

1. To validate and extrapolate available soil management technologies to other countries beyond the TropSoils primary research sites.

2. To develop the capability of collaborating country personnel to conduct, interpret and report user-oriented soil management research.

Project Leader: J. R. Benites, North Carolina State University

Principal Collaborators: Research leaders in national programs in the humid tropics of collaborating countries in Asia, Africa and Latin America.

Rationale

TropSoils has developed technology components of improved soil management in acid soils of the humid tropics during the last 12 years. Some examples are improved land clearing methods, selected acid-tolerant crop cultivars, soil constraint determinations, monitoring soil dynamics, improved grass-legume pastures and managed fallows. Many of these findings are ready to be tested across the humid tropics in order to ascertain their validity and determine the necessary modificiations to specific physical and socio-economic situations.

Several national institutions responsible for research and extension in humid tropical regions wish to apply TropSoils technology to their development programs. Attempts at doing so have identified the lack of on-site trained personnel as one major constraint to the validation and transfer of technology. On the other hand, TropSoils scientists need to know whether the technologies that appear promising at the primary research sites are viable in other humid tropical environments. This project attempts to bridge a major gap between CRSP-sponsored research and its utilization by national research institutions.

Relevance to Other Activites

This project will bring together the most promising results of TropSoils research and will promote its validation and modifications on a systematic basis. The on-farm and on-station research done by trained local scientists will provide much needed feedback to TropSoils.

Scope of Work

The Peruvian portion of this project is to be funded by INIPA's National Selva Program. CRSP funds will be used for the international dimension. The overall project is to be headquartered at the training center being built at the Yurimaguas Experiment Station. Subprojects that focus on technology validation and transfer in Peru include economic analysis of technology options (Y-706), validation of continuous cropping technology (Y-710), low input systems (Y-720), legume-based pastures (Y-730), agroforestry (Y-740), flooded rice technology (Y-750) and reclamation of eroded hillsides (Y-760), the Training Center itself (Y-780) and communication services (Y-790).

The CRSP-sponsored activities concentrate on the international dimension of the research network (Y-770). The remainder of this project proposal concentrates on this issue.

Generalized Procedures:

The Research Network is a successful mechanism that has served to validate CGIAR-generated technology throughout the world. Examples of successful networks are INSFFER, coordinated by IRRI and IFDC, CIAT's Cassava and Pasture Networks, originally supported by IDRC, and several others. This project aims at using the experience gained by the various networks with a farming systems research focus.

Close cooperation is expected with TropSoils scientists from Hawaii and Cornell to take advantage of their acid soils expertise and to provide a feedback mechanism to them.

Network participants will consist largely of B.S.-level research officers of national institutions who are stationed in humid tropical areas of collaborating countries and are responsible for conducting field research. During the first five years, work will be limited to Spanish, Portuguese and English speakers, to be arranged in two groups. French capability is envisioned beyond that period. Examples of potential collaborating countries and their national institutions with a considerable likelihood of willingness to collaborate are listed below according to language groups. Those marked with an asterisk have USAID Missions.

Spanish/Portuguese Speaking:

Bolivia*: Instituto Boliviano de Tecnologia Agropecuaria (IBTA)
Brazil: Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA)
Commissao Executiva do Plano da Lavoura Cacaueira (CEPLAC)
Instituto Nacional de Pesquisas Amazonicas (INPA)
Colombia: Instituto Colombiano Agropecuario (ICA)
Costa Rica*: Ministerio de Agricultura y Ganaderia (MAG)
Centro Agronomico Tropical de Investigacion y Ensenanza

(CATIE)
Dominican Republic*: Ministerio de Agricultura (MA)
Ecuador*: Instituto Nacional de Investigaciones Agropecuarias (INIAP)
Honduras*: Ministerio de Agricultura (MA)
Escuela Superior Agricola El Zamorano
Mexico: Instituto Nacional de Investigaciones Agricolas (INIA)
Escuela Superior de Agricultura Tropical (ESAT)
Panama*: Instituto de Desarrollo Agropecuario (IDIAP)
Peru* Instituto Nacional de Investigacidn y Promocion Agropecuaria (INIPA)
Other participating institutions in the National Selva Program
Sao Tome*: Ministrio da Agricultura
Venezuela: Fondo Nacional de Investigaciones Agropecuarias (FONAIAP)
Instituto Venezolano de Investigaciones Cientificas (IVIC)

English Speaking

Belize*: Ministry of Agriculture
Cameroon*: Center for Soils Research
Ghana*: Soils Research Institute
Guyana*: Ministry of Agriculture
Indonesia*: Center for Soils Research (CSR)
Institut Pertanian Bogor (IPB)
Jamaica*: Ministry of Agriculture
Malaysia: Malaysian Agricultural Research and Development Institute (MARDI)
Rubber Research Institute of Malaysia (RRIM)
Institute Pertanian Malaysia
Liberia*: Ministry of Agriculture
Sierra Leone*: Ministry of Agriculture and Forestry
Surinam*: Ministry of Agriculture
Trinidad*: Caribbean Agricultural Research and Development Institute (CARDI)

Selection of participants will be done via the USAID Missions and the national institutions with preference given to those countries that have a USAID Mission. Cost of participant training will be borne by the Missions or other institutions.

Efforts will be made to start validation trials on four additional humid tropical countries outside of Peru, Brazil and Indonesia. Consultations will be made with the AID Bureaus for Latin America and the Caribbean, Africa and Asia. LAC Bureau agricultural staff has expressed strong interest in this possibility. Informal linkages already made through REDINAA and IBSRAM are likely to facilitate site selection. Candidate countries are Bolivia, Ecuador, Panama, Costa Rica, Zaire, Liberia, Sierra Leone and the Ivory Coast. After the in-service training portion is complete, cooperative agreements will be established during these five years to initiate on-site work.

Network activities consist of five components: in-service training, on-site research, cooperator meetings, data base, and monitoring tours.

In-Service Training:

A group of up to 20 selected participants will take the Soil Management course to be held at the Training Center of the Yurimaguas Research Station once a year. The course will be of six weeks duration; both theoretical and practical aspects will be taught. The theory portion includes lectures on basic climatology, soils, land clearing and preparation, crop management, experimental design, economics, communications, TropSoils philosophy and research results on different soil management options. Workshops on "sondeo" in cooperation with the University of Florida and FCC methodologies are included along with design of network trials. Individual consultation with TropSoils and INIPA scientists on-site will also form part of the theory portion of the source. Practical training includes soil classification, laboratory analyses, land clearing, land preparation, fertilizer management practices in the field, and micro-computer use.

Field Research:

Prior to the conclusion of the course, participants will design on-farm and on-station trials that will be installed upon their return to their institutions. The focus is likely to be the low input management option as a starting point for addressing the more pressing problems of shifting cultivators.

The low input technology developed at Yurimaguas may be the first option to be validated. The hypothesis can be formulated as follows: "A low-input cropping system will increase the farmer's overall output per unit of land facilitating their transition from shifting cultivation to permanent agriculture."

A variety of research activities could be adapted. Particularly useful will be surveys, on-station research, research-managed trials, farmer-managed tests, component trials, and on-station research.

Surveys will include the "sondeo" methodology in cooperation with the University of Florida's Farming Systems Support Program and soil constraint analysis using the FCC system.

On-station research. Research stations in selected areas will test the Yurimaguas low-input technology under local conditions and evaluate its potential.

Researcher-managed trials. Researchers manage experiments on farmer's fields. These trials help the team to define the characteristics of the research area more precisely. Also, they assist the team in recognizing the gap between current and potential yields. Finally, they

provide means for screening TropSoils technology according to its suitability for different types of farmers and conditions.

Farmer-managed trials. Farmer-managed trials provide an excellent means for evaluating how new technologies fit into the farmer's system and how farmers react to the proposed changes. For best results, farmers need to manage these tests using resources normally available to them. Plots need to be large enough to permit accurate measurements of the farmers' activities, particularly the use of family labor. The last set will be farmer-managed test using commerical scale plot supervised by the extension workers, without TropSoils involvement.

Component trials. Component trials combine the methods of researcher-managed trials and farmer-managed tests to examine technologies for a range of conditions. These trials tend to be single factor experiments, e.g., fertilizer treatments that are superimposed on farmer's ongoing activities or on farmer-managed tests.

Follow-Up and Feedback:

A series of activities is designed to provide the necessary follow-up that makes a real research network. It includes site visits by the TropSoils network coordinator, annual meetings of cooperators that have established trials, developing a data base of results adaptable to microcomputers, and monitoring tours by leaders of the different national institutions.

Principal Research Sites: Throughout the humid tropics

Duration: Five years

Soil Management Research Network for the Humid Tropics
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	12	16	16	13	13	70
Fringe Benefits	1	1	1	1	1	5
Supplies	18	13	13	12	15	71
Equipment	3	4	4	1	2	14
Travel	18	22	24	17	17	88
Allowances	5	5	5	0	0	15
Other Direct Costs	26	26	28	12	7	99
Indirect Costs	16	17	16	10	11	70
TOTAL	99	104	107	66	66	442

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.00	0.30	0.30	0.30	0.30	1.20	0.00
Field Based Scientist	0.20	0.30	0.30	0.30	0.00	1.10	0.00
Other	0.50	0.50	0.50	0.50	0.50	0.00	2.50
TOTAL	0.70	1.10	1.10	1.10	0.80	2.30	2.50

Program: Humid Tropics

Research Project:

Title: Soil Erosion and Reclamation of Humid Tropical Uplands

Objectives:

1. To adapt and modify the management principles developed at the Yurimaguas primary research site to tackle immediate soil management problems faced by colonists to this area.

2. To conduct original research on watershed hydrology of direct relevance to CRSP objective.

Project Leader: D. K. Cassel, North Carolina State University

Principal Collaborators: H. Elsenbeer, D. del Castillo, J. R. Benites, K. Reategui, A. Sanchez, J. Vargas, T. Paucar, T. Cruz, A. Yanayaco, L. Capunay, F. Alvarado

Rationale:

The Pichis-Palcazu region of the Central Selva of Peru is being rapidly connected to the rest of the country through a massive colonization project. The entity in charge (Proyecto Especial Pichis-Palcazu (PEPP) requested the direct involvement of INIPA and NCSU to validate the Yurimaguas results under local conditions. A special grant from PEPP was awarded for a three-year period (1984-1986) to conduct this work and NCSU field activities started this year with the arrival of one senior soil scientist and one junior scientist in Puerto Bermudez. The Pichis-Palcazu region is located at 400 m elevation, with mean annual temperature of 26.5C, annual rainfall of 3400 mm with no dry season, and a perudic soil moisture regime. The main soils are Ultisols and Dystropepts. Most of the topography is rolling to steeply sloping with only 15 percent of the area with slopes less than 4 percent. Virgin forests and degraded pastures are the main forms of ground cover. The main differences in relation to Yurimaguas is the significantly higher rainfall and sloping land. Many of the problems associated with the High Selva development are present there.

Initial operations started with the selection of an experiment station that encompasses the different soil-landscape positions of the valleys. Drs. S. W. Buol and P. A. Sanchez studied the area in March 1983 and selected the 600 ha La Esperanza Station, about 15 km north of Puerto Bermudez with boundaries at the Pichis River and the Marginal Highway. This highway opened several months ago. A tremendous influx of settlers have cleared land on extremely steep slopes, planted corn and

subsequently abandoned it resulting in rather dramatic runoff and erosion.

Relevance to Other Programs:

The rapid clearing of steep soils along newly opened highways is unfortunately typical of humid tropical development. This Pichis area provides the CRSP with a unique opportunity to conduct research on both the prevention of erosion and the reclamation of eroded lands abandoned after shifting cultivation.

Scope of Work:

The overall plan of work for this region consists of 11 experiments of which nine are technology validation for the area and one is of worldwide relevance to the CRSP. Research in the first category includes: crop germ-plasm introduction from national programs (Y-800), pasture germplasm evaluation (Y-801), permanent crop germplasm evaluation (Y-802), weed control (Y-803), soil dynamics in low input systems (Y-804), grazing pressure trials (Y-805), liveweight gain trials (Y-806), soil dynamics under different management options (Y-807), reclamation of eroded slopes (Y-808) and flooded rice in alluvial soils (Y-809). The chronologic experiment Y-804 has the same design as the one in Manaus (M-901) and the two proposed for Yurimaguas (Y-215) and Sitiung (S-1009). The work on comparative soil dynamics (Y-807) is roughly comparable to that in Yurimaguas (Y-412). All these experiments will be supported by counterpart funds and are not described here.

One experiment proposed for CRSP support focus on watershed hydrology (Y-810).

Soil Erosion in Upland Area of the Humid Tropics (Y-810)

Personnel: D. K. Cassel, H. Elsenbeer

Objectives. 1) To determine the baseline transport rates of water, selected solutes, and sediment from an upland forested site before clearing; 2) to determine changes in the transport rates of water, selected solutes, and sediment from the same upland site after it is cleared and managed according to technological options suited to specific landscape positions.

Justification. Despite the great concern raised by the prospect of severe land degradation following deforestation, there is a wide gap between the number of preconceived opinions about the problem and the number of actual data. The lack of runoff and erosion rates determined over a long period of time and under different topographical, vegetation, and cropping systems is conspicuous, especially for the humid tropical areas of Latin America, and no data are available for the Amazon Basin. The results of the few studies that have been undertaken cannot

be extrapolated due to restricting climatic and/or lithological factors. Others are semi-qualitative or merely descriptive, based on visual observation. The available evidence, however, indicates considerable potential for accelerated erosion as a result of land clearing and subsequent cropping, especially on steeper slopes. This assumes particular importance for although only 8% of the Amazon Basin's total land surface is on slopes greater than 30%, the more recent development schemes in the Peruvian portion are planned for regions where steep slopes are of considerable areal extent, e.g., the basins of the Pichis and Palcazu Rivers, and the Alto Huallaga Valley. If adverse ecological and hydrological implications are to be avoided and continuous crop production to be guaranteed, the implementation of conservation practices on steeply sloping land will be crucial, as well as the establishment of limits for tolerable soil loss. Both require a sound knowledge of type and magnitude of runoff and erosion processes before and after forest clearing. Investigations in the Amazon headwater areas with respect to their potential for power generation also stress the need for erosion research. Large-scale forest clearing alters not only the hydrological balance of a watershed, but also sediment production and transport, and, by implication, half-life times of reservoirs.

Hence, there exists an urgent need for erosion research data which are essential for the sound development of the upland humid tropics, be it with respect to agriculture, ecology, or hydrologic balance.

The land in Yurimaguas where the TropSoils research has been concentrated is relatively level with very little land with slopes exceeding 4%. As indicated above, much of the future land clearing and development will necessarily occur on slopes greater than 4% in some areas, appreciable acreages of land with greater than 4%; slope are already being farmed. The External Evaluation Panel in their review raised a concern about soil erosion on the nearly level land in Yurimaguas. In our opinion, a more pressing concern is the necessity of dealing with erosion on steeper land (4-20%). By measuring the equilibrium levels of erosion and nutrient transport before clearing, we will be able to relate them to the rates of accelerated erosion and nutrient transport from cleared, cropped land for particular management practices.

Procedure. Possible locations of the research site were investigated in June 1984 by Helmut Elsenbeer, Dennis del Castillo and Keith Cassel. Findings of this trip led to a decision to select the experimental site near the Pichis area at INIPA's new La Esperanza Station. A small forested watershed, 1 to 4 ha in area, will be instrumented to monitor runoff, sediment removal, and nutrient transport of individual rainfall events during a 1- to 2-year period. The land will then be cleared and the appropriate crops planted and various management practices used. Runoff, sediment removal, and nutrient removal from specific management areas will be monitored and analyzed for their effectiveness in controlling erosion.

After the specific research watershed has been selected, the appropriate catchment and monitoring devices will be installed. Weirs, Gerlach troughs, and suction lysimeters will be placed at appropriate locations and fluxes of water, sediment, and nutrients will be monitored for many individual rainfall events. Soil solution and runoff samples will be sent to Yurimaguas and analyzed for selected nutrients.

After sufficient transport information has been collected on forested land, it will be cleared and selectively managed according to soil and slope. Different areas within the watershed will be planted to one or more of the following: row crops, pasture crops, or tree crops. Runoff, sediment and nutrient transport from the area in individual runoff events will be measured for selected management systems.

Principal Research Site: La Esperanza Experiment Station, Pichis Valley, Peru

Duration: Five years or more

Soil Erosion and Reclamation of Humid Tropical Uplands
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	14	16	8	9	14	61
Fringe Benefits	1	1	1	1	1	5
Supplies	1	1	1	1	1	5
Equipment	4	1	0	0	1	6
Travel	2	2	3	2	3	12
Allowances	6	6	1	6	6	25
Other Direct Costs	3	3	3	3	3	15
Indirect Costs	5	4	4	4	4	21
TOTAL	36	34	21	26	33	150

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.10	0.10	0.10	0.10	0.10	0.00	0.50
Field Based Scientist	0.30	0.30	0.30	0.30	0.30	0.00	1.50
Graduate Student	1.00	1.00	1.00	1.00	1.00	5.00	0.00
TOTAL	1.40	1.40	1.40	1.40	1.40	5.00	2.00

Program: Humid Tropics

Research Project:

Title: Soil Fertility Management in Oxisols of Manaus

Objectives: To adapt soil management practices developed primarily in sandy Ultisols to clayey Oxisols in near ustic humid tropical environment in Central Amazonia.

Project Leader: T. J. Smyth, North Carolina State University

Principal Collaborators: P. A. Sanchez, J. B. Bastos, J. C. Correia, E. Moraes M. Cravo, M. Pinheiro, E. C. Italiano, E. U. Galvao

Rationale:

The near-ustic semievergreen seasonal forest ecosystem occupies approximately 57 percent of the Amazon. It is characterized by a strong 3-4 month dry season, with a total wet season potential evapotranspiration of less than 1300 mm. Oxisols occupy 45 percent of the Amazon Basin, mostly in near ustic and ustic soil moisture regimes. In order to test the TropSoils results from the primary research site to the less humid areas of Central Amazonia, an agreement was signed between EMBRAPA, IICA and NCSU to conduct cooperative work at EMBRAPA's UEPAE Station located at 3°S latitude, 38 km east of Manaus at 56 m elevation. Predominant vegetation in Manaus is primary forest as opposed to secondary forests in Yurimaguas. Soils are clayey, very fine, kaolinitic Typic Acrorthox located mainly on flat plateaus, in contrast with the fine loamy, siliceous Typic Paleudults of Yurimaguas. Phosphorus sorption capacity for the clayey Oxisol in Manaus is intermediate between the high levels for the Cerrado Oxisols and the Yurimaguas Ultisols. The joint project started in mid-1981 when Dr. T. J. Smyth arrived at Manaus. It is jointly funded by EMBRAPA, the Rockefeller Foundation (RF) and the Potash Phosphate Institute (PPI). The RF grant is scheduled to terminate in 1985 and is unlikely to be extended because of the Foundation's shift in its priorities. Considering the contribution of this project to overall TropSoils goals, NCSU proposes its continuation under partial CRSP support from 1986-1989.

Relevance to Other Programs:

The chronologic design developed by this project is extensively used by the Program in other countries. The experiment is in its third year and it appears highly desirable that it should continue. The differences between Yurimaguas and Manaus in terms of vegetation, phosphorus sorption and rainfall regime show the value of this type of cooperative extrapolation. Since most experiments are long-term in

nature, continuation of this work for the quinquennium will provide valuable information at low marginal costs.

Scope of Work:

For this region nine experiments are currently established, four of which are to be supported by the CRSP and the remainder by EMBRAPA with direct involvement by NCSU personnel. Research in the former category includes: soil dynamics (M-901), phosphorus fertilization (M-902), potassium fertilization (M-903), and guarana fertilization (M-904). In the latter category research consists of: lime requirements and downward movement of Ca and Mg (M-905), tillage systems (M-906), selection and management of green manures (M-907), selection of planting dates and evaluation of crop rotations (M-908), and micronutrient fertilization (M-909).

EMBRAPA-supported subprojects complement the CRSP studies by providing information on additional factors not included in the CRSP-supported studies which are necessary for the evaluation and adaptation of practices developed in Yurimaguas Ultisols to Central Amazonia Oxisols. Studies on crop rotations provide adjustments for the differences in socioeconomically important crops and rainfall patterns betweeen Manaus and Yurimaguas. Green manure studies are designed to evaluate the potential modifications of existing cropping and fertilization schemes in order to minimize fertilizer inputs. Studies with lime and micronutrients provide insight into soil management practices which are not appropriately covered by the CRSP-supported studies.

Soil Nutrient Dynamics and Fertility Management for Sustained Crop Production on Oxisols in the Brazilian Amazon (M-901)

Farmers in the Brazilian Amazon have traditionally depended on nutrients added to the soil by slash-and-burn clearing for the production of one or two crops before the land is returned to fallow. Soil management systems developed for continuous cultivation on the Ultisols at Yurimaguas, Peru have indicated that a key component for maintaining continuous and favorable crop yields has been the judicious applications of lime and fertilizers as indicated by soil analysis during the continual monitoring of soil nutrient dynamics. Applications of these continuous cropping systems to other ecosystems in the Amazon would require an understanding of soil nutrient dynamic patterns over time, relative to those of the Typic Paleudults in Yurimaguas. Differences in the ecosystems between Yurimaguas (secondary forest, weak dry season, Typic Paleudult, fine loamy, siliceous soils) and Manaus (primary forest, pronounced dry season, Typic Acrorthox, clayey, kaolinitic soil) suggested that soil nutrient dynamic patterns and fertility managment would also differ between sites.

Objectives. 1) To establish the patterns of soil nutrient depletion as a function of time after clearing for a Central Brazilian Amazon

Oxisol under continuous cultivation 2) to determine the fertilizer inputs required for sustaining continuous crop production on these Oxisols 3) to compare soil fertility management systems of the Manaus Oxisols with those of the Yurimaguas Ultisols.

Experimental Approach. An area of primary forest in size sufficient to contain replicated treatments for N, P, K, Mg, S, lime and micronutrients was cut and burned in September, 1981. Cultivation was initiated in November, 1981, and two crops are grown annually in rotation. Treatments for three or four rates of each nutrient are established when soil and plant analyses suggest a possible deficiency. A uniform rate of each nutrient is applied to all remaining plots (excluding the check treatment) in subsequent crops, once a yield response is obtained for a specified nutrient. Consequently, yield responses to individual nutrients are evaluated as they occur, with corrections for all previously observed deficiencies.

State of Progress. Nutrient levels in the ash from secondary forests in Yurimaguas and those in the primary forest in Manaus were similar, although primary forest biomass was more than twice the biomass of secondary forests. Phosphorus was an immediate limitation to crop production on the Brazilian Oxisol, as opposed to the production of one or two crops on the Peruvian Ultisol before P was required. Soil K depletion patterns and fertilizer K requirements were similar at both sites. Increases in soil Ca and Mg and decreases in soil acidity were larger in the Oxisol than in the Ultisol. Consequently, Al saturation levels in the Manaus Oxisol were maintained below toxic levels for a longer period of time than in the Yurimaguas Ultisol.

Additions of P, K and lime beginning with the first, second and third crops, respectively, of rice-soybeans-soybeans-cowpeas rotation provided a cumulative grain yield of 7.3 t/ha, as opposed to 1.5 t/ha in the absence of any fertilizers.

Results obtained in this project provide information as to what extent soil nutrient dynamics and cropping systems developed on Ultisols in Yurimaguas, Peru, are applicable to Oxisol regions of the Central Brazilian Amazon.

Phosphorus Fertilization Alternatives for Continuous Cropping Systems in Amazon Oxisols (M-902)

Phosphorus deficiency is a common property of Oxisols in the Brazilian Amazon. For clayey Oxisols, P fertilization could become economically important, as their P sorption capacities are of similar magnitude to Oxisols in the Cerrado region. Although several studies in the region have demonstrated marked yield responses to P fertilization with annual crops, information is needed on soil test calibrations and the long-term effects of different P fertilization strategies.

Objectives. 1) To obtain detailed P response curves and soil test calibration data for the main annual crops cultivated in the region; 2) to obtain a description of the residual P fertilizer value; 3) to provide indications of appropriate maintenance P fertilizer rates for sustaining adequate crop yields.

Experimental Approach. A phosphorus study was established on a clayey Typic Acrorthox cleared by burning from primary forest. Treatments were arranged in a split-plot design, with broadcast P rates (0, 22, 44, 88 and 176 kg P/ha) as main plots and banded P rates (0, 12.5, 22 and 44 kg P/ha), applied to each crop, as subplots. Two crops are grown annually, with all other nutrients under non-limiting conditions.

State of Progress. The annual rotation of corn-cowpeas was utilized for the first two years of the study. For the Mehlich 1 extractant, critical soil test P values were determined as 7 and 11 ppm, respectively, for corn and cowpeas. The application of 44 kg P/ha maintained soil test P values at the recommended level only for the first crop. With 88 kg P/ha, soil test P levels were maintained above the critical values for three crops. Yield responses to banded P were negligible at rates higher than 22 kg P/ha/crop. Yield increases to banded P declined with increasing rates of broadcast P. The small yield response to banded P with initial broadcast P rates of 88 and 176 kg P/ha would not justify the additional fertilizer inputs.

The similarities in cumulative yields for the four initial crops on treatments with identical rates of P applied by different methods suggested that yields for this crop rotation were primarily a function of total applied P. Cumulative yield of 7 t/ha with 88 kg P/ha was near maximal for this study. In the absence of applied P, total yield was 1.1 t/ha.

Applicability of Results. Since P is one of the major fertilizer inputs for the clayey Oxisols in the Brazilian Amazon, a thorough understanding of the quantities, methods of application, and residual effects of P fertilizers would be vital to establishing the economic feasibility of continuous cropping systems in the region. Comparisons to similar studies in the Cerrado region can provide insight to differences in the management of these Oxisol ecosystems.

Potassium Fertilization for Annual Cropping Systems in Amazon Oxisols (M-904)

The high levels of rainfall in the Central Brazilian Amazon and the natural low cation exchange capacities of Oxisols in the region provide conditions conducive to K leaching. Native soil K reserves can be expected to be small, since clay mineralogy is predominantly kaolinitic. These conditions suggested that K fertilizers could be a continual requirement for crop production on these soils and that management systems should consider alternatives for minimizing K losses.

Objectives. 1) To establish K response curves and soil test calibration data for the main annual crops cultivated in the region 2) to develop soil K management systems which optimize fertilizer K utilization efficiency.

Experimental Approach. Potassium fertilization studies have been established in phases. The initial phase was to characterize yield response curves and soil test relationships with K fertilization. An experiment with five rates (0, 16.5, 33, 66 and 132 kg K/ha) of annually broadcast applied KCl was initiated in November, 1982. A corn-cowpea rotation is grown annually with K applied prior to planting corn.

A second phase of the project was initiated in November, 1983, with the establishment of a study for split applications of K fertilizer. Four levels of K were utilized in this study (0, 13.5, 33 and 46.5 kg K/ha) in factorial combination with three times of application during corn growth (0, 25 and 55 days after planting). Subsequently, cowpeas will be grown on residual K.

State of Progress. Movement of K added to the soil by burning the primary forest was accompanied by profile measurements at different dates after burning. At 2.5 months after burning K levels were higher in the profile of burned plots than in the standing forest to the maximum depth sampled (75 cm). Five months later K levels at all soil depths in the burned plots declined but remained higher than the areas of standing forest. Topsoil K levels in the burned plots declined to the original levels for the standing forest (20 ppm K) at 20 months after clearing.

Corn yields increased significantly to the rate of 33 kg K/ha. Cowpeas, grown on residual K applied before planting corn, responded in yield to the rate 66 kg K/ha. These two treatments provided the highest efficiency for K fertilizer utilization, with 33% K fertilizer removal at harvest over both crops.

Results for corn yields and tissue and soil K analysis on treatments with crop residue incorporation have suggested that K fertilizer input could be reduced by minimizing removal of non-harvestable plant components. Yields on treatments with crop residue incorporation and no fertilizer K applied have approached yields achieved where crop residues were removed and 33 kg K/ha was applied annually.

Applicability of Results. Results will provide information for K fertilizer recommendations for major crops in the region and crop and fertilizer management systems to optimize K utilization in these ecosystems.

Guarana Fertilization (M-906)

Guarana (Paullinia cupana) is a major permanent cash crop for small farmers in the state of Amazonas. Commercial production is stimulated by a strong demand for a national soft drink produced from the ground seed and by a growing export market. To date, research on guarana has centered on the selection of high-yielding cultivars. However, nutritional problems may become a future limitation, as seed yields on some of the most promising clones would represent an annual removal of 68, 4, 14 and 3 kg/ha of N, P, K and Mg, respectively. Short-term studies have demonstrated yield responses by guarana to applications of fixed quantities of fertilizers. However, the absence of data on yield response curves for guarana to fertilizers has restricted the development of fertilizer recommendations for this permanent crop.

Objectives. 1) To characterize the yield response curves of guarana to rates of N, P, K and Mg fertilization; 2) to establish soil test and tissue analysis calibration data on guarana for these nutrients.

Experimental Approach. Individual response curves for N, P, K and Mg are established with four annual rates of each nutrient, while maintaining the remaining nutrients constant at the highest rate. Early vegetative growth rates are known to vary considerably among guarana clones. Therefore, three promising clones of guarana were established as subplots on each fertilizer treatment. Plants derived from vegetative propagation were transferred from the nursery to the field in February 1983. Planned measurements include propagation and extension rates of leaves and branches, yield, foliar analysis and soil analysis.

State of Progress. A prolonged dry season immediately after planting the guarana resulted in a high mortality rate of all three clones. Over 50% of the original plants were replaced. Plant growth measurements in September 1983, indicated that all plants had been successfully established. Visual observations thus far have suggested a probable response to N fertilization.

Investigations in this project provide insight to the soil-plant nutrition relationships of a relatively unknown but important cash crop for the Central Brazilian Amazon. The existence of adjacent fertility studies with annual crops on the same site also provides oportunities to compare fertilizer requirements between annual and perennial cropping systems on the same soil.

Principal Research Site: EMBRAPA's UEPAE Station, Manaus, Brazil

Duration: Three years

Soil Fertility Management in Oxisols of Manaus
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	4	29	31	0	0	64
Fringe Benefits	0	5	5	0	0	10
Supplies	0	3	3	0	0	6
Equipment	0	2	2	0	0	4
Travel	2	8	11	0	0	21
Allowances	1	10	10	0	0	21
Other Direct Costs	0	7	8	0	0	15
Indirect Costs	0	9	9	0	0	18
TOTAL	7	73	79	0	0	159

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.10	0.10	0.10	0.10	0.10	0.00	0.50
Field Based Scientist	0.10	1.00	1.00	0.00	0.00	2.10	0.00
Other	0.90	0.00	0.00	0.00	0.00	0.00	0.90
TOTAL	1.10	1.10	1.10	0.10	0.10	2.10	1.40

Program: Humid Tropics

Research Project:

Title: Soil Management in Transmigration Areas of Sumatra

Objectives:

1. To adapt management principles developed at the Yurimaguas primary research site to tackle agronomic problems of transmigrant farmers in Sitiung, West Sumatra.

2. To assist in developing methods for reclaiming and maintaining soil physical properties in mechanically cleared land.

3. To develop methods for managing and improving soil chemical properties in continuously cultivated land.

Project Leader: M. K. Wade, North Carolina State University

Principal Collaborators: E. J. Kamprath, D. K. Cassel, A. K. Makarim, D. W. Gill, T. J. Smyth, P. A. Sanchez, G. Uehara, J. Thompson, C. Colfer, Dr. M. Sudjadi, Dr. Soleh, D. Santoso, Irs. Heriyadi, Sukmana, Agus Sophian, Cahyono, R. Heriyatno, Martono, Witjahyono, Suwadi

Rationale:

Transmigration projects in the outer islands of Indonesia constitute the largest expansion of agriculture in humid tropical regions. The rate of deforestation and the numbers of people involved pose problems of greater immediacy than in the Amazon. In July 1983 TropSoils initiated its research activities in Sitiung, West Sumatra as a joint effort of the Agency for Agricultural Research and Development's Center for Soils Research (CSR), the University of Hawaii and North Carolina State. Our role as the support institution consists of conducting agronomic experiments which are part of the overall program. The rationale for NCSU's role is to apply some of the results obtained at our primary research site, Yurimaguas, test them, validate or modify them to suit the physical and socioeconomic conditions of this transmigration area. This extrapolation is aided by a striking similarity in the physical setting. Sitiung is located at 1°S latitude, 100 m elevation, with 25.9C mean annual temperature, 2471 mm mean annual rainfall with a weak dry season, undulating topography, predominantly clayey Ultisols and Oxisols and virgin rainforest vegetation. Yurimaguas' latitude is

nearly 6°S, elevation is 182 m, mean annual temperature is 26°OC, mean annual rainfall is 2135 mm with a weak dry season, topography is undulating, the main soils are loamy Ultisol but most shifting cultivation is practiced on secondary forest. Although levels of infrastructure development vary, perhaps the most important socioeconomic variable is spontaneous settlement in Yurimaguas vs. directed settlement at Sitiung. Road infrastructure is better in Sitiung but urban development is not. The basic food crops, rice, corn and cassava, are the same. Pasture development is important in Yurimaguas but not so in Sitiung. Alang-alang (Imperata cylindrica), a grass invader, is not found in Latin America. Knowledge of soil properties and distribution is excellent in both areas. The main difference is the consequence of bulldozer land clearing of primary forests in Sitiung in comparison with the traditional slash and burn clearing of secondary forests by individual farmers in Yurimaguas. Another important difference is that although the range in soil-landscape positions is similar to that of Yurimaguas, most transmigrants are given a 2-hectare piece of land which limits their management options.

Relevance to Other Programs:

TropSoils Indonesia can make a contribution of worldwide impact if soil management research can turn around the detrimental effects of lack of land clearing and soil management technology. Our modest role in relation to the one played by the lead institutions, University of Hawaii and CSR, should contribute to the overall effort.

Scope of Work:

NCSU proposes to concentrate its involvement on 9 experiments which are described in this proposal. Five subprojects are presently ongoing: reclamation of bulldozed lands (1001); lime rates and maintenance (1003); lime sources and application methods (1002); phosphorus rates and placement (1004); and potassium fertilizer management (1006). Four new subprojects are proposed: residual effects of phosphorus (1005); sulfur fertilization (1007); micronutrients survey (1008); and a soil dynamics one (1009). Sub-project 1003 is scheduled for termination in early 1985 and will not be included.

Reclamation of Bulldozed Lands (S-1001)

Personnel: A. K. Makarim, D. K. Cassel, M. K. Wade

Objectives. To develop methods for 1) reclaiming for continuous cultivation those soils with topsoil removed by mechanical land clearing or erosion, 2) effective management of natural rainfall for plant growth.

Justification. Areas of soils with little or no topsoil exist in the Sitiung area as well as in many other areas of the humid tropics.

Loss of topsoil in some cases resulted from poor techniques associated with mechanical land clearing activites. On sloping lands, erosion may have been and still may be the main factor removing topsoil. Regardless of the mechanism, reclamation of this severely damaged land is important in many situations. For example, in Sitiung, where a massive reclamation project is already in progress, some of the land in the resettlement area has no topsoil. Farmers assigned to this land can grow only one crop per year (rather than 3 crops grown by his neighbors) and it is not really a good crop. These soils have high clay contents and appear to have poor infiltration rates with subsequent poor efficiency of water storage for crop use. Techniques for reclaiming or restoring the productivity of soils with little or no topsoil are desperately needed. The proposed research will investigate several techniques for restoring crop productivity to soils that have lost most or all of its topsoil.

First experiment. A highly eroded, mechanically cleared site was selected in Sitiung IId. Six tillage treatments were installed: hoeing to 15 cm, hoeing to 15 cm plus applying mulch to the soil surface, hoeing with incorporation of organic matter, turning soil by spading fork to the 30 cm depth, spading in alternate 40 cm strips to the 30 cm depth, and roto-tilling to 15 cm. Three soil fertility treatments superimposed upon each tillage treatment were: F0, the addition of no lime and no fertilizer; F1, application of lime, N, P, K, Mg, S, Cu, and Zn at rates of 1500, 120, 49, 72, 70, 93, 1, and 4.5 kg/ha; and F2, application of the above nutrients at rates of 6840, 150, 572, 144, 140, 187, 2, and 6 kg/ha, respectively. The randomized complete block experimental design has 4 replications. The site has already been cropped for 10 months of the 2-year period. Soil physical and chemical properties were intensively measured before implementing the study. Plant growth parameters and soil physical and chemical properties will be periodically monitored during this 2-year period.

Second experiment. Several tillage treatments, with at least one of them involving some type of mulching, will be examined for their effect on water storage and water use efficiency by the plant. Details for this field study have not been formalized but will hinge partially on the results of experiment 1 described above and on other studies currently in progress in Sitiung. Two or more tillage treatments from the first study or newly devised treatments will be installed. The differential effect of those treatments on water balance of rainfall will be evaluated. Soil water status will be evaluated using moisture blocks, tensiometers, and the neutron meter. Plant stress will be evaluated using the infrared thermometer and possibly other techniques.

Residual Effects and Maintenance Rates of Lime (S-1003)

Personnel: M. K. Wade, E. J. Kamprath, D. Santoso, R. Heriyatno

Objectives. 1) To determine the critical level of soil acidity parameters for optimum production of upland rice, soybeans, and mung

beans, 2) to determine a method predicting lime rates necessary to achieve a specified level of Al saturation, 3) to determine the annual lime application rate required to maintain a specified level of soil acidity, 4) to monitor the residual effect of various rates of one-time lime applications on a rotation of annual food crops.

Justification. Soils in the Sitiung area, as well as many in the outer islands of Indonesia in general, are quite acid. Most unamended soils from Sitiung have pH values less than 4.5 and exchangeable acidity greater than 2.5 meq/100 ml soil, with a resulting base saturation greater than 60% (many reach 80-90%). In order to successfully grow most food crops, e.g., peanut, soybean, mungbean, corn, liming is necessary. Even acid-tolerant crops such as cassava and upland rice might be expected to respond to lime on the more acid soils. Although much is understood about the science of liming soils for agricultural purposes, on-site verification of rates and establishing critical soil test acidity levels for the major crops is desirable. Beyond determining critical levels and initial rates for a given soil and crop, it is necessary to study the residual effect of applied lime under the local rainfall and soil conditions to determine how much and how often lime will have to be reapplied in order to maintain a desired level of base saturation.

An on-farm researcher-managed trial as a long-term study with a minimum of three years was planted in Sitiung Block IIe in September 1983. The experiment is 2-fctor factorial with four replications in a RCB design. Plots are 5 x 8 m^2. The treatments are:

Lime rates (tons $CaCO_3$ eqivalent/ha): (1) 0; (2) 1/2 (3/8 x exch. Al); (3) 1 (3/4 x exch. Al); (4) 2 (1.5 x exch. Al); (5) 4 (3 x exch. Al).

Lime maintenance: (1) Residual only; (2) Annual application to maintain first crop levels of Al saturation.

All plots received a blanket application of N, P, K, Mg and S as predicted necessary to eliminate deficiencies. The three-crop-a-year rotation is upland rice-soybean-mungbean. Soil acidity parameters are being monitored at different depths with time.

Phosphorus Rates and Methods of Application (S-1004)

Personnel: M. K. Wade, D. Santoso

Objectives. 1) to determine optimum rates of TSP (triple superphosphate-20% P) fertilizer on a newly cleared soil (clay loam Ultisol), 2) to deter-mine cost: benefit ratio of various methods of applying TSP fertilizer, 3) to study long-term effects of various P management schemes (i.e., various rates and methods of application) on crop production and soil P levels, 4) to determine critical P soil test values for rice, peanut and cowpea.

Justification. Current transmigration policy is to supply 100 kg TSP/ha twice per year. This is irrespective of soil type, soil analysis, or crops grown. Most soils in the Sitiung area are extremely deficient in available P and doses of 100 kg TSP (20 kg P) per ha are not likely to be adequate.

The need for crop response and soil test correlation data is great for all areas of Indonesia, especially for upland crops. It is hoped that this research can help to start the development of a soil test correlation data bank that can aid scientists and policy-makers make scientifically-based decisions for P fertilizer rates and distribution.

It has been observed in the fields that farmers here generally have poor P fertilizer management practices regarding method and timing of application. The Food Crops Research Institute currently recommends that P fertilizer be banded. This is a very labor intensive operation and one that farmers are very reluctant to follow. More labor efficient application method that can achieve equal or better crop production are needed especially for these farmers who do all field operations with only a few simple hand tools.

An on-farm, research managed trial was planted in January 1984 in a clayey Ultisol in Sitiung Block Vc. Eleven treatments are arranged in a randomized complete block design with three replications. Plot size is 4 x 6 m^2. A rotation of peanut-soybean and rice is planned. The treatments are:

1. No P
2. 20 kg P/ha broadcast and incorporated
3. 40 kg P/ha broadcast and incorporated
4. 80 kg P/ha broadcast and incorporated
5. 20 kg P/ha banded
6. 40 kg P/ha banded
7. 80 kg P/ha banded
8. 20 kg P/ha placed in dibble hole 50 cm to the side of the seed hole.
9. 20 kg P/ha placed in hole with seed
10. 20 kg P/ha banded in between every other row
11. 80 kg P/ha broadcast and incorporated plus 2T lime, 50 kg K and 100 kg $MgSO_4 . 2 H_2O$ per ha

It is hypothesized that if Al-tolerant crops are grown (prior to treatment the soil had 40% Al sat.), then P would be the major nutrient limitation on these recently cleared, unfarmed soils. Therefore, for this low input approach, only P fertilizer has been applied; except for treatment 11 which was given lime and all macronutrients to test the hypothesis that available P indeed is the primary limiting soil factor for crop production.

The first crop, peanut, was given a blanket application of 325 kg $Ca(OH)_2$/ha near the base of the plants at flowering to supplement Ca nutrition of the developing pods.

Residual Effects of Phosphorus Fertilization (S-1005)

A long-term experiment is being designed to evaluate the effect of larger rates of P than the previous one either on a broadcast and band placement. The actual rates will be determined after the sorption capacity of the soil is evaluated by P sorption isotherm. The design is likely to be similar to the long-term P experiment installed at CPAC in Brasilia in 1972 which keeps providing good data.

Potassium Dynamics in Weathered Soils of Sumatra (S-1006)

Personnel: D. W. Gill, E. J. Kamprath

Objectives. 1) To determine the effect of K rates at three levels of base saturation on the yield and uptake of K and basic cations of upland crops in the Sitiung area of Sumatrai; 2) to determine the effect of different levels of base saturation on the retention and movement of K applied at various rates.

Justification. The soils in Central Sumatra are very acidic with aluminum saturation of 80 to 90 percent and low levels of bases and potassium. Sustained crop growth on these soils will require additions of fertilizer potassium. The relatively high rainfall in the area enhances the potential for leaching losses of potassium. Leaching of potassium can be reduced to some extent by neutralization of exchangeable aluminum which increases the accessibility of exchange sites for potassium. Relatively little information is available on the potassium requirements for sustained production of cropping systems in Sumatra.

Field experiments will be conducted in the Sitiung area of Sumatra. A uniform phosphorus fertilization will be applied to the experimental area. The rate of phosphorus required to bring the soil to the critical soil test level will be determined from phosphorus fixation studies. Lime rates to be used will be based on incubation studies measuring the exchangeable aluminum level after various rates of lime have been applied. Starter application of nitrogen and phosphorus will be applied at planting to grain crops and phosphorus to legume crops. Potassium will be broadcast just prior to planting. Grain crops will receive a nitrogen sidedressing approximately four weeks after emergence of the crop. Plant tissue samples will be taken at flowering for determination of calcium, magnesium, potassium, nitrogen, and phosphorus. Total plant content of these nutrients in the grain and grain yield will be determined. Soil samples will be taken at 15 cm intervals to a depth of 60 cm prior to planting of the next crop.

Two cropping systems will be used, 1) corn-soybeans-mungbeans, and 2) rice-peanuts-cowpeas. These will be planted in areas adjacent to each other. Lime rates will be 500 kg $CaCo_3$/ha and rates of $CaCO_3$ to give 0 and 50 percent aluminum saturation. Rates of K applied as KCl to each lime rate and crop will be 0, 20, 40, 80, 120, and 240 kg K/ha.

Laboratory studies will be conducted to determine the quantity-intensity relationships for potassium as influenced by base saturation. These values will be determined for surface soils and subsoils.

Sulfur Responses and Reactions in Soils of Sumatra (S-1007)

Personnel: M. K. Wade, E. J. Kamprath, Heryadi

Objectives: 1) To determine the total sulfur and sulfate content of soils recently cleared and those under cultivation for five or more years; 2) to determine the response of grain crops and legumes to sulfur fertilization on soils recently cleared and those cultivated for a period of time.

Justification. Very little information is available on the sulfur status and response to sulfur fertilization on the highly weathered soils of Sumatra. Sulfur deficiencies and response to sulfur fertilization have been reported on soils in Java and Sulawesi. Since urea and triple super-phosphate are the major sources of nitrogen and phosphorus, very little sulfur is added through fertilization. This will increase the likelihood of sulfur being a limiting factor in crop growth after correction of acidity and nitrogen, phosphorus and potassium deficiencies. Development of a sound fertilizer management system requires knowledge about the sulfur status of soils.

The sulfur studies would be done by an Indonesian graduate student either at the doctoral or masters level. The field work in Indonesia would be under the supervision of Michael Wade and the laboratory studies under the supervision of Eugene Kamprath.

Field experiments would be conducted on two sites in the Sitiung area representing a recently cleared area and one that has been cleared for at least 5 or more years. Fertilization practices would be those considered optimum for sustained production of high value crops. The cropping system to be used is corn-soybeans and mung beans.

Experiments:

Field. Sulfur rates to be applied as $CaSO_4$ are 0, 10, 20 and 40 kg S/ha. The 10, 20 and 40 kg S/ha rates will be duplicated and one set will receive an application for each crop and the second set will only receive one initial application to determine the residual effect on the succeeding crop. Tissue samples will be taken at flowering to determine concentration of nitrogen and sulfur. Soil samples will be taken at the beginning of the study and at the end of each crop to determine movement and adsorption of sulfate at various depths.

A number of sites which vary in length of time they have been cleared would be sampled to determine the total sulfur and adsorbed sulfate levels at various depths.

Laboratory. The adsorption of sulfate of the A and B horizons will be determined on soils representative of the Sitiung area. The effect of pH and P levels on sulfate adsorption will be determined.

Micronutrient Status of Soils in Transmigration Areas (S-1008)

Personnel: M. K. Wade

Objectives: 1) To determine the available level of Zn, Cu, and Mn 2) to determine the plant tissue concentration of Zn, Cu, Mn, and B of major crop plants.

Very limited information is available on the micronutrient status of the soils in Sumatra. Observations of plants in the field have indicated that Zn deficiency may occur if certain soils are limed. Experiences with Oxisols in Brazil would suggest that Zn deficiency is likely on the soils in the Sitiung area.

Existing field experiments will be used for soil samples and plant tissue samples. Soil and tissue samples will be taken at flowering.

Determinations will be made of available Mn, Cu, and Zn using the modified Olsen solution and using the Mehlich-III extracting solution. The ear leaf of corn, the most recent fully developed leaf of soybeans, peanuts, mungbeans and cowpeas, and mature leaves of rice will be sampled at flowering. The plant tissue will be analyzed for Mn, Zn, and Cu.

Soil Dynamics on a Newly Cleared Forest Ultisol (S-1009)

Personnel: M. K. Wade, Dr. Soleh, Ir. Cahyono

Objectives: 1) To monitor changes in soil fertility under continuous cultivation after forest clearing; 2) to identify soil nutrient limitations as they exist initially and develop over time and determine the necessary corrective measures to achieve optimum yields.

Justification. Thousands of hectares of forest are cleared every year in Indonesia transmigration by local farmers and by goverment and/or private production programs. Most of these lands are similar to the Ultisols in the Sitiung area of West Sumatra.

Initial soil properties upon clearing the forest are often quite good, both physically and chemically. However, soil is a dynamic entity and rapidly goes through many changes once the forest is cleared and annual crop production ensues. In order to achieve and maintain good yields during the transition from initial clearing to stable continuous cropping, we need to monitor soil properties and to test corrective amendments as problems develop. By so doing, a proper soil management program can be developed that can prevent soil degradation. It would be

far more efficient to maintain a productive soil than frequently having to reclaim or rejuvenate a depleted one.

Procedure. The "chronologic" design developed by Smyth and Bandy and implemented in Manaus will be established on a 1.12 hectare site located on a primary forest at the 200 hectare forest concession recently acquired by the Center for Soils Research, 12 km south of Gunung Medan in West Sumatra. The chronologic design, described in detail in experiment M-901, consists of 35 treatments with four replications arnanged in a randomized complete block design. Individual plot size is 80 m^2. The soil is a deep, well-drained Ultisol with moderate slope. The experimental area will be felled, burned and cleared and put into crop production. Cropping should be continued for at least five years. An annual crop rotation of rice-soybeans-peanuts will be used.

Initial treatments will be 3 rates of lime and 3 of P. However, some 25 additional plots will be included in each replication. These will be used to add additional treatments as new chemical problems arise. The unused additional plots will be given "best treatment" base amendments as time goes by, and then will be used three at a time, to all nutrient rate treatment when a new suspect deficiencies occurs. During the first crop, the unidentified plots can serve for geostatistical analysis.

Leaf samples from all plots will be taken at flowering and stover and grain samples will be taken for total nutrient uptake analysis from the improved treatments. Soils will be sampled before clearing, after clearing and after each crop to the following depths: 0-15, 15-30, 30-45 cm.

This process will be repeated with each successive crop. The optimum rate or treatment will be applied as a basal treatment to all plots except those used in testing the variable in question. It is expected that K and Mg may be the next candidates. This experiment will complement the three other planned "chronologic" experiments at Manaus, Yurimaguas and Pichis Palcazu.

Given funding limitations, this experiment is not likely to start until the potassium subproject (S-1006) is finished.

Principal Research Site: Sumatra, Indonesia

Duration: Five years

Soil Management in Transmigration Areas of Sumatra
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	56	56	52	61	53	278
Fringe Benefits	6	6	6	6	6	30
Supplies	6	6	6	6	4	28
Equipment	8	5	7	5	7	32
Travel	23	13	14	14	14	78
Allowances	10	11	11	12	12	56
Other Direct Costs	5	6	5	6	6	28
Indirect Costs	25	26	28	29	30	138
TOTAL	144	135	135	146	137	697

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.20	0.30	0.30	0.30	0.30	0.40	1.00
Field Based Scientist	1.00	1.00	1.00	1.00	1.00	5.00	0.00
Graduate Student	1.00	1.00	1.00	1.00	1.00	5.00	0.00
Other	1.00	1.00	0.00	0.00	0.00	0.00	2.00
TOTAL	3.20	3.30	2.30	2.30	2.30	10.40	3.00

Program: Acid Savannas

Research Project:

Title: Influence of Texture and Liming on P and Zn Soil Test Levels and Fertilizer Management of Cerrado Oxisols

Objectives:

1. To determine soybean yield response to extractable P and Zn concentrations when grown on Oxisols of different texture and pH.

2. To determine effect of rates of fertilizer P and Zn applied to Oxisols varying in pH and texture on the extractable P and Zn concentrations with time.

3. To determine P retention by Oxisols as influenced by pH and clay content.

4. To develop a model to predict the necessary P and Zn rates to reach and maintain adequate soil test P and Zn levels for maximum soybean economic returns.

5. To validate the developed model with field data.

Project Leader: F. R. Cox, North Carolina State University

Principal Collaborators: Ibere D. G. Lins, Eric R. Stoner, Edson Lobato, Wenceslau J. Goedert, Djalma M. Souza, Plinio I. Souza, Eneas Z. Galrao

Rationale:

Besides Al toxicity and Ca deficiency, low native soil test P and Zn levels and high P retention capacity are major factors that limit crop production on Oxisols of the Cerrado of Brazil.

It is well known that with an increase in soil pH there will be an increase in P availability and a decrease in Zn availability for plant uptake. Also, increasing rate of P fertilizer may lead to a Zn deficiency.

As a general rule, clayey Oxisols have a higher P adsorption capacity maximum and require a lower extractable soil P concentration to achieve maximum yields than loamy Oxisols. Also, it seems that as clay content increases, extractable Zn increases. Thus, P and Zn in Oxisols should be studied considering the effect of both pH and clay content on the availability of these nutrients for plant growth.

When the levels of available P and Zn in Oxisols are inadequate, increasing these levels by addition of fertilizer P and Zn will increase soybean yield. However, soybean yields on Oxisols will increase progressively less with each additional unit of soil available P and soil available Zn until a sufficiency level for soybean yield is attained. It is, therefore, important to have a soil test which indicates both whether any P and Zn fertilizer is needed, and if so, how much of each nutrient should be applied to an Oxisol with a given clay content and pH for maximum economic returns.

Relevance to Other Activities:

These studies will provide data complementary to other research components of the TropSoils Acid Savanna Program to develop appropriate soil management practices for the different textured Oxisols of the Cerrado region of Brazil and other developing countries with similar soil-crop-climatic regions.

Generalized Procedures:

To meet objective one, the following steps are proposed:

1. Six different textured Oxisols will be used in a greenhouse experi-ment with five levels of applied P; four P extraction methods will be investigated;

2. Extract P, with the same four extractants, from soil samples from five previous P field calibration studies on various textured Oxisols; extractable P will be correlated for each method with previous soybean yields from these experiments to determine critical soil test P levels;

3. Three different textured Oxisols, limed to reach three pH levels, will be used in a greenhouse experiment with five Zn rates three Zn extractants will be used at least one of these three Oxisols will be selected from a previous Zn experimental site;

4. Relate greenhouse and field response data to construct a model which can predict both P and Zn critical soil test levels for different textured Oxisols varying in pH.

The second objective will be met by applying various P and Zn rates to the same Oxisols as in objective one and thrice cropping sequentially in the greenhouse. Also, data from previous P field experiments cropped over time will be used to relate effect of P rate on extractable P for different textured Oxisols.

To meet objective three, a lab experiment with the same six soils will be conducted. Each of the different textured Oxisols will be limed to pH 5.2, 5.7, and 6.2, and will receive five P rates. Three methodologies will be used to determine P adsorption maximum for each treatment.

With the information obtained from greenhouse experiments, lab experiments, and previous P and Zn field studies, the model will be developed to meet objective four.

To meet objective five, three field experiments will be installed on different textured Oxisols at the Cerrado Center. Each experiment will consist of a 3 x 3 x 3 factorial arranged in a split split-plot design with three lime rates as main plot treatments, three P rates as sub-plot treatments, and three Zn rates as sub-sub-plot treatments.

Experiments:

1. Laboratory. Lab experiments will be carried out using the same six Oxisols, varying in clay content, as used in greenhouse experiments. Each soil will be limed to reach pH 5.2, 5.7, and 6.2. Lime rates will be based on incubation studies. P rates of 0, 66, 132, 264, and 528 kg/ha will be applied to each soil. Extraction of P will be by Bray-1, Mehlich-I, Mehlich-III and modified Olsen. Phosphorus retention capacity will be determined by: 1) phosphate sorption isotherms described by Fox and Kamprath; 2) quicktest methodology developed by McLean; and 3) availability following P applications according to Hunter's methodology.

Also, Zn sorption studies will be carried out using Oxisols from three field sites which have clay content around 18, 45 and 70%. Each soil will be limed to reach pH 5.2, 5.7 and 6.2. Zn rates of 0, 3, 6, 9, 12 kg/ha will be applied to each soil. Extraction of Zn will be Mehlich-I, Mehlich-III and modified Olsen and the Zn retention capacity of each soil, at each pH, will be determined following Zn application according to Hunter's methodology.

2. Greenhouse. Two greenhouse experiments are proposed. The first was designed to study soybean yield response as a function of P and soil clay content and to determine extractable soil test P as a function of P rates over time.

The six different textured Oxisols to be used in this experiment will be limed to pH 5.5 and the same five P rates to be used in the lab experiments will be applied to each soil. Each plot will contain 4 kg of soil. Only one soybean variety will be used in this experiment. Seed will be inoculated with the appropriate rhizobia and a Mo slurry. Seed will be covered lightly with soil and a 2 cm layer of clean, acid washed quartz sand will be added to reduce surface evaporation.

A basal fertilizer dose of essential elements will be added according to soil test predictions. Three replications of the randomized complete block design will be used. This experiment will be thrice conducted with fertilizer treatments applied only prior to the first planting. Harvest of the shoots will be six weeks after emergence. Analysis of soils prior to, after treatment, and at harvest will be for O.M., Ca, Mg, P (using the four extractants designated in the lab part),

Al, Fe, Mn, Zn and Cu. Dry weight will be taken at harvest and a complete foliar analysis conducted on the plant tissue.

The second greenhouse experiment will study soybean yield response as a function of Zn, pH and soil clay content as well as to determine soil extractable Zn as a function of Zn rates over with time. Three different textured Oxisols to be used in this experiment will be limed to reach pH 5.2, 5.7 and 6.2; five Zn rates will be applied to each soil. Soil Zn will be extracted by three methods (Mehlich-I, Mehlich-III and modified Olsen) other methodologies will be the same as described in the P greenhouse experiment.

3. Field. The three field experiments proposed to validate the model developed from the greenhouse studies and previous P and Zn field experiments to predict rate of P and Zn fertilizer to be applied will be conducted at the Cerrado Center on different textured Oxisols (18, 45 and 70% clay) varying in pH.

Lime, based on incubation studies, will be applied to each soil to raise the pH to 5.2, 5.7 and 6.2. Required P rate to bring each soil to the critical soil test level will be determined from phosphorus fixation studies. Three rates of P fertilizer, to sandwich the critical level, will be used. Three rates of Zn, based on Zn adsorption studies, will be used in each experiment.

In all trials, lime and P will be applied well in advance so that by the planting time (October, 1985), both lime material and P fertilizer will have already equilibrated with the soils. Fertilizer addition of other essential elements will be added according to soil test predictions. Soybean seed will be treated with Mo and inoculated with the appropriate rhizobia. Nitrogen fertilizer will not be used.

Plant tissue samples will be taken at flowering for determination of Ca, Mg, K, N, P, Fe, Al, Mn, Cu and Zn. Total plant content of these nutrients in the grain and grain yield will be determined. Soil samples will be taken before planting and just after harvesting at 15 cm intervals to a depth of 45 cm.

Correlations between model predicted and observed soybean yields will be made.

This project is likely to be revised at the end of two years, after which a decision for work to be done in years 3 to 5 will be proposed.

Principal Research Site: CPAC, Brasilia

Duration: Five years

Influence of Texture and Liming on P and Zn
Soil Test Levels and Fertilizer Management
of Cerrado Oxisols
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Supplies	2	2	3	3	3	13
Travel	3	3	4	4	4	18
Other Direct Costs	2	2	2	2	2	10
Indirect Costs	4	4	3	3	3	17
TOTAL	11	11	12	12	12	58

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.10	0.10	0.10	0.10	0.10	0.00	0.50
Graduate Student	1.00	1.00	1.00	1.00	1.00	0.00	5.00
TOTAL	1.10	1.10	1.10	1.10	1.10	0.00	5.50

Program Backstopping Support
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	84	90	95	100	105	474
Fringe Benefits	16	16	18	18	18	86
Supplies	8	8	8	8	10	42
Equipment	5	4	5	4	5	23
Travel	16	13	14	15	16	74
Other Direct Costs	10	10	10	12	12	54
Indirect Costs	33	33	35	35	37	173
TOTAL	172	174	185	192	203	926

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.50	0.60	0.60	0.60	0.60	2.40	0.50
Other	4.00	4.00	4.00	4.00	4.00	20.00	0.00
TOTAL	4.50	4.60	4.60	4.60	4.60	22.40	0.50

SEMI-ARID TROPICS PROGRAM

TEXAS A&M UNIVERSITY

Semi-Arid Tropics Research Program Proposal

Texas A&M University

Synopsis

Research Topic 1. Characterization of the Soil-Plant-Atmosphere Systems in Semi-arid Environments

Goal: To describe and model components of the soil-plant-atomosphere system to semi-arid climates to determine options for modifying the environment to increase agricultural and forestry production.

Project 11: Quantification of Rainstorm Characteristics, Rainfall Patterns and Hydrology of Representative Cropped Soils of Niger.

Objectives: Assess drop size distribution, kinetic energy and intensity/duration relationships of rainstorms; identify and quantify spatial and temporal variation, frequency distribution, overall trends and periodicities and patterns of wet and dry spells of rainfall; establish and quantify the physical and hydrological properties of major cropped soils; estimation of actual evapotranspiration of economically important crops from climatic data.

Project 12: Spatial Variability of Soil Physical and Chemical Properties and Crops in Semi-arid Environments.

Objectives: Scale hydraulic properties of soils using algorithms based on the concept of similar media; optimization of sampling techniques and design of research plots by characterizing the spatial variability of soil and crop properties using geostatistical procedures.

Project 13: Water and Energy Balance of Bare and Cropped Soils in Semi-arid Environments.

Objectives: Calculate soil temperatures as a function of time and depth with a model based upon soil thermal properties and air temperature; mechanistically calculate and describe the water and energy balance of a bare soil with a simulation model using as input soil physical properties and daily weather variables; predict water use by crops with a partial canopy using a dynamic and mechanistic model of root water uptake; assess water balance in a Sahelian Forest.

Project 14: Classification, Characterization and Distribution of Soils in Semi-Arid Environments.

Objectives: Group soils into natural and technical classification systems relevant to land-use management by describing and mapping the major soil resources used for TropSoils research; establish soil/geomorphological/hydrological relationships of principal agroecological subzones of the semi-arid tropics; establish the quantity and physical-chemical-mineralogical composition of dust inputs as a nutrient renewal vector on soils in the Sahel; elucidate and model surface soil sealing and crust formation processes under semi-arid environments.

Research Topic 2. Modification of the Soil-Plant-Atmosphere Systems in Semi-Arid Environments

Goal: To modify selected components of the soil-plant-atmosphere system in semi-arid environments to increase agricultural and forestry production.

Project 21: Soil Surface and Profile Modifications to Increase Agricultural and Forestry Production in Semi-Arid Environments.

Objectives: To increase crop yield by improving the status of soil water using selected tillage treatments; enhance crop yield by decreasing runoff with land farming practices; rejuvenate crusted forest soils by selected mulch and tillage treatments; decrease crop growth variability and yield loss based upon the findings of the spatial variability studies.

Project 22: Increasing Crop Yields in the Sahel through Microclimate Modifications.

Objectives: Maximize efficient use of water through manipulation of cropping patterns and fallow rotations; decrease soil evaporation from bare soils using windbreaks; increase millet growth and yield by modifying the crop microclimate with windbreaks.

Project 23: Relationship Between Soil Water and Plant Nutrient Utilization in Semi-Arid Environments.

Objectives: Increase crop utilization of soil water by changing rooting patterns through placement of appropriate rates of applied plant nutrients; enhance water use efficiency of crops with applied plant nutrients; improve soil physical and chemical properties through use of fertilizers and soil amendments; increase available soil water and crop yields under rainfed conditions with a combination of fertilizers and tillage practices.

Summary of Budget by Projects for the Semi Arid Tropics Program
Texas A & M University

Project Short Title	Year 4	5	6	7	8	Total
			x $1000			
Quantification of Rainfall Characteristics	85	94	65	45	21	310
Spatial Variability of Soils	54	53	59	25	4	195
Water and Energy Balance	88	92	58	47	28	313
Soil Characterization	105	90	86	60	55	396
Soil Surface and Profile Modification	112	119	149	166	189	735
Micro-Climate Modification	56	65	118	130	156	525
Soil-Water-Plant Nutrient Interaction	87	88	94	99	117	485
Backstopping	142	151	159	169	178	799
TOTAL	729	752	788	741	748	3758

Summary of the Budget by Object Items
and of the Staffing Plan for the
Semi Arid Tropics Program
Texas A & M University

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	275	283	307	297	301	1463
Fringe Benefits	66	74	73	71	72	356
Supplies	57	52	59	58	59	285
Equipment	64	61	59	43	44	271
Travel	97	104	105	95	96	497
Allowances	25	27	29	27	25	133
Other Direct Costs	24	24	23	23	22	116
Indirect Costs	121	127	133	127	129	637
TOTAL	729	752	788	741	748	3758

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	2.70	2.60	2.60	2.50	2.50	6.25	6.65
Field Based Scientist	2.00	2.00	2.00	2.00	2.00	10.00	0.00
Graduate Student	8.00	8.00	8.00	8.00	8.00	38.00	2.00
Other	12.60	11.80	11.80	11.70	11.70	45.60	14.00
TOTAL	25.30	24.40	24.40	24.20	24.20	99.85	22.65

Semi Arid Tropics Research Program Proposal

Submitted by

Texas A&M University

Frank G. Calhoun

Program Coordinator

There is a food crisis in semiarid Africa. Estimates coming out of Niger are that millet and cowpea yields underwent anywhere from 50 to 85 percent declines for 1984. Vast tracts of land lay barren well past the latest possible planting date for millet. The long-term solution lies in upgrading of human resources and of infrastructures better able to deal with food production problems within national boundaries. It has been emphasized that deforestation and a general decline in soil productivity in concert with periodic droughts are the major contributing factors to inadequate subsistence-level food supplies in Africa. The TropSoils program in Niger represents, at this time, the only major commitment of AID to addressing specific problems of physical soil and water management under rainfed conditions in semiarid Africa.

The Soil Problem In Semiarid Africa.

Large areas of the Sahel have soils that are high in sand and have low water storage. Crops grown in these areas are subject to sandblast and burial during early stages of growth. Soils with higher clay content form crusts immediately after rains so that 80% or more of subsequent rainfall is lost to runoff. Crusting also causes problems in crop establishment e.g. seedling emergence.

Chemically, the soils are also deficient as far as crop production is concerned. They are acid, low in available N, P, K, Ca, Mg, organic matter and high in Fe and Al. Due to low cation exchange capacities, many of the soils are very fragile chemically and must be handled with care. Furthermore, spatial variability exists which makes the interpretation of research results from cropping systems and experiments difficult.

The climate is harsh and the rainfall is erratic and decreasing. During the past decade rainfall has decreased 30-40%. Air temperatures commonly exceed 40 C, and soil temperatures 5 cm deep often exceed 50 C. With no inputs, local varieties of crops outyield introduced varieties. This is probably due to the fact that local varieties have been selected over time under the soil deficiencies and harsh climate of the area and; thus, are better adapted. In temperate zones with virgin fertile soils,

the common procedure has been to introduce germplasm to determine which species would best use the soil and climate resources of the area concerned. In Africa, the soils resource is so deficient that soil management problems need to be solved before much new germplasm can be introduced to be evaluated. Although the principles of solving soils problems may be universal, the techniques of solving such problems may be site or area specific depending on area resources.

With due consideration of political, socio-economic as well as resource constraints, several general requirements necessary for a successful soil management research program aimed at increasing the agricultural productivity of West Africa are:

1. Long term commitment from donor agencies to host countries and providers of technical assistance.
2. Training of host country staff at all levels at appropriate training centers and/or universities.
3. Generation of viable and socio-economically acceptable technology.
4. Identification and characterization of the variety of Sahelian ecologies.
5. Thorough evaluation of previous research conducted by other countries, especially France and The Netherlands.
6. Development of a library of French literature dealing with agricultural research in the Sahel.
7. French language training for TAMU-TAES faculty and staff as well as the overseas staff.
8. Efficient and sensitive administrative, technical, and logistical backstopping program at Texas A&M for the West African program.
9. Sensitivity to the fact that West Africa is a group of independent countries that differ in government, temperament and culture.
10. Programs that solve problems in specific countries as well as gather base line data. In some cases the problem solving may be just technology transfer.
11. Flexible research programs that fit the unpredictable climate of each growing season.
12. Capability to execute agreements with a sense of urgency.

The TropSoils Program In Semiarid Africa.

With the analysis and review of the problem by Texas A&M University as outlined in the previous section, a collaborative research support program was established in Niger beginning in early 1983. Two important points must be emphasized as a preamble to the overall extension proposals which will follow. These are (1) overall research strategy and (2) status of the host country institution's (INRAN) research capabilities.

Research Strategy

Based on our analysis and review of Soil Management problems in semiarid Africa our primary goal is to develop and enable the adoption by small, low resource farmers of improved soil management technology for productive, sustained farming systems on the marginal soils of the semiarid tropics. The overall research strategy in the early stage of this program has been one with a primary focus on characterization of the soil-plant-atmosphere system. A secondary focus has been on modification of this system based on principles and knowledge gained from research in other semiarid agroecological zones. As we gain more information, characterization research will diminish in proportion to modification research. The "handshaking" relationship between these two general research topics is shown in Figure 1.

INRANN

TropSoils must interface with a number of programs and institutions in Niger. The two primary collaborating institutions are INRAN and ICRISAT. The ICRISAT Sahelian Research Center (ISC) is supported by a TropSoils senior scientist involved primarily in agroforestry, tillage, water balance and spatial variability research. Much of this research is in collaboration with scientists from the Sahelian Center. This research team, at the ISC, is well-trained, highly motivated and backed by the well-established reputation of the parent institution at Hyderabad, India.

INRAN is a relatively young research institution. Less than a decade has elapsed since its formal creation. It is still developing both physically and institutionally but it does have a good organizational structure. The lead scientists in the various sections have a good appreciation of research needs and would like to see INRAN grow into a viable and respected research organization in the West African Sahel. Many sections of the INRAN organization are, however, currently inactive because of lack of suitable personnel and/or funding. INRAN scientists are very willing to work with TropSoils scientists and have been very receptive to our workplans. All workplans in this proposal involving INRAN have been discussed with the responsible INRAN collaborators and their suggestions have been incorporated. They have assured TropSoils of their continued commitment, support and cooperation. However, because of financial and personnel constraints the full levels of technical support and collaborative staffing for all programs may not be immediately available. Such constraints with few exceptions, are common throughout the Sahel and semiarid Africa.

Work Plans

The work plans are divided into two general groups: (1) characterization and (2) modification. Within these two general groups, coded 1 and 2 respectively, the following projects, with their respective codes, will be conducted:

1. Characterization
   11. Rainstorm characteristics, hydrology
   12. Spatial variability
   13. Water and energy balance
   14. Soil mapping and classification

2. Modification
   21. Soil surface, profile modification
   22. Microclimate modifications
   23. Fertility/water interactions

Collaboration

The names of the collaborating scientists are given with the associated project. The institutions represented by these personnel are: National Institution for Agricultural Research, Niger; University of Niamey; Niger Meteorology Service; International Tillage Laboratory, Wageningen; Forest Land Use Project, USAID/Niamey; Texas Agricultural Experiment Station, Lubbock; Institution of Rural Economy, Mali; National Office for Forest Regeneration, Cameroon; University of Haiti; and Ministry of Agriculture, Haiti.

RESEARCH FRAMEWORK

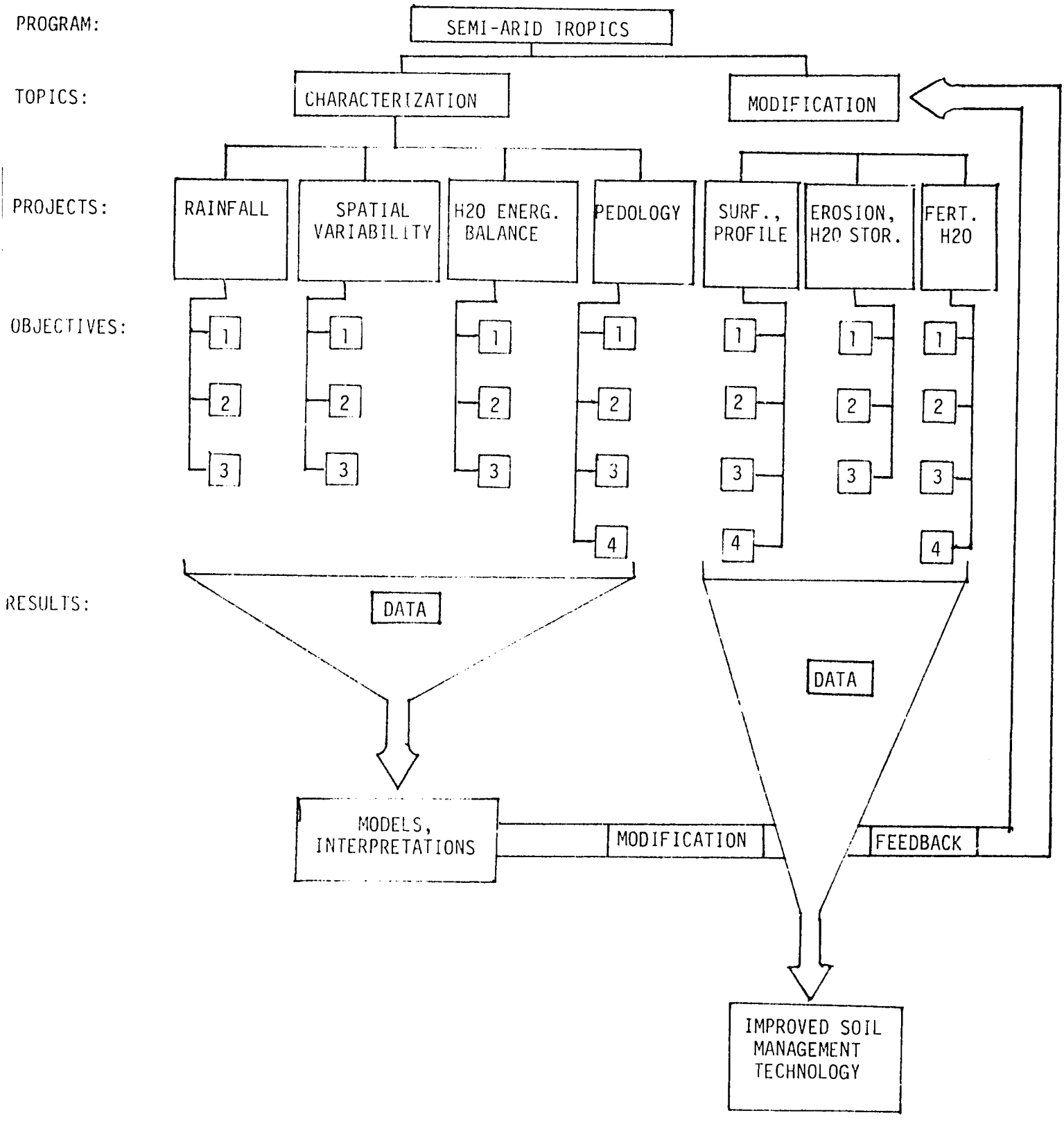

Figure 1. Overall soil management research framework for the Semi-arid Tropics Program.

Program: Semiarid Tropics

Research Topic 1:

Title: Characterization of the Soil-Plant-Atmosphere Systems in Semiarid Environments.

Goal: To describe and model components of the soil-plant-atmosphere system in semiarid climates to determine options for modifying the environment to increase agricultural and forestry production.

Project 11:

Title: Quantification of Rainstorm Characteristics, Rainfall Patterns and Hydrology of Representative Cropped Soils of Niger.

Objectives:

111. Assess drop size distribution, kinetic energy and intensity/duration relationships of rainstorms.

112. Identify and quantify spatial and temporal variation, frequency distribution, overall trends and periodicities, and patterns of wet and dry spells of rainfall.

113. Establish and quantify the physical and hydrological properties of major cropped soils.

114. Estimate evapotranspiration of economically important crops from climatic data.

Project Leader: Naraine Persaud
Texas A&M University

Collaborating Scientists: M. Gandah, A. Abdoulaye, A. Garba, A. Karimou, Idrissa, Maidoukia

Reasons for Investigation:

Objective 111. The rainfall characteristic which is directly related to erosion is its kinetic energy. Studies by Ellison have demonstrated the important role of drop impact in inducing detachment of soil particles and their suspension in #off. In the Universal Soil loss Equation the energy/unit of rainfall is obtained by an empirical relation to its intensity. This relationship has been found to be inapplicable for tropical rainstorms. Rainfall erosivity estimation may be

obtained from drop size distributions and velocities. A need exists to seek and evaluate physical, as opposed to empirical models, to characterize rainfall erosivity. Measurement of drop size distributions is a move in this direction. The design of a realistic rainfall simulator to aid in erosion research requires a knowledge of typical drop sizes and distributions of natural rainstorms. Finally, drop size measurements may help in analysis of results of experiments to measure rainfall erosion in field plots.

Analysis of recording rain gauge charts provide depth or intensity / duration / frequency relationships, and hydrographs (mass curves). Such information is required for estimating surface runoff and erosion, and in the design of channels, levees, spillways, terraces, and other conservation works.

Objective 112. Rainfall is a critical factor in soil and crop-water relations in Niger. Too much or too little, or a poor distribution during the rainy season, its spatial and temporal variability, have a considerable influence on agricultural production and productivity. Statistical analysis of daily rainfall records are useful for identifying and quantifying spatial and temporal variation, frequency distributions, overall trends and periodicities, and patterns of wet and dry spells of rainfall. These results provide valuable information in estimating runoff and moisture balances, designing of rainfall networks, and planning of experiments and hydrological projects.

Objective 113. Information is scarce on soil physical and hydrological characteristics such as bulk density, infiltration rates, water characteristics curves, etc. for major cropped soils in Niger. Some field measurements have been made in irrigated perimeters by ORSTOM and IRAT scientists, and some laboratory measurements by INRAN scientists in the course of soil survey investigations. Soil hydrological characteristics are essential to estimate soil water storage and balance components in the field and in evaluation for irrigation. They need to be measured in the field since laboratory generated data are often not representative of the field situation.

Objective 114. Few investigations exist on crop evapotranspiration (ET) in Niger. Such information is vital for irrigation design and scheduling and for estimating crop water deficits, during the growing season. The CILSS (Comite' Inter Etats pour la Lutte contre la Se'cheresse dans le Sahel) Program in Niger is in the process of installing class A agrometeorological stations throughout Niger, in addition, to those already existing. Several of these new installations are already operational. Data from these installations can be used to estimate potential evapotranspiration (PET). Several formulae need to be tested and this would require independent measurements of PET for a reference crop. If simultaneous measurements of actual ET can be made, suitable crop coefficients can be obtained for estimating PET from climate-based PET estimates, for various crop growth stages and field conditions.

Revelance to Other Programs:

This project is conducted with the collaboration of the staff of INRAN, Tapis Vert and University of Niamey. It will provide baseline data applicable to a wide range of soil and water planning and management problems. It will also provide the basis for applied field research and provide data for theoretical models which form part of the overall program.

Generalized Procedures:

Objective 111. The flour pellet method is somewhat time consuming, but is cheap and provides good results. Measurements from dual-trace raingauges will be analyzed to obtain depth or intensity/duration relationships. The techniques used in these analyses are standard and are used by the U.S. Soil Conservation Service.

Objective 112. Available daily rainfall records from non-recording and recording rain gauges will be assembled. Sources of such data are the Meteorological Service Agency of the GON, the CILSS, and Centre for Training and Applications in Agrometerology and Operational Hydrology (AGRHYNET). Available daily rainfall records will be analyzed to obtain quantitative measures of:

a) the probability a given day will be wet or dry,

b) the probability a given sequence of wet or dry days will occur at a particular time of the year,

c) the probability a given number of days will be wet or dry in a particular sequence of days,

d) the spatial and temporal variability of rainfall,

e) the presence of trends or periodicities, and

f) the frequency distributions of extreme values.

The techniques for such analyses are well-known and have been extensively applied and discussed. With reference to a, b, c above, wet and dry days will be appropriately defined.

Objective 113. Any previous reports on these measurements will be researched and the results extracted and compiled. New measurements will be made using field techniques. Rainfall simulation will be used to measure infiltration, and the effects of surface conditions on infiltration at various rainfall intensities. Tensiometers, gravimetric sampling and Bouyoucos blocks will be used to obtain field moisture characteristic curves. Neutron probes will be used to quantify the hydrodynamic characteristics on wetting and drying. Repeated measure-

ments at each site will be made to estimate field variability of these characteristics.

Objective 114. At several locations near agrometeorological installations plots will be established. A grass species (*Paspalum notatum*, L.) which has been shown to provide good vegetative cover, maintains good active, vegetative growth throughout the year and revives rapidly after cutting, will be used as a reference crop for PET measurements. Various climate-based equations for estimating PET will be evaluated. Actual ET of various crops will be measured using water balance methods in lysimeters or field plots. From these measurements crop coefficients for various crop growth stages and field conditions will be evaluated.

Experiments	Location	Duration
Measurements of physical characteristics of rainstorms.	Niger	1985-86
Statistical analysis of rainfall records.	Niger	1984-85
Physical and hydrological properties of major cropped soils of Niger.	Niger	1984-89
Estimation of actual evapotranspiration of economically important crops of Niger.	Niger	1985-87

Management Entity Comment:

The project is to be revised to reflect the applicability of currently established principles to local situations and additional justification for the approach proposed. Funding beyond year four will be based on an evaluation of the revised project.

Quantification of Rainstorm Characteristics, Rainfall Patterns and Hydrology of Representative Cropped Soils of Niger
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	32	41	22	17	8	120
Fringe Benefits	8	10	5	4	2	29
Supplies	6	5	4	3	1	19
Equipment	8	7	9	3	1	28
Travel	11	10	10	6	3	40
Allowances	4	3	2	2	1	12
Other Direct Costs	2	2	2	2	1	9
Indirect Costs	14	16	11	8	4	53
TOTAL	85	94	65	45	21	310

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Field Based Scientist	0.35	0.35	0.25	0.20	0.20	1.35	0.00
Graduate Student	2.00	3.00	1.00	1.00	0.00	7.00	0.00
TOTAL	2.35	3.35	1.25	1.20	0.20	8.35	0.00

Program: Semiarid Tropics

Research Topic 1:

Title: Characterization of Soil-Plant-Atmosphere Systems in Semiarid Environments.

Goal: To describe and model components of the soil-plant-atmosphere system in semiarid climates to determine options for modifying the environment to increase agricultural and forestry production.

Project 12:

Title: Spatial Variability of Soil Physical and Chemical Properties and Crops in Semiarid Environments.

Objectives:

121. Scale hydraulic properties of soils using algorithms based on the concept of similar media.

122. Optimization of sampling techniques and design of research plots by characterizing the spatial variability of soil and crop properties using geostatistical procedures.

Project Leaders: Robert Chase and Robert Lascano
Texas A&M University and Texas Agricultural Experiment Station.

Collaborating Scientists: M. Ouattara, I. Mahmane, L. Fussell, D. Kleij, J. Heermans

Reasons For Investigation:

Objective 121. To characterize the hydraulic properties, i.e. relation between water potential and unsaturated hydraulic conductivity to volumetric water content, of any agricultural field requires many measurements of these two functions. The problem is then how to average and summarize these properties to adequately describe the area of interest. This is particularly true when these properties are used as inputs to models of the flow of water and energy. The calculations obtained with a mechanistic model only apply to average conditions without consideration to the statistical variation of the property. A solution to this problem is by applying the concept of similar media that allows scaling of the properties. The scales generated can then be used to estimate statistical variation with the model.

In general, scaling of hydraulic properties can be used for two purposes. First, to simplify and combine measured hydraulic properties of numerous locations within an experimental unit into representative means. The scale factor then relates the measured data at each location to the representative means. The second purpose is the prediction of the soil-water flow through the experimental area as a function of the scaling factor. Once the distribution is known, key values of the scaling factor can be used in dynamic simulation models to predict the variability of hydraulic processes.

Objective 122. A serious obstacle to evaluate data obtained from research plots in Niger is the variability, e.g. large coefficients of variation of measured parameters. This occurrence is common throughout Niger. It is a problem at the ICRISAT Sahelian Center, Maggia Valley and the Guesselbodi forest. The variability applies to soil as well as to crops.

Extreme crop variability, such as dwarfed or dead plants immediately adjacent to those producing heads, is common in research plots and in the farmer's fields. For the researcher, discarded results and failed experiments cause losses in time and productivity, and waste of agricultural funds. For the farmer, variability results in decreased crop yields.

The sources of variability are many. Among them we have long-term sources. These include the presence of termite mounds, old house or stable sites, and differences in soil physical and chemical properties. Uneven rainfall distribution both in time and space, and high wind speeds causing sand blasting and burial of millet plants are examples of short-term sources. These factors plus the heterogeneous nature of the soils in the Sahel region complicate the identification and control of these problems.

The variability is not unique to crops as it is also present in Sahelian forests. For example, the reasons for the patchy nature and characteristic shape of Tiger- and Leopard-bush stands, named due to the shape of the vegetated clumps as seen from the air, are not understood. Study of chemical and physical properties of the soils within and between vegetated areas may offer an explanation of their variability. If limiting factors are determined improved methods to revegetate areas that are now barren may be found.

To reduce this variability it is necessary to first define and identify the causes. This will allow researchers to make recommendations to decrease the variability and will result in strategies to increase crop yields. To evaluate these properties optimal sampling frequency within a grid or along a transect must be determined. This will minimize the number of samples to be taken and facilitate the interpretation of experimental data.

Relevance To Other Programs:

The stated goal of TropSoils is to develop and adopt improved soil management technology which is agronomically, economically and ecologically sound for developing countries in the tropics. Variability in research plots and in farmers field is a major constraint in agricultural production in the semiarid tropics. Before crop yields and forest vegetation problems can be solved a knowledge of the causes of variability is required.

The studies will have impact on experimental and farmers fields where variability in crop growth is a problem. The studies will be conducted in collaboration with the staff of ICRISAT, The Soil Tillage Laboratory, INRAN, Forest Land Use Project, and the University of Niamey.

Generalized procedures:

Objective 121. The procedures of this objective are to code computer programs to calculate the scale factors based upon soil water retention curves. The soil water retention curves are calculated from a semi-empirical model proposed by Arya and Paris (1983). These curves are based upon particle-size distribution data measured with the MICROTRAC method. Data previously obtained along a 100 m transect will be scaled and analyzed using the above procedures. A summary of the procedures is to: (1) collect soil samples along a transect or grid; (2) determine the particle-size distribution using the MICROTRAC method; (3) calculate the soil-moisture retention curves using the model of Orya and Paris (1983); (4) calculate the scale factor using the procedure suggested by Rao et. al (1983); (5) calculate the distribution of the scale factor; and (6) calculate the statistical and geostatistical properties of the scale factor.

Objective 122. The procedures of this objective can be divided in two parts. The first part deals with geostatistical techniques that will be used to analyze the data and the second, deals with the experimental procedures.

The spatial variability of soil properties is a subject that has been investigated by many researchers. Traditionally, because it is recognized that soils are indeed variable, treatments within an experimental site have been replicated, the premise being that duplication is necessary to find the average property and the deviations from the mean. In turn, the variability is quantified by using common statistical methods that in part have originated as a result of observed deviations. This approach is commonly referred to as "classical statistical methods".

Classical statistics is based on the central limit theorem, which requires that the following assumptions be met: 1) the samples should be

random, i.e. equal probability of being selected from the population; 2) the samples must be independent of one another, and; 3) the populations must be normally distributed. If any of these assumptions fail, the selected statistical test used to analyze the data is in error. Furthermore, if the samples are not independent, classical statistics does not offer an alternative solution.

The concept of spatial versus statistical variation has caused some confusion. Statistical variation is simply the numerical variability of a property and assumes that it is the same in space, i.e. within an experimental unit the variations around the mean are the same and no inferences can be made about the distribution in space. The spatial variability does describe how a property is distributed in space and also provides the statistical variation associated with each observation. This approach is called "geostatistics".

The fundamental theory of geostatistics was developed by Matheron (1963). The theory behind it is called the "Theory of Regionalized Variables". Basically this theory describes the space-functions and their correlation from one place to another. This is known as autocorrelation. The values can be interpolated by the Kriging method. Also, the analysis can be applied in time to distinguish between temporal and transient properties.

Geostatistics is simply a tool to analyze data. The purpose of this objective is to assess the observed variability of soil and plant properties using geostatistical techniques. The experimental procedures can be divided in four parts. The procedures are as follows.

A. Selection of field plots to assess the observed variability in crop growth. Experimental plots will be located at the ICRISAT Sahelian Center and at the Guesselbodi forest.

B. Measurement of soil physical and chemical properties in a grid or along transects within the experimental plots. Soil properties are soil texture, pH (water and KCl), available phosphorus, organic matter, exchangeable acidity and bases, cation exchange capacity, bulk density, soil resistance, and water contents at different values of soil water potential. Crop properties are leaf area index, light interception, height and yield. The measurements of these properties will be done with the cooperation of the INRAN's soils laboratory, staff from ICRISAT and the Soil Tillage Laboratory, and with the help of Dr. Eugene Perrier. Other properties to be studied include the water balance, i.e. water content, infiltration rates, etc. of selected plots in relation to the spatial variability of the soil parameters.

C. The main crop that will be studied is millet and the plant community found in the Guesselbodi forest.

D. The results will be used to define a "precision plot," to be located at the ICRISAT Sahelian Center that can later be used for other experiments. We will also attempt to optimize sampling techniques to minimize the number of samples. The results will be mapped using geostatistical techniques given by Dr. Russell Yost.

Experiments	Location	Duration
Scaling of soil moisture retention curves.	TAES, Lubbock, TX	1983-1985
Causes of variability of agricultural soils in the Sahel.	Niger	1983-1988
Precision field plot variability.	Niger	1984-1985
Soil physical and chemical properties within an outside vegetated areas in the Guesselbodi forest.	Niger	1984-1986
Optimum distance between samples for various soil parameters in a Labucheri soil.	Niger	1984-1985

Management Entity Comment:

Before the end of year five, an assessment will be made of progress in this project with particular attention to the usefulness of the information in other research and in soil management under field conditions. Funding beyond year five will be influenced by the results of the assessment.

Spatial Variability of Soil Physical and Chemical Properties
and Crops in Semi Arid Environments
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	17	17	19	10	1	64
Fringe Benefits	4	4	5	2	0	15
Supplies	4	3	4	2	1	14
Equipment	6	6	6	1	0	19
Travel	9	9	9	3	0	30
Allowances	3	3	3	2	0	11
Other Direct Costs	2	2	3	1	1	9
Indirect Costs	9	9	10	4	1	33
TOTAL	54	53	59	25	4	195

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.20	0.20	0.20	0.20	0.00	0.80	0.00
Field Based Scientist	0.15	0.15	0.15	0.15	0.10	0.70	0.00
Other	0.40	0.40	0.40	0.20	0.05	1.45	0.00
TOTAL	0.75	0.75	0.75	0.55	0.15	2.95	0.00

Program: Semiarid Tropics

Research Topic:

Title: Characterization of Soil-Plant-Atmosphere Systems in Semiarid Environments.

Goal: To describe and model components of the soil-plant-atmosphere system in semiarid climates to determine options for modifying the environment to increase agricultural and forestry production.

Project 13:

Title: Water and Energy Balance of Bare and Cropped Soils in Semiarid Environments.

Objectives:

131. Calculate soil temperatures as a function of time and depth with a model based upon soil thermal properties and air temperature.

132. Mechanistically calculate and describe the water and energy balance of a bare soil with a simulation model using as input soil physical properties and daily weather variables.

133. Predict water use by crops with a partial canopy using a dynamic and mechanistic model of root water uptake.

134. Assess water balance in a Sahelian forest.

Project Leaders: Robert Chase and Robert Lascano
Texas A&M University and Texas Agricultural Experiment Station.

Collaborating Scientists: M. Gandah, M. Suvakumar, E. Boudouresque

Reasons for Invescigation:

Objective 131. Soil temperatures often reach 50 C at 5 cm at the ICRISAT Sahelian Center (ISC) during crop establishment. This creates problems in millet establishment and early crop growth. Due to the interest in the effects of these high soil temperatures at the ISC, temperature profiles have been routinely collected at 0, 2, 5, 10, 25, 50, 100, and 150 cm depths, and periodically at 2.0 and 3.0 m depths over a two year period in a Labucheri soil of the ISC experiment station. The purpose of this experiment is to simply relate soil temperatures, through an appropriate model, to the air temperature of the area.

Objective 132. The characterization of the water balance of bare soils is necessary to quantify the processes involved for water management of the area under investigation. These include water loss due to evaporation and drainage and water gains due to rainfall and capillary rise integrated over the soil profile. Of particular importance is the amount of water lost due to evaporation, and the amount of plant available water stored in the soil profile. The realization of these measurements has to be done in the context that the processes involved are dynamic. The quantification of each component of the water balance equation is not practical, if not impossible. One solution to the problem is to use a physical model that mechanistically describes the system.

A mechanistic model provides the means to evaluate the water balance of a soil over time with minimum information, and more importantly it provides information about the status of the soil water near the soil surface, which normally is difficult to measure. This in turn can be used to manage agronomic practices of importance for the region in question, such as conditions for seed germination, water runoff, etc. However, the applicability of a model to a field situation depends upon the accuracy of the model itself. This means that the model first has to be verified and tested under the conditions in which it is intended to be used. Furthermore, the model must also be able to describe the inherent variability associated with the soil properties of the area.

Objective 133. Crops in semiarid environments are often produced without the benefit of irrigation and, under these circumstances, yield depends upon the stored soil water and rain. The rate of crop water use cannot be described by a simple formula. It is necessary to have a water balance for the crop as a function of time, weather, growth of the crop and properties of the soil.

The simulation can be simplified considerably for conditions of high Leaf Area Index (LAI). However, for a crop with an incomplete cover (low LAI), planted in rows, the radiation-geometry of the crop is complex and difficult to test with field experiments. The importance of handling the radiation geometry of the crop canopy is to calculate the amount of radiation intercepted by the canopy and the soil surface. These quantities are crucial for the calculation of soil evaporation and plant transpiration. In turn these quantities are required for the calculation of the so- called water use efficiency (WUE). The topic of WUE has generated considerable interest in the last couple of years and is the subject of several controversial articles.

Objective 134. By comparing aerial photographs from 1950 and 1979, we have estimated that the area covered by trees in the forests near Niamey, Niger has decreased dramatically during this 29 year period. Because forest lands represent sources of animal fodder, fire-wood, gum, medicines and many other domestic and commercial byproducts, the loss of this resource has direct impact on the lives of rural inhabitants as

well as on the soil and environmental factors of the area. The crusted, barren soils left as vegetation receeds causes severe water runoff from rainstorm events, decreasing soil water recharge and increasing soil erosion downslope. Soil temperatures increase greatly, influencing the environment of the entire forest. In order to reverse this form of desertification, we must understand how the system functions by studying energy and water balances of areas within and between vegetated and barren forest soils.

Little is known about the mechanisms that cause "Tiger-bush" and "Leopard-bush" vegetative structures nor the reason they are decreasing in size. It is generally believed that this is in response to decreasing rainfall, overgrazing and wood harvesting. There may, however, be other factors including the interaction between soil water-holding capacity and the energy and water relationships within the forest ecosystem that contribute to their formation. Knowledge of these interactions would support efforts to revegetate degraded forest areas.

Relevance to Other Programs:

The stated goal of TropSoils is to develop and adopt improved soil management technology which is agronomically, economically and ecologically sound for developing countries in the tropics. To determine what parts of the system have the best opportunity for manipulation and to best transfer technology, descriptions and models of the system are needed.

This project will be conducted in collaboration with the staff of TDL, INRAN, ICRISAT, The Forest Land Use Project, and the University of Niamey.

Generalized Procedures:

Objective 131. Soil temperature can be calculated as a function of depth and time of the year, provided yearly and daily fluctuations of air temperature of the region are taken into consideration as described by Van Wijk and De Vries, (1966). The calculation proposed by these authors uses a product of a sine and an exponential function, as a solution of the equation of continuity in a homogeneous soil, subjected to a periodic energy input at its surface.

A simple FORTRAN algorithm has been written that numerically solves the above equations (John Sadler, personal communication). In view of the fact that soil temperature data are routinely collected at the ISC, it is proposed that such data be analyzed in conjunction with a model such as the one proposed by Van Wijk and De Vries (1966). Other available models and several solutions will be compared as to their applicability to Sahelian soils. A model that adequately estimates soil temperature from air temperature can then be used to predict soil temperatures at the ISC and other similar locations in the Sahel.

The model proposed by Van Wijk and De Vries (1966) will initially be used and requires the following inputs:

A. soil thermal properties such as thermal conductivity and heat capacity of the soil;

B. air temperature - annual temperature at screen height, annual amplitude of the variation in daily average temperature, the daily amplitude of the variation in temperature; and

C. time in days from January 1 to the yearly maximum of the average temperature and time in hours from midnight to the daily maximum of the temperature.

This will be a cooperative effort between the ISC and the TAES, Lubbock. The Lubbock program will set up the programs and calculate the thermal properties of the soils. After the programs are coded they will be sent to Niger to be used on the Zenith computer.

Objective 132. A model that fits the requirements of this objective is CONSERVB, a numerical model designed to compute water content and temperature profiles under a bare surface soil. The model calculates water and temperature profiles over time, using the soil's hydraulic characteristics and standard meteorological data as input. The model has been experimentally tested, and is suitable for a field situation.

Parameters to be measured at the ISC include (1) Meteorological, daily global radiation, wind run, temperature (maximum and minimum), humidity (maximum and minimum), and rainfall; (2) soil water (neutron attenuation and gravimetric); (3) soil temperature (surface and profile); (4) albedo, and; (5) saturated conductivity of the soil surface.

Determinations to be made at TAES, Lubbock, include soil moisture retention curves, soil thermal characteristics, and unsaturated hydraulic conductivity.

All data will be analyzed at Lubbock using the CONSERVB model, and measured and calculated profiles of water and temperature will be compared to evaluate the water balance of the soil over the experimental period.

Objective 133. As a first step to formulate a mechanistic model for water use of plants with incomplete cover, the work of others will be reviewed. From this review a theoretical model of cotton will be coded that could be used to calculate the water use of crop with a low LAI. The model will be tested and verified in the field with appropriate experiments. Weather variables to be monitored include air and dewpoint temperature, solar radiation, net radiation, and windspeed. Soil water content measurements will be used to estimate evapotranspira-

tion. An attempt will be made to independently measure soil evaporation aid plant transpiration a a function of time. This is a long-term project, because it involves the verification of several algorithms within the model. We are starting from a simple case with the idea of building or adding different components as experimental verification is obtained.

Objective 134. It will be necessary to evaluate relative infiltration rates of various vegetated and non-vegetated zones in the Guesselbodi Forest using a rainfall simulator and complete energy and water balances for these zones. Air, surface and subsurface soil temperatures will be measured using an infrared radiometer, thermocouples, and a datalogger. Soil moisture profiles will be determined by gravimetric surface sampling (to 30 cm) and by using neutron probe readings to 3 m depth. Monitoring these factors over a three year period along with climatological data (rainfall, air temperature, humidity, solar radiation, and wind run, using the CR7 weather station) will permit an accurate description of how the forest is changing and, possibly, why. This may also permit a better understanding of how and why regeneration strategies such as those currently used at the Guesselbodi impact the environment.

In sandy agricultural fields, the water uptake of the four dominant species of native bush and of one perennial grass will be determined by measurement of soil water content in the profile over time, particularly, following rainstorms. This will be done by soil sampling and neutron attenuation in a grid around each plant.

Experiments	Location	Duration
Soil temperature regimes and modification	Niger/TAES	1983-85
Water and energy balance of a Nigerien agricultural Soil.	Niger/TAES	1983-85
Water use by cotton: measurement and simulation.	TAES	1984-86
The water and energy balance within a "Tigerbush" forest and its relationship with adjacent barren soil.	Niger	1986-89
The infiltration rates of crusted, naturally vegetated and modified forest soils in the Guesselbodi forest.	Niger	1985
Relative water utilization of scrub vegetation of the Sahel and their evaluation as dry-land windbreak material.	Niger	1987

Water and Energy Balance of Bare and
Cropped Soils in Semi Arid Environments
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	32	34	23	20	13	122
Fringe Benefits	8	8	6	5	3	30
Supplies	5	5	2	1	1	14
Equipment	9	9	4	2	1	25
Travel	13	14	7	6	3	43
Allowances	4	5	4	3	1	17
Other Direct Costs	2	2	2	2	1	9
Indirect Costs	15	15	10	8	5	53
TOTAL	88	92	58	47	28	313

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.60	0.60	0.60	0.55	0.70	3.05	0.00
Field Based Scientist	0.20	0.20	0.15	0.15	0.10	0.80	0.00
Other	0.70	0.70	0.70	0.70	0.60	3.40	0.00
TOTAL	1.50	1.50	1.45	1.40	1.40	7.25	0.00

Program: Semiarid Tropics

Research Topic 1:

Title: Characterization of Soil-Plant-Atmosphere Systems in Semiarid Environments.

Goal: To describe and model physical-chemical-mineralogical-biological components of the soil plant atmosphere system in the semiarid environments. Such baseline data will determine the best strategies and options for modifying the environment to increase agricultural and forestry production.

Project 14:

Title: Classification, Characterization and Distribution of Soils in Semiarid Environments.

Objectives:

141. Group soils into natural and technical classification systems relevant to land-use management by describing and mapping the major soil resources used for TropSoils research.

142. Establish soil/geomorphological/hydrological relationships of principal agroecological subzones of the semiarid tropics.

143. Establish the quantity and physical-chemical-mineralogical composition of dust inputs as a nutrient renewal vector on soils in the Sahel.

144. Elucidate and model surface soil sealing and crust formation processes under semiarid environments.

Project Leaders: Frank Calhoun and Larry Wilding
Texas A&M University and Texas Agricultural Experiment Station.

Collaborating Scientists: M. Ouattara, G. Goube, A. Garba, L. Fussell, A. Karimou, M. Simpara, P. Louis, F. Marcelin, J. Moukori

Reasons for Investigation:

Objective 141. Soil management research and technology generated by TropSoils can play an important role during the coming years in reversing crop yield declines in large areas of the semiarid tropics. Potential success rests, to a great degree, on the transferability of this technology from the principal and secondary research sites. A project which includes comprehensive pedological input will be a major step forward in neutralizing some of the site specific constraints to technology transfer. Information on the range of TropSoils studies will facilitate predictions of crop response under different management practices. A thorough understanding of the edaphic basis upon which soil management recommendations are developed will better enable research scientists, extension agents and other professional agriculturalists to evaluate successes and failures in the agrotechnology transfer process.

Travels in Niger, Upper Volta, Cameroon, Mali, Sudan and the soil survey geomorphological work in selected areas of Niger verify the diverse spectra of climate, landforms, hydrology, erosion and land-use in different agroecological regions of the semiarid tropics. Pedological inputs are fundamental for the design, and to conduct technology transfer of the soil management research to different regions of the Sahel. Too often soil management/fertility research emphasizes primarily the upper 10 to 30 cm of the soil profile with little or no attention given to lower subsoil conditions. Pedologists commonly focus on the whole soil in a landscape setting. In landscapes, the impact of management on one segment affects a lower-lying segment i.e., soil water, nutrients, and erosion. Therefore, soil management research must be placed in a landscape context and interpreted for the soil system as a whole; pedological research will help results from plot-loci research to the surrounding landscape body.

Soil Taxonomy provides an excellent vehicle to catalogue similarities and differences among soils and to network sites into patterns of soil management-fertility responses. The FCC System based on Soil Taxonomy provides an initial effort to obtain soil fertility and management interpretations specific to given sites. Cataloguing the soils into a classification scheme permits more accurate extrapolation of fertility responses from one given site (soil) condition to another. Soil Taxonomy provides an acceptable basis for this effort, because the system is currently being adapted on a world scale.

Small-scale spatial variability in soils of current target areas in Niger, Mali and Cameroon are pronounced. Commonly micro-topographic highs of 0.3 - 1 m are more productive than microlows and yield the most positive management responses. The precise causual factors are still elusive but likely represent some combination of physical, chemical, and biological elements. The latter needs careful evaluation and are not currently receiving due attention in spatial variability studies. Microbial and biochemical tests of organic components focused on phytotoxines may be most productive.

Soil surveys and land-use information for other regional research centers within the Sahel are often small scale, broad in context, relatively old, and not readily translated into Soil Taxonomy equivalents. Because soil classification serves as a vehicle for agrotechnology transfer, project leaders will visit other research centers in the semiarid tropics to classify their soils into Soil Taxonomy equivalents and correlate them with principal and secondary sites of TropSoils projects.

Objective 142. The purpose of this work is to establish baseline soils data so the hydrological linkage between uplands as water-recharging areas and lowlands as water-receiving areas can be established. In Niger, this is critical to evaluate the beneficial aspects of soil-water conservation practices in plateau and valley wall segments of the uplands. Such work should significantly increase our knowledge of the impact of stratigraphy, geomorphology, and soils on the hydrological system, agroforestry, soil erosion and desertification. It should also permit us to evaluate the seasonal water-table levels in Dallole as potential sources for small-scale, subsistence supplemental irrigation and/or sub-irrigation for adapted crop and tree species. The current study in Dallol Besso permits evaluation of this soil resource for intercropping of millet and trees for wind erosion control, water conservation and enhanced crop productivity.

To better understand water movement in a landscape setting and its importance to soil management, both saturated and unsaturated flow through these systems must be established. Perhaps most of the flow in both sandy Alfisols in Niger and Vertisols of the Cameroon is by unsaturated flow, but during periods of high rainfall intensity, short duration storm events, infiltration may be limited by the saturated hydraulic conductivity of subsoil or restrictive layers (petroferric or laterite contact). It is important that these parameters be measured in situ under field conditions by either natural lysimeters or by tests on large natural blocks. The target areas chosen will permit research on extremes in soil texture and soil cracking patterns; very limited knowledge is currently available concerning the influence, extent and pattern of cracking in Vertisols on water movement, erosivity of water supplying capacity.

In summary, this work will permit us to determine the representivity of soils at the ICRISAT Sahelian Center relative to surrounding millet-cowpea production centers of southern Niger and other regional areas of the semiarid tropics where similar research has been conducted. This type of work permits the best broad-scale technology transfer to generalized cartographic maps available in many areas of Niger and the semiarid tropics.

Objective 143. Eolian dust inputs from "harmattan" winds from the northern and eastern regions during the dry season and high intensity convectional storms during the rainy season are well established.

However, the quantity, mineralogical composition, particle-size distribution, seasonality, and potential contributions of mineral reserves is still unknown. Evidence from soil characterization research, in support of the Soil Survey of the ICRISAT Sahelian Center and Landeck's M.S. thesis (1984) from the Center, suggest greater abundance of fine-clay size quartz and silt-size feldspar minerals than would be expected from the acid, highly weathered iron oxide-kaolinite-quartz mineral systems observed. It has been postulated that eolian dusts from the Sahara Desert serve as a renewal vector for nutrients in these soils. Thus, a system of dust traps to verify or negate this hypothesis will be established in Niger at current research sites.

Objective 144. Sealing of surface layers and thin superficial crusts, that form in coarse and moderately course-textured soils, are deterrents to water infiltration and recharge in many soils of the semiarid tropics. Their presence enhances surface runoff, erosion and desertification. This condition is often enhanced when subsoil materials are exposed to dessication. It is not clear what physical-chemical bonding mechanisms are operative in contribution to crust formation, its stability or hardness. For example, how do elevated surface temperatures of 50-60 C, mineralogical composition and particle-size influence crust formation and its stability? Which of these parameters are more functional and which can be modified by management practices? Occurrence of crusting conditions and their detrimental effect appear to be most pronounced on thin soils of coarse or moderately-course texture occupying plateaus or valley segments where erosion has been pronouned. In both situations it results in enhanced desertification and decreased biomass production. Similar conditions occur in temperate regions and are particularly common to selected soils of Texas and the semiarid Southwest. Consequently, information gained in the TropSoils project may well have applicability to other regions of the world with crusting problems. Comparative studies with crusting soils of Texas with Niger conditions will permit evaluation and verification of generalized or specific mechanisms.

Relevance to Other Programs:

This project will provide detailed soils information in areas of the semiarid tropics where such information is not available. The type of information generated will benefit a broad spectrum of agricultural researchers by providing them with a reference point they can use for comparison. The pedological approaches used in this project will provide examples of U.S. methodologies used for inventory and characterization of soil resources. Within TropSoils, data on pedons and landscape relationships in the semiarid tropics can be shared with the humid-tropics and the acid savanna programs to facilitate a better understanding of soil management problems of mutual concern. These include nitrogen movement, soil erosion, tillage, phosphorus management and soil variability. The project leaders will maintain close ties with the Soil Management Support Services Project (SNSS) and the

International Benchmark Sites Network for Agrotechnology Transfer Project (IBSNAT). Both of these projects are supported also by AID/Science and Technology. SMSS and IBSNAT are heavily involved in pedological research and crop modeling. The TropSoils data can be combined with these and data of other projects into a much larger data bank network for soil characterization and classification in the tropics. Such work will also contribute to in-country collaborators (INRAN of Niger and ONAREF of Cameroon), FAO, IRAT, ORSTOM, IFDC, INTSORMIL, CARE and other agencies with allied interests in technology transfer from a soil resource data base.

Generalized Procedures:

Objective 141. In most cases soil survey and characterization research will be initiated upon invitation from leaders of other projects in the semiarid tropics program. When soil surveys are to be conducted or characterized in the semiarid tropics the - approach will be similar to that used for the ICRISAT Sahelian Center and compatible with order I or order 2 soil surveys by The National Cooperative Soil Survey Program in the U.S. It will consist of: 1) field mapping the spatial distribution, quality and extent of soils on an appropriate scale aerial photo base; 2) laboratory characterization of the physical, chemical, mineralogical and biochemical properties of representative profiles (pedons) and satellite samples for central tendency and variance estimates pertinent to classification and interpretation assessments; and 3) preparation of soil survey documents reporting the soil map, soil descriptions, laboratory data, and multiple-use interpretations of the soils identified in the survey area. When appropriate, the mapping will include the entire area of study. In other situations, only representative transects sufficient to provide verification of the spatial distribution and relationships of the soils present will be conducted. Graduate students and technical support staff under the supervision of the project leaders will serve as personnel inputs into this objective. Consultants such as Drs. Yaelon, Daniels and Bouma will be utilized as necessary.

Soil profile descriptions, sample collection and laboratory determinations will be made following U.S. Soil Survey standards. Some routine chemical and physical determinations will be made in host country laboratories. Most analyses will be conducted at the TAES Soil Characterization Laboratory. The TAES Laboratory will run selected standard samples as a quality control for checking routine analyses conducted in host-country laboratories. They will also collaborate with host country laboratories on equipment and procedures for accuracy and efficiency.

International and regional research centers in the semiarid tropics will be visited and major soils classified according to Soil Taxonomy for comparison with soils under investigation in TropSoils projects.

Research will be disseminated at national and international conferences and published in appropriated journals, bulletins and TropSoils outlets.

Objective 142. This research project was instituted as follow-up of a reconnaissance soil/geomorphology study in plateaus, sandy valley systems, sand plains and dallols of the millet/cowpea production areas in southern Niger. In this reconnaissance survey, representative geomorphic landforms were observed in several locations, soil conditions were described as associated with these landforms (36 observations), and the geomorphology, stratigraphy, hydrology, and wind and water erosion attributes were compared to the ICRISAT Sahelian Center. It was concluded on the basis of this study that priority for future work in Niger should be given to the dallols because of their potential for intensive agricultural use from crop production and shallow groundwater supplies. It is on this basis that the following approach to this project was designed.

(a) A detailed soil geomorphology field study was conducted from August to December, 1984, along E-W transects oriented perpendicular to the N-S trending Dallol Bosso. The northern transect was near Filingue and the southern transect proximal to Birnin Gaura. Each transect extended from the tiger-bush plateau on the east across the dallol to the plateau uplands on the west.

(b) Along each transect a soil mapping legend was established that reflected major geomorphic landforms, stratigraphic units, and corresponding soils. A 2-4 km wide strip was mapped along each transect.

(c) Major soils, geomorphic landforms, and stratigraphic units are being sampled to serve as baseline data for soil classification, hydrology, soil management and erosion interpretations. This work will be referenced to the soil survey of the ICRISAT Sahelian Center so applicability of research transfer can be evaluated.

(d) Access tubes will be installed at selected sites previously characterized in a toposequence from an upland plateau, to downslope sand valley wall segments, to the Dallol Bosso so soil moisture profiles and free standing watertables can be evaluated at respective sites. This work will be in collaboration with INRAN and TropSoils personnel.

At selected sites in Niger, Cameroon, and Texas the above work will be complemented by studies on the saturated and unsaturated in situ hydraulic conductivity of soils reflecting representative surface, subsoil, restrictive layers (laterite) and cracking conditions. In situ soil lysimeters or carved blocks will be used for this work with and without synthesized crusts to reflect flow under different soil moisture tensions.

Personnel involved in these studies will be primarily graduate students under close supervision of the project leaders. Consultants such as Dr. Ray Daniels, an internationally renowned soil geomorphologist, and Dr. Johan Bouma, an internationally renowned soil physicist-pedologist from the Soil Survey Institute, Wageningen, The Netherlands, will be employed when appropriate. Dr. Daniels of North Carolina State University is currently involved as a consultant on the Dallol Bosso study. Dr. Bouma has expertise in situ techniques to determine saturated and unsaturated flow rates in soils. This information is critical to modeling hydrological linkage between uplands with Dallols. He has extensive experience in Vertisols and course-textured Ustalfs common to the TropSoils target areas. Comparison of these hydrological soil parameters in Texas with those of target areas in West Africa will be mutually beneficial.

Objective 143. Dust traps fabricated similarly to those reported by Rabenhorst et al., and installed at two heights (2.5 m and 7.5 m) will be located at two TropSoils research sites (Chickal and the ICRISAT Center, Sonderi). Eolian dusts will be collected over integrated sample periods corresponding to seasonal rainfall and wind direction fluctuations. Elevations of the dust traps are to reflect primarily long-distance transport rather than local input sources. Locations are chosen to reflect gradients in mean annual precipitation, vegetative cover and land-use. The northern site at Chickal will be closer to the Sahara Desert which is believed to be the principal dust source.

Dusts collected will be weighed and characterized by particle-size distribution, mineralogy, and elemental content. Calculations of annual and seasonal inputs to soils of respective areas will be compared to comparable soil properties at these sites and evaluated in terms of probable Ca and K nutrient inputs.

Personnel involved with this objective in addition to project leaders, in country senior scientists, Mr. Drees (TAES), and part-time laboratory analysts, will be Dr. Dan Yaalon, The Hebrew University of Jerusalem. He is a world expert on dust inputs into the Sahel region of Africa and on the pedogenesis and management of soils in arid and semiarid regions of the world. As a consultant, his services will be used for the dust impact aspect of the program and for the enrichment of graduate students training.

Objective 144. Selected soil samples will be investigated for crusting from regions of West Africa with those soils of similar soil characteristics in Texas. Investigations will focus on mineral composition, particle size, surface characteristics, CED and Al/Fe substitution in Fe-oxides using wet chemistry, X-ray, TEM, and SEM analyses.

The bonding mechanisms between existing mineral phases namely Fe-oxides, quartz and kaolinite in these soils will be identified using IR, Nosabauer spectroscopy and selective chemical dissolutions. The exact

Al- and Fe-oxide phases will be evaluated to determine the effect of temperature on such bondings. The role of Fe-oxides on induration of selected B-horizons from both West Africa and Texas will be compared when exposed to respective surface environments. The strength of materials to temperature will be correlated with the amount, type and crystallinity of Fe-oxides. A micro-penetrometer will be used to determine the strength of the materials.

The effect of Fe-amendments will be evaluated on the strength of crusts from Texas and West Africa. The effect of Fe on aggregate stability and dispersion will be demonstrated.

Principal Sites for Research:

Primarily the Sahel zone of Niger and the Sudan-Sahel regions of Mali and Cameroon are targeted for research on Alfisols, Utisols and Vertisols. These soil resources are utilized primarily for subsidence rainfed millet, sorghum, cowpea, peanuts and pastorial agriculture. Agroforestry is also important in many areas as a source of fuel, construction material, and shade. The major occurrence of Vertisols in the world, of which the Cameroon site is representative, is in the semiarid tropics. Niger and Mali are representative of major sandy Alfisols and Ultisols which also occur extensively in the semiarid tropics.

Experiments	Location	Duration
Survey and characterization of TropSoils research sites.	Niger, Mali	1985-89
Biochemical characterization of soils associated with topographic and vegetative spatial variability.	Niger, Mali	1986-89
Soil geomorphological relationships of the Dallol Bosso.	Niger	1985-86
Properties and interpretations of Vertisols for agricultural and forest production.	Cameroon	1985-86
Groundwater hydrology of plateau-valley sand and Dallol Bosso toposequence.	Niger	1985-89
Soil classification and soil loss from steeplands.	Haiti	1984-85
Impact of dust on properties of soils.	Niger	1985-89

Role of amorphous and crystalline iron in the formation of surface crust and ironstones.	Niger, Mali Texas	1985-89

Classification, Characaterization and Distribution
of Soils in Semi Arid Environments
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	50	34	36	28	26	174
Fringe Benefits	12	14	8	6	6	46
Supplies	7	5	6	5	4	27
Equipment	8	6	6	3	3	26
Travel	7	11	11	5	4	38
Allowances	2	3	3	2	2	12
Other Direct Costs	2	2	2	1	1	8
Indirect Costs	17	15	14	10	9	65
TOTAL	105	90	86	60	55	396

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.60	0.50	0.50	0.40	0.40	0.00	2.40
Field Based Scientist	0.15	0.15	0.15	0.15	0.15	0.75	0.00
Graduate Student	2.00	1.00	1.00	1.00	1.00	6.00	0.00
Other	2.60	1.80	1.80	1.60	1.50	7.30	2.00
TOTAL	5.35	3.45	3.45	3.15	3.05	14.05	4.40

Program: Semiarid Tropics

Research Topic 2:

Title: Modification of the Soil-Plant-Atmosphere Systems in Semiarid Environments.

Goal: To modify selected components of the soil-plant-atmosphere system in semiarid environments to increase agricultural and forestry production.

Project 21:

Title: Soil Surface and Profile Modifications to Increase Agricultural and Forestry Production in Semiarid Environments.

Objectives:

211. To increase crop yield by improving the status of soil water using selected tillage treatments.

212. Enhance crop yield by decreasing runoff with land forming practices.

213. Rejuvenate crusted forest soils by selected mulch and tillage treatments.

214. Decrease crop growth variability and yield loss based upon the findings of the spatial variability studies.

Project Leaders: Robert Chase, Naraine Persaud and Charles W. Wendt Texas A&M University and Texas Agricultural Experiment Station.

Collaborating Scientists: M. Gandah, G. Goube, L. Fussell, D. Kleij, E. Boudouresque, M. Simpara, J. Heermans

Reasons for Investigation.

Objective 211. Both the Sahel and West Texas have common problems in management of soils during and following intense thunderstorms. In sandy soils, the fine soil particles are leached from the surface following a rain. The coarse soil particles are easily moved by the winds following the rain. This soil movement can cause sand blasting and/or burial of young crops. The sandfighter is a tool used in West Texas to increase surface roughness immediately following rainfall and decrease sand blasting and burial.

In 1982 a tractor drawn sandfighter was shipped from West Texas to the ISC in the Sahel. It was readily accepted by the ICRISAT scientists to stabilize the soils at the ISC research fields during planting. It was also observed that the weeds were controlled and rainfall redistribution was less in sandfought fields than controls. If the sandfighter can be shown to increase seedling survival, as well as having an effect on weed control and rainfall distribution, the National Extension Service would develop its use for the farmers.

However, for the Sahelian farmers to benefit from the research the tool must be adopted to animal traction. Such a modification was made in 1982. From the positive effects seen at the ISC, USAID personnel associated with Niger's National Extension Service have expressed interest in testing a modified sandfighter on Niger's extension farms. The last version of the sandfighter makes three holes at the proper depth and spacing for seed and fertilizer placement while increasing surface roughness between rows to protect emerging seedlings. The tines for planting and fertilization can be removed for inter-row sandfighting after crop emergence.

By definition, water is the primary constraint in rainfed agricultural production systems. Conservation efforts in such areas should be aimed at increasing infiltration and decreasing evaporation. Such problems also exist in both the Sahel and West Texas in that crusting and runoff are major problems. The common methods of increasing infiltration in West Texas is through tillage. Techniques such as plowing immediately after rainfall to prevent crust formations and subsoiling and furrow diking to prevent runoff are commonly practiced. Such practices need to be accelerated in the Sahel.

Subsoils can also cause problems in infiltration in both areas in that they may become dense or cemented upon drying. Tillage is the common method of alleviating this problem in West Texas. The millet soils in the Sahel are usually dune sands overlying an iron enriched horizon which may become cemented during the dry season. Because of the unreliable rainfall, millet is intercropped with millet or cowpeas for insurance. Tillage practices developed in the U.S. need to be evaluated under the various cropping systems.

Another practice common to West Texas which decreases wind erosion and enhances infiltration, and decreases runoff is stubble mulching. In this practice cereal crop residues (sorghum, wheat, and corn) are kept on the soil surface through minimum or no till operations. Similar practices such as leaving millet stalks on the surface have potential for the Sahel. It is realized that such investigations have limitations because of the demand of millet residue for other uses. However, due to the success of similar practices in the United States, stubble mulching with minimum or no tillage deserves investigation.

Objective 212. The tillage practices discussed under objective 211 are normally performed by the farmer every year. Land farming practices

are generally permanent treatments or structures which are installed and maintained over a period of years rather than every year. Such structures include level or contoured terraces for diverting or holding water and water harvest areas. Such permanent structures may have a place in the Sahel. At the beginning of the rainy season the soils are dry. Seeds are often sown in dry soil. If rainfall less than the 15-20 mm required for germination is received, the stands are spotty and replanting is necessary. If a series of sloping ridges impervious to water could be created to shed water into adjacent untreated strips of soil, the problem might be alleviated and the stands and yields stabilized.

In many parts of Niger, the landscape is characterized by elevated hardened laterite surfaces adjacent to lower areas of callurium and allurium which are cultivated in sorghum and millet. During rains, the water rushes from the impervious laterite areas into the valleys below. If the water could be spread or impounded and allowed to infiltrate in the valleys the potential exists to increase sorghum and millet production by overcoming the erratic rainfall.

Objective 213. Firewood is the main source of energy for cooking and for heating in the Sahel. In 1973, in Niamey, for example, the 70,000 inhabitants consumed an estimated 20,000 tons of wood. Niamey's population now exceeds 200,000 and firewood is becoming difficult to obtain. Since it is shipped greater distances, it is increasingly expensive.

Harvesting of the forests near Niamey has been restricted to dead wood as a conservation method against the rapid loss of nearby forested areas. This "desertification" is due to over harvesting, over grazing and/or climatic factors. Tiger bush and Leopard bush stands, named for the shape of the clumped tree/grass association, have diminished 35-50% over the last 30 years (Eric Boudouresque, University of Niamey, personal communication). Between the diminishing stripes and spots of forested area are expanding areas of crusted and barren soil with low infiltration rates, high runoff, and increasing soil erosion.

A cooperative research project was begun in April, 1983, between the AID/Niger mission-funded Forest Land Use Project (FLUP), INRAN Soils Laboratory and TropSoils to study methods of halting and reversing this trend in the Guesselbodi Forest. The treatments compared were (1) control; (2) hand tillage to 10 cm; (3) mulching with small branches; and (4) a combination of tillage and mulching. Eight weeks into the rainy season, grasses and legumes were established on all treated plots. Soil moisture in treated plots were 2-4 fold higher than in control plots which remained barren throughout the first season of the experiment. Although no seeding was done, tree species were found in 60% of the mulched plots (Eric Boudouresque, personal communication).

By December 1983, the tilled plots were again partly crusted. The mulched surfaces, on the other hand, had considerable termite activity

and residual surface deposits of sand trapped by the mulch. The mulch treatment; thus, affords the potential of becoming an economical method of rejuvenating forests in the Sahel. Studies need to be continued for a period of time to determine the long term effects on the vegetation and on the soil physical and chemical characteristics.

Although tree branches, which comprise one half of the weight of trees harvested in the Sahel (J. Heermans, personal communication) are a waste product in commercial firewood harvesting. They are still in limited supply. Optimal methods for the use of this resource must be defined if they continue to appear useful in the rejuvenation of Sahelian forests. Proximity of mulched plots to a vegetated area and total area mulched appear to have important effects on plant production in these treated plots. These factors must be defined before an effective strategy for forest rejuvenation can be established.

Objective 214. At ICRISAT, TropSoils' research has identified three soil properties, i.e. pH, Al saturation and surface crust, which are highly correlated with poor crop growth, causing high variability in research fields. Methods must be found to test these small and scattered pockets of soil to decrease variability in research plots and increase farmers' yield.

Revelance to Other Programs

The stated goal of TropSoils is to develop and adopt improved soil management technology which is agronomically, economically and ecologically sound for developing countries in the tropics. Improved utilization of rainfall and soil water through soil surface and profile manipulations is common in the semiarid areas of the world. Care will be taken to use local resources in developing the tillage and mulching techniques so they will be economically sound.

All of the objectives in this program will be coordinated with other organizations. Objectives 211 - 213 - Collaborators include ICRISAT, INRAN, DTL (Dutch Tillage Laboratory), and University of Niamey. Objective 214 - Collaborators include FLUP (Forest Land Use Project), ICRISAT, INRAN, and University of Niamey. Objective 211 - Collaborators include IER (Mali) and INTSORMIL.

Generalized Procedures:

Objective 211. The sandfighter will be further evaluated in Niger to study the effect of a sandfighter on plant establishment. Millet will be planted in even rows following the first significant rainfall. The sandfighter will be used between rows at planting and following each significant precipitation. Measurements will include plant population, plant loss due to sand burial, sandblast damage, and yield.

To evaluate the effect of a sandfighter on weed control an area will be seeded with weeds during the dry season. The area will be irri-

gated to assure weed emergence. Weed populations will be measured before and after treatment with a sandfighter.

The effect that sandfighting has on infiltration will be studied at the ISC. During the dry season, an area will be irrigated. The infiltration rate will be determined with a rainfall simulator on replicated areas with and without the sandfought treatment. Short- and long-term effects of the sandfighter on infiltration will be determined.

Several prototype animal-draww sandfighters have been built and tested. The latest model is a 3-row sandfighter with removable tines that make 4 rows of seed and fertilizer holes at proper intervals while the inter-row area is being sandfought. The tines can be removed for sandfighting following crop emergence. This tool will be assessed as to its function and value in protecting millet seedlings at the ISC and on an extension farm.

Other tillage studies to enhance infiltration will be conducted in both Niger and Mali. In Niger, sites will be established in the 350, 500, and 700 mm rainfall zones. The effect of tillage versus no tillage in combination with several cropping systems, population densities, and levels of fertilization will be evaluated. Measurements to be made include soil moisture status, plant growth and yield.

A tillage study will be initiated at the IER Center, Cinzana, Mali. Treatments will include control, subsoiling, ridging, ridging + subsoiling, tied ridges (furrow dikes), and subsoiling + tied ridges. The area will be planted in sorghum in a randomized block with four replications. Parameters to be measured include pH, soil chemical characteristics, plant population, plant height, dry weight and grain yield.

Objective 212. Water-harvest areas will be established in low, medium, and high rainfall areas in Niger. Plastic will be installed on sloping ridges adjacent to strips of soil to absorb runoff. Millet and sorghum production from these strips will be compared with traditional treatments. Studies of nutrient levels and population density will also be included. Soil moisture dynamics and crop germination, growth, root distribution and yield will be determined. When available biodegradable sealants will replace the plastic.

At other sites in Niger, the potential of using structures for water spreading and control losses of surface water from rainfall to the valleys. Initial studies will involve characterizing the water-shed by describing the profile and physical and hydrological characteristics of the lower collection areas. In the elevated areas similar parameters will be measured as well as the intensity and duration of the rainfall and the runoff. From these data an assessment of the areas for water spreading can be made and design and construction of the structures needed can be undertaken.

Objective 213. The initial treatments of (1) control; (2) tillage; (3) mulching; and (4) mulching plus branches will be continued. The initial 5 X 5 m plots were randomized on 20 sites in areas with and without protection from grazing. The second season, 6 more sites were established in a similar manner to compare differences between seasons.

Both qualitative and quantative measurements of the vegetation were made at the end of each growing season. The species present were recorded and dry matter production harvested and weighed. This will continue in further years.

Periodic soil samples will also be obtained for physical and chemical analyses. Physical analyses will include texture, strength, bulk density, water retention at -0.01 and -1.5 HPa, and soil moisture to compare with data obtained at the onset of the experiment. Infiltration rates on selected plots will be made with a rainfall simulator. Chemical analyses will include pH, organic matter, exchangeable cations and acidity, nitrogen, phosphorus, and potassium.

Additional sites will be developed at the ISC beginning in 1985.

Objective 214. At ICRISAT, a large field with extreme crop growth variability has been mapped. Treatments will be applied to these plots to minimize the variability based on the results obtained in Objective 122.

Experiments:

	Location	Duration
Evaluation of the effectiveness of a sandfighter in crop establishment and weed control.	Niger	1988-89
Evaluation of the effectiveness of a sandfighter in enhancing water distribution and infiltration.	Niger	1986-89
Modification of the sandfighter to meet the needs of the Sahelian farmer.	Niger	1983-86
Comparison of several soil preparation techniques on soil water status and sorghum yield.	Mali	1985-86
Improvement of soil-water storage, crop growth and yield with tillage, cropping systems and optimum plant densities and nutrients.	Niger	1985-87
Increasing cereal production with contour strip rainfall harvesting.	Niger	1985-87

Decreasing runoff losses by water spreading in small watersheds.	Niger	1987-89
Rejuvenation of crusted soils in "Tiger-Bush" areas of Niger.	Niger	1983-89
Determination of the optimum density of mulch in rejuvenation efforts in the Guesselbodi Forest.	Niger	1985-86
Optimum plot size and location relative to clumps of vegetation for forest rejuvenation efforts.	Niger	1986-88
Tie effect of mulch and fertilizers on the survival of planted tree seedlings.	Niger	198S-87
Methods to reduce small scale soil related crop variability and yield loss.	Niger	1985-89

Soil Surface and Profile Modification to Increase
Agricultural and Forestry Production
in Semi Arid Environments
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	40	44	59	65	73	281
Fringe Benefits	10	11	14	16	18	69
Supplies	8	9	12	13	15	57
Equipment	13	12	13	13	14	65
Travel	15	16	19	23	26	99
Allowances	4	4	5	5	7	25
Other Direct Costs	3	3	2	3	4	15
Indirect Costs	19	20	25	28	32	124
TOTAL	112	119	149	166	189	735

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.10	0.10	0.10	0.10	0.10	0.00	0.50
Field Based Scientist	0.60	0.60	0.65	0.70	0.75	3.30	0.00
Graduate Student	1.00	1.00	2.00	2.00	2.00	8.00	0.00
Other	0.60	0.60	0.50	0.60	0.70	2.00	1.00
TOTAL	2.30	2.30	3.25	3.40	3.55	13.30	1.50

Program: Semiarid Tropics

Research Topic 2:

Title: Modification of the Soil-Plant-Atmosphere Systems in Semiarid Environments.

Goal: To modify selected components of the soil-plant-atmosphere system in semiarid environments to increase agricultural and forestry production.

Project 22:

Title: Increasing Crop Yields in the Sahel Through Microclimate Modifications.

Objectives:

221. Maximize efficient use of water through manipulation of cropping patterns and fallow rotations.

222. Decrease soil evaporation from bare soils using windbreaks.

223. Increase millet growth and yield by modifying the crop microclimate with windbreaks.

Project Leaders: Naraine Persaud, Robert Chase and Robert Lascano Texas A&M University and Texas Agricultural Experiment Station.

Collaborating Scientists: G. Goube, A. Garba, M. Sivakumar, S. Dennison, S. Long

Reasons for Investigation:

Objective 221. It is estimated that millet and sorghum require approximately 300 mm of available soil moisture to reach maturity. In years of rainfall deficits, bare fallow may result in moisture storage which can be used during the following cropping season. A period of 7-9 months elapses between the last rain and the beginning of the following season. Additional understanding of soil water storage and fluxes during this period is needed especially as it relates to various crop systems and yields of cereals and grain legumes. A need exists to quantify, in terms of crop growth and yields, the effect of bare fallow and cropping patterns in a given season on soil moisture carryover to the next season.

Objective 222. It has been suggested that the main benefit from windbreaks in arid and semiarid regions is in the reduction of water use

under conditions of sensible heat advection. From a review of the literature Rosenberg et al. (1983) concluded that windbreaks have the following effects: alter microclimate; reduce potential evapotranspiration; reduce actual evapotranspiration; improve internal water relations of the crop, i.e., higher leaf water potential, lower stomatal resistance; provide improved opportunity for photosynthesis; and generally increase crop yield.

They pointed out that the majority of the experiments have been done under a variety of climates under irrigated conditions and that few studies on the performance of shelters in a semiarid environment under dryland conditions have been conducted.

It was of interest to evaluate the effect windbreaks have on crop yield under dryland conditions. Such an experiment was attempted in 1983 at the Texas Agricultural Experiment Station in Lubbock, TX, and will be described in the generalized procedures section.

To fully understand the effect windbreaks have on the water and energy balance of the sheltered area, it is necessary to separate soil evaporation from plant transpiration. To delineate the separate effects of the windbreak and the competition of the crop being used as a windbreak for soil moisture, it is necessary to use a nontranspiring windbreak. Therefore, subsequent studies should be rather simple involving a wooden windbreak around a bare soil. Such studies would be followed by introducing crops into the windbreak and finally by introducing crops as windbreaks with the test crop. Without such a step-by-step approach it will be difficult to determine how the system functions.

Objective 223. The CARE Maggia Valley shelterbelt/windbreak plantings of Neem trees provide an opportunity for studying the role of shelterbelts and windbreaks in Niger for improving crop growth and yield of millet. The value of these plantings is being recognized by the local population. There appears to be an increasing interest on their part to extend these plantings. Their motivation may be due mainly to a perceived increase in comfort and protection for themselves, their dwellings, and animals as a result of being shielded from high winds and dust rather than a perception of the possible effect of the trees in moisture conservation, crop growth, and yields. As pointed out elsewhere in these discussions, this was the case in the Great Plains of the United States and was no doubt the case with the Russian plainsman.

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, effort, and land removed from production.

Due to lack of materials and capital, live windbreaks are the only feasible means for Sahelian farmers to reduce wind damage on their

crops. Dense rows of trees can only be grown in areas with a shallow water table and/or need frequent watering during their early growth period or during dry years. These are luxuries not available to most Sahelian farmers. Tree windbreaks, therefore, can only be developed in a small percentage of areas in the Sahel. On the other hand, native shrub trees, bushes, grasses and even millet plants are seen to grow close enough to each other to form an effective screen against direct wind. In order to provide the majority of Sahelian farmers with the benefits of windbreaks, these species must be evaluated in terms of feasibility and effectiveness.

Relevance to Other Programs:

The stated goal of TropSoils is to adopt improved soil management technology which is agronomically, economically and ecologically sound for developing countries in the tropics. To best develop this technology it is necessary to quantify the components of the water budget (transpiration, evaporation, deep percolation, and runoff). To assure that the windbreak modifications have the best opportunity to be economically sound, local plant species are being used.

This project will generate a large amount of experimental data. Interpretation of these results will depend heavily on basic studies outlined under Topic 1 - Characterization Research. Some of these results, for example may be useful in developing and validating models of water and energy balances.

This project will be conducted in collaboration with INRAN, CARE, DTL, ICRISAT, and University of Niamey to obtain the best expertise possible.

Generalized Procedures:

Objective 221. Experimental sites will be established at three locations in Niger, one each in the 350 mm, 500 mm, and 700 mm rainfall zones. The following crop sequences will be evaluated over at least two seasons: fallow-cereal, cereal-cereal, fallow-cereal/legume intercrop, and cereal-cereal/legume intercrop. The cereals will be either millet or sorghum and the legume either cowpea or peanut depending on the sites chosen for this experiment. Treatments will include fertilizer and no fertilizer in a suitable field design. Soil moisture status and fluxes will be monitored throughout the year. Observations will be made on crop growth, yield and nutrient status.

Objective 222. The calculation of the soil evaporation flux from a bare surface requires calculation of the simultaneous flows of water and heat. Such an algorithm was proposed by Van Bavel and Hillel (1976). The computer code and details of the procedure are found in a document by Van Bavel and Lascano (1980). The model is known as CONSERVB, which is an acronym for the conservation of mass and energy for a soil system

with a bare surface. The model has been tested and it was concluded that it is suitable for field work and evaluation (Lascano and Van Bavel, 1983). Details of the model can be found in the above mentioned publications.

Inputs to the model consist of three functions, three parameters and weather variables. The three input functions consist of relationships between (1) volumetric water content and pressure potential; (2) volumetric water content and unsaturated hydraulic conductivity; and (3) surface albedo and surface water content. To develop the three functions, a well-equipped soil physics laboratory and proper calibration of the neutron and gamma attenuation probes is necessary. Initial input parameters are the surface roughness length, the saturated hydraulic conductivity, and porosity of the soil surface. Weather variables as a function of time required are global irradiance, air and dewpoint temperature, and windspeed. The total amount of rain, is also an input. Initial values measured at the start of the simulation are water and temperature profiles. The initial studies will be conducted on bare plots with and without a wooden windbreak.

In 1983 the following experiment was done in Lubbock to evaluate the effect of windbreaks on the yield of two crops. Cotton and peanuts, were used as the test crops. The windbreak was sunflower plants, planted in a rectangular pattern around the crops. Throughout the experimental period the sunflowers competed for the soil water, causing drastic reductions in the yield of cotton and peanuts. Because of this reason it was difficult to evaluate the effect of windbreaks and a simpler approach was adopted.

Objective 223. 1) Wind modification studies. At the Maggia Valley windbreak project, anemometers will be used to measure wind velocities at several heights above the ground and at various distances to the leeward and windward of the planted rows and trees. These measurements will be repeated at several locations within the shelterbelt and in the open, using anemometers with analog signal output. The installation outside the shelterbelt will be fixed. The set of anemometers used inside the shelterbelt will be mounted on an elevator which moves up and down on a mast which can move from location to location. Some index of permeability of the windbreak rows will be derived, by some suitable method obtained from literature or from theoretical analysis. It would be desirable to study the wind flow patterns within the shelterbelt. Methodology for such studies could not be found in the literature reviewed thus far, but it is possible to get some idea of flow patterns using smoke trails or neutrally buoyant soap bubbles.

Analysis of the data from these studies should provide some definite conclusions on wind modification by the windbreak rows, and help to decide on an optimum spacing of rows for future plantings.

2) Soil moisture balance studies. Reduced soil moisture losses as a result of less wind over growing crops and soil is considered to be

the main factor for observed increases in yields of protected crops. Several filled-in, free-draining, non-weighing type lysimeters will be set up within the shelterbelt at various distances from the windbreak row. These lysimeters will be 2 X 2 sq. m. and will be cropped along with the surrounding area in the traditional manner. A similar lysimeter will be installed in a cropped field outside of the shelterbelt. A total of four such lysimeters is envisioned. The moisture content and fluxes, drainage, and runoff from these lysimeters will be monitored using tensiometers, and neutron scattering techniques. In the vicinity of the lysimeters inside and outside of the shelterbelt, measurements will be made of total rainfall by a non-recording type rain gauge, air temperature and humidity using a hydrothermograph, evaporation from black and white Livingston atmometers and an evaporation recorder, total wind, and solar radiation (mechanical pyranograph). These measurements will provide some information on microclimate effects of the shelterbelt, and can be used to estimate potential evaporation. Measurements of soil moisture status and fluxes using tensiometers and gravimetric sampling will be made in the area surrounding these lysimeters. Observations will be taken on crop growth and development, and final grain and dry matter yield.

For the evaluation of dryland shrub windbreaks, a field at the ISC will be cleared in such a manner as to leave 5 m wide rows of native bush between 21 m wide cleared fields 50 m long (N-S direction). Three series of three fields with windbreaks will be separated by clear-cut fields of the same dimensions. Many of the same monitoring and sampling procedures outlined for the Maggia Valley project, above, will be followed in collaboration with ICRISAT's Agroclimatologist.

Experiments:	Location	Duration
Effect of fallow rotation on soil moisture status and cereal yields.	Niger	1985-87
Windbreak study.	TAES	1983-85
Effect of Neem shelterbelt plantations on microclimate, soil moisture balance and growth and yield of intercropped millet.	Niger	1984-86
Evaluation of the effects of a dryland shrub windbreak on microclimate, soil moisture balance and crop growth.	Niger	1987-89

Increasing Crop Yields in the Sahel
Through Micro-Climate Modifications
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	13	16	42	45	53	169
Fringe Benefits	3	4	10	11	13	41
Supplies	3	3	8	10	12	36
Equipment	8	9	9	9	11	46
Travel	15	16	20	22	29	102
Allowances	3	4	6	7	8	28
Other Direct Costs	2	2	3	4	4	15
Indirect Costs	9	11	20	22	26	88
TOTAL	56	65	118	130	156	525

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.20	0.20	0.20	0.25	0.30	1.15	0.00
Field Based Scientist	0.25	0.25	0.30	0.30	0.35	1.45	0.00
Graduate Student	1.00	1.00	2.00	2.00	2.00	6.00	2.00
Other	0.10	0.10	0.10	0.10	0.20	0.60	0.00
TOTAL	1.55	1.55	2.60	2.65	2.85	9.20	2.00

Program: Semiarid Tropics

Research Topic 2:

Title: Modification of the Soil-Plant-Atmosphere Systems in Semiarid Environments.

Goal: To modify selected components of the soil-plant-atmosphere systems in semiarid environments to increase agricultural and forestry production.

Project 23:

Title: Relationship Between Soil Water and Plant Nutrient Utilization in Semiarid Environments.

Objectives:

231. Increase crop utilization of soil water by changing rooting patterns through placement of appropriate rates of applied plant nutrients.

232. Enhance water use efficiency of crops with applied plant nutrients.

233. Improve soil physical and chemical properties through use of fertilizers and soil amendments.

234. Increase available soil water and crop yields under rainfed conditions with a combination of fertilizers and tillage practices.

Project Leaders: Arthur B. Onken, Charles W. Wendt and Robert Chase Texas Agricultural Experiment Station and Texas A&N University.

Collaborating Scientists: I. Mahmane, G. Goube, L. Fussell, M. Sivakumar, A. Batiano, M. Simpara

Reasons for Investigation:

Objective 231. Dr. L. Fussel, of the ICRISAT Sahelian Center, has found that certain varieties of millet work well when intercropped with certain varieties of cowpea, the common Sahelian intercropping system, while other varieties do not. This is undoubtedly due to competition between the roots of the plants for water and/or nutrients. Exactly how this happens and, in fact, general root patterns of these crops within an intercropping system are not well understood. It would be of great benefit to plant breeders and agronomists if these root patterns could be described and plant competition mechanisms better understood.

Wendt and McMichael (personal communication) have shown that, in Texas High Plains soils, root growth and water extraction are much less in zones low in phosphorus supply (12 to 30 inch increments) than in zones of adequate nutrient supply even when the surface of the soil has an adequate supply of phosphorus. Significant amounts of water (1 to 2 acre inches/acre) that could be used by plants are being left in the soil.

Objective 232. Phosphorus has been shown to be sufficient in the Northern grazing lands of the Sahel but deficient in the Southern agricultural soils. In all years, crops respond to applications of nitrogen and phosphorus, even in drought years. Stroosnijder found that nutrient deficiencies resulted in usable water being left in the soil profile by native forage vegetation in the Malian Sahel. He concluded that application of nutrients, particularly if proper N/P ratios can be maintained in plant tissue, could result in five-fold increases in forage growth in the Southern Sahel under natural rainfall conditions.

Nutrient deficiencies are also being observed in dryland production in the Texas High Plains. Low levels of phosphorus are being observed in the subsoil at the TAES Lubbock station. Nitrogen deficiencies are also being observed especially in the sandy soils. Newman showed that efficient use of water increased 8% under dryland conditions at Lubbock with proper fertilizer applications. Thus, to obtain the most efficient use of the limited water in semiarid areas, plant nutrients will have to be in adequate supply. Research as to what fertilizer level is adequate where water is limited needs to be conducted.

In the summary by Tanner and Sinclair (1983) in which soil evaporation was controlled, water requirements of plants did not increase until the dry weight yields of plants had been held to 50% of normal growth due to plant malnutrition. Similar data by Kiesselbach (1916) show the same trend. De Wit (1958) arrived at similar conclusions from other data. The data are very limited in proving this high rate of water loss in nutrient-poor crops. Perhaps this research has not received much emphasis in the temperate zones of the U.S. because few of the agricultural soils here are nutrient deficient to the point that only 50% of potential yield would be obtained without nutrient application.

In West Africa, however, the soils are much more deficient in plant nutrients. This is a particularly bad situation since fertilizers are much more expensive and will be used only if farmers can be assured of a 100 percent increase in yield. Research is therefore needed to determine the minimum nutrition levels required to obtain the maximum water use efficiency of the crops adapted to the Sahel.

Onken and Peterson have identified sorghum breeding lines that are significantly different in phosphorus and nitrogen use efficiencies when grown in phosphorus and nitrogen deficient soils. One of the major differences between the genotypes is their ability to extract nutrients

from the soil, which reflects a difference in root systems. The question has been raised by Sinclair et al. (1984), as to whether differences in water use efficiency exist within species or if nutrients influence water-use efficiency. Since these materials differ in nutrient-use efficiency, there is an excellent possibility they differ in water-use efficiency. Plants that could use water more efficiently would make better use of stored soil water.

Objective 233. The deficiency of phosphorus in most soils of SAT Africa is well documented. Due to the high cost and difficulty in obtaining fertilizers in Africa, economically and quantitatively optimal strategies must be developed for nutrient applications in the Sahel. The reactions of nutrients within these generally sandy soils under the extreme temperature regimes experienced in the Sahel is unknown. A procedure for obtaining dissolution rate constants has been developed and the rate constants correlated with sorghum response to fertilizer phosphorus. The use of dissolution rate constants offers a method of studying phosphorus reactions in soils as they relate to plant responses and can be applied to optimizing phosphorus-use and water-use efficiency in sandy soils.

In Niger, phosphorus analyses of several thousand soil samples have been made by the INRAN soils laboratory. These have not been correlated with yield responses to phosphorus fertilization. This is a necessary step in order to make phosphorus fertilizer recommendations based on soil analyses.

It has been observed in several fertilizer studies conducted by INRAN that nitrogen and phosphorus alone and in combination have no effect on millet yields. It has also been reported that copper and zinc are deficient in several soils in Northern Nigeria which are similar in origin to some soils in Niger. In addition, several alluvial valley soils have high pH accompanied by free calcium carbonate, which has been associated with micronutrient deficiencies.

Objective 234. While plant nutrients are the most limiting element in the millet-growing part of the Sahel, droughty periods cause severe water stress and frequent yield or crop loss in West Africa. To increase water available for plants, various types of tillage are commonly used in West Texas. Plant nutrient problems are solved with fertilization. Due to the cost of both tillage and fertilizers in West Africa, studies are needed which involve both, to determine what combinations are most economically feasible to increase yields in West Africa.

Relevance to Other Programs:

The stated goal of TropSoils is to develop and adopt improved soil management technology which is agronomically, economically and ecologically sound for developing countries in the tropics. Improved utiliza-

tion of rainfall and soil water coupled with increased water use efficiency by alleviating nutrient deficiencies, under rainfed conditions in the semiarid tropics, directly addresses the major constraints to food production in developing countries in this ecological zone. The proposed projects are designed to meet these needs through use of improved soil management technology which should not only result in increased crop production per unit of water, but also in improvement in the currently deteriorating soil resources in these countries.

These studies will be conducted in collaboration with INRAN, ICRISAT, INTSORMIL, IER, and IFDC.

Generalized Procedures:

Objective 231. In the study of root growth as a function of phosphorus rate and placement, neutron probe access tubes were placed in IFDC millet plots containing three levels of fertilizer (0, 45, 90 kg $P_2,0,_5$/ha) and three placement methods (drilled, banded and broadcast) at the ISC. In this collaborative effort, IFDC monitored crop parameters while TropSoils measured soil moisture profiles. At heading, roots were sampled using a 5 cm diameter coring tube. Replicated 15 cm deep samples were taken at specific distances and depths around representative millet plants in each treatment, preserved, stained, measured (using a statistical line-intercept method) and weighed to determine the spatial distribution of each plant's root system. Comparisons between treatments are now being made.

Root studies are notoriously difficult, yet the sandy soils of the Sahelian region make root sampling much easier to accomplish. Two sets of cowpea/millet varieties that are known to compete and two that do not will be grown at two locations in Niger; at the ISC (average rainfall = 500 mm) and at Guya to the south (average rainfall = 700 mm). Soil water profiles will be monitored and, at the time of heading, pits will be dug to permit a study and comparison of the rooting patterns of each combination at each site.

A study will be conducted on an Acuff loam (Aridic Paleustolls) at the TAMU Agricultural Research and Extension Center at Lubbock. Two rates of phosphorus, 0 and 80 pounds of P_2O_5 per acre will be applied through chisels into a subsurface phosphorus deficient soil layer. Placement will be in two bands 10 inches either side of the seed furrow. The phosphorus source will be liquid (11-37-0 or 10-20-0). Nitrogen will be applied as a urea ammonium nitrate solution to equalize the nitrogen level at 80 pounds per acre for all plots. A control treatment which will consist only of surface soil fertilization will be included. Treatments will be arranged in a randomized block design with three replications. If the surface soil is deficient in phosphorus this deficiency will be corrected by fertilizer application based upon soil test results. Soil samples will be taken in six inch increments through the

soil profile. These samples will be analyzed prior to fertilizer application in order that the fertilizer be applied in zones low in phosphorus available for plant growth. Neutron access probe tubes will be placed in the seed furrow, 10 inches and 20 inches from the seed furrow. Water extraction will be measured by neutron probe which will also give an indication of root development. Water extraction from a given zone will be correlated with the original soil test value for phosphorus using regression analysis.

Based upon results, additional rates and placements (both vertical and horizontal) in the phosphorus deficient zone will be incorporated in subsequent years in order to establish the best rates and configuration of placement to maximize efficient use of soil water. It is envisioned that these treatments could consist of as many as seven combinations of vertical and horizontal placements and six rates for a total of 42 treatments.

Objective 232. The most widely accepted method of determining water-use efficiency of plants is to grow plants in sealed pots and weigh them. The procedure proposed for this objective is the one used by Briggs and Shantz (1913) in their classic transpiration ratio studies in 1912 in which plants grown in large containers were placed under rainout shelters in the field and weighed at the beginning and end of the experimental period.

It is proposed that crops adapted to the Sahel such as sorghum and millet be studied in a similar manner. Nutrient levels applied in increments from deficient to excessive are proposed. Initially the studies will involve nitrogen and phosphorus, the most limiting nutrients in the Sahel. These studies will be followed by studies of the other nutrients as deemed necessary in the future.

In the INTSORMIL program, sorghum breeding lines have been identified under greenhouse conditions that differ in nitrogen, phosphorus, and water-use efficiency when grown in nutrient deficient soils. These lines will be planted in phosphorus and nitrogen deficient soils. Neutron probe access tubes will be installed and differences in soil water extraction will be measured below 30 cm. If available and calibrated, the surface 30 cm will be measured with a calibrated gamma attenuation probe or by time domain reflectrometry.

Objective 233. Soil samples from the surface 15-30 cm of tropical and temperate Alfisols low in phosphorus will be obtained. The soils will be treated with a soluble source of phosphorus, incubated at various temperatures and sampled at periodic intervals. The dissolution rate constants will be compared.

Field studies will be conducted in Niger with differential phosphorus fertilizer rates in small plots in order to obtain phosphorus response curves. Other nutrient deficiencies will be corrected by

blanket applications. Soil samples from these plots will be analyzed for phosphorus using the Bray 1 and Truog methods. Appropriate statistical procedures including the Mitscherlich equation and the Cate-Nelson analysis of variance method will be used to analyze the data to obtain the best correlation possible between soil test data and crop response.

Pot experiments will be conducted using soils suspected of being deficient in one or more micronutrients. Differential rates of micronutrients will be applied and growth response determined. Millet, maize, sorghum, and groundnut will be used as indicator crops. The soils will be analyzed, prior to use, for DTPA extractable micronutrients using atomic absorption spectrophotometry.

Objective 234. Studies to be initiated at the Cinzana Experiment Station in Mali include the following treatments: (1) control; (2) control plus nitrogen and phosphorus fertilizer; (3) subsoiling plus tied ridges; and (4) subsoiling plus tied ridges plus nitrogen and phosphorus fertilizer.

The area will be planted in sorghum in a split-block randomized complete block design with four replications. Parameters to be measured include the following: runoff; soil water content; compaction; soil textures; soil chemical characteristics; pF; plant population; plant height; dry weight; grain yield.

Experiments	Location	Duration
Millet root distribution and water use as a function of phosphorus rate and placement.	Niger	1984-85
Root distribution and water balance in competing and non-competing millet/cowpea intercrops.	Niger	1986-87
Sorghum root distribution and water utilization from a given portion of a soil profile as a function of plant nutrient status.	TAES	1984-87
Relationship between plant water use efficiency and soil plant nutrient status.	TAES	1985-87
Soil water extraction from nutrient deficient soils, under rainfed conditions, by sorghum genotypes differing in nitrogen and phosphorus-use efficiencies.	TAES	1984-87

Comparison of phosphorus reactions in temperate and tropical Alfisols.	TAES	1985-86
Phosphorus soil test correlations.	Niger	1985-89
Micronutrient deficiencies in selected soils of Niger.	Niger	1985-86
Use of a combination of fertilizer and tillage practices to increase available soil water and crop yields.	Mali	1985-89

Relationship Between Soil Water and Plant Nutrient
Utilization in Semi Arid Environments
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	34	36	41	43	53	207
Fringe Benefits	8	9	10	11	13	51
Supplies	9	6	6	6	6	33
Equipment	6	6	6	6	8	32
Travel, International	9	9	9	9	9	45
Allowances	5	5	6	6	6	28
Other Direct Costs	3	3	1	1	1	9
Indirect Costs	13	14	15	17	21	80
TOTAL	87	88	94	99	117	485

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.40	0.40	0.40	0.40	0.40	0.00	2.00
Field Based Scientist	0.30	0.30	0.35	0.35	0.35	1.65	0.00
Graduate Student	2.00	2.00	2.00	2.00	3.00	11.00	0.00
Other	2.30	2.30	2.40	2.40	2.40	8.30	3.50
TOTAL	5.00	5.00	5.15	5.15	6.15	20.95	5.50

Program Backstopping Support
Projected Budget and Staffing

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	57	61	65	69	74	326
Fringe Benefits	13	14	15	16	17	75
Supplies	15	16	17	18	19	85
Equipment	6	6	6	6	6	30
Travel, International	18	19	20	21	22	100
Other Direct Costs	8	8	8	9	9	42
Indirect Costs	25	27	28	30	31	141
TOTAL	142	151	159	169	178	799

B. Staffing

Category	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Campus Based Scientist	0.60	0.60	0.60	0.60	0.60	1.25	1.75
Other	6.30	6.30	6.30	6.30	6.30	24.00	7.50
TOTAL	6.90	6.90	6.90	6.90	6.90	25.25	9.25

MANAGEMENT ENTITY PROGRAM

SYNOPSIS

The Management Entity will continue to operate in its traditional role as a support organ for TropSoils while fulfilling the responsibilities assigned by the primary funding agency for overall oversight in both program and fiscal affairs. Close involvement is projected in the evaluation of ongoing and proposed research and in exploring opportunities for expanded activities and funding.

The Management Office will continue to operate with the two-person administrative staff, with the assistance of occasional temporary labor when needed.

An increase in the frequency of meetings of the Board of Directors and the Technical Committee is planned. This action is necessary to insure maximum involvement in the decision making process and to insure effective communications among the groups.

The basic role of the External Evaluation Panel will continue--as an independent evaluator of the program. An increase in the level of activity is anticipated but no change is planned in the number of persons on the permanent panel. Special appointments will be made on a short-term basis as needed to provide expertise for selected reviews.

A major increase is anticipated in the communication activities as a result of more information becoming available from the research program and employment of a full-time editor. Publications will include information that will meet the needs of both the technical and lay audience interested in the TropSoils program.

Summary of Budget by Activity for the Management Entity

Activity	Year 4	5	6	7	8	Total
	x $1,000					
Management Office	135	179	189	200	195	898
Board of Directors Meetings	21	21	28	28	28	126
External Evaluation	41	53	63	77	98	332
Communications	100	107	114	125	134	580
Special Projects	120	120	120	120	120	600
TOTAL	417	480	514	550	575	2536

Summary of Budget by Object Items and
the Staffing Plan for the Management Entity

A. Budget

Object	Year 4	5	6	7	8	Total
	x $1000					
Salaries	95	116	123	140	145	619
Fringe Benefits	19	23	25	27	29	123
Special Projects	120	120	120	120	120	600
Travel	50	55	65	71	82	323
Printing	25	26	27	28	29	135
Consulting Fee	15	18	20	25	30	108
Other Direct Costs	10	12	13	15	16	66
Indirect Costs	83	104	114	124	137	562
TOTAL	417	474	507	550	588	2536

B. Staffing

Cate ry	Year 4	5	6	7	8	Total CRSP Funded	Total Other Funded
	SY/YR					SY	SY
Director	1.00	1.00	1.00	1.00	1.00	5.00	0.00
Administrative Assistant	1.00	1.00	1.00	1.00	1.00	5.00	0.00
Editor	1.00	1.00	1.00	1.00	1.00	5.00	0.00
TOTAL	3.00	3.00	3.00	3.00	3.00	15.00	0.00

Management Entity Program Extension Proposal

Submitted by

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Director, Management Entity

Introduction

The responsibilities and functions of the Management Entity are proposed to remain essentially the same as those which have existed from the beginning of the Soil Management CRSP -- but with increased attention to leadership that will enhance effective utilization of financial resources. The broad responsibilities are defined in the grant document: "Program and fiscal responsibility for performance of this (Soil Management) CRSP rests with the Management Entity". Following this statement is a list of fifteen functions which are delegated to the Management Entity. Experiences to-date do not suggest a need to modify these guidelines, but rather to give more attention to implementation. In the sections that follow, actions are proposed which are perceived to contribute to this goal.

Management Office

From the beginning of operations, the Management Office has consisted of two people -- the Director and an Administrative Assistant. In May, 1984 an editor was employed. This position is jointly funded: 70 per cent from Soil Management CRSP and 30 percent from the International Programs office of the University.

The two-person administrative personnel staff, with the assistance of occasional temporary labor, is considered adequate to meet the foreseeable needs of the office. This situation would be significantly enhanced if the Program Coordinators would give more attention to timeliness and detail in responding to requests and if the international editor position were increased to full-time on SM-CRSP activities.

The budget for the Management Office (Table 1) provides for no new positions and only a modest annual salary increase and operational costs. The larger than normal increase in salaries from year four to year five results from an increase in time of the Director charged to the project from 75 per cent to 100 percent. The travel budget is conservative; judicious selection of trips will be necessary.

Projected Costs for Operations of the Management Office

Object	Year 4	5	6	7	8	Total
			x $1000			
Salaries	63	80	84	96	97	420
Fringe Benefits	13	17	18	19	20	87
Temporary Labor	2	3	3	3	3	14
Travel	12	14	14	15	16	71
Other Direct Costs	6	7	8	9	10	40
Indirect Costs	39	52	55	58	62	266
Total	135	173	182	200	208	898

Board of Directors and Technical Committee Meetings

An increase in the frequency of meetings of the Board of Directors and Technical Committee, both jointly and separately, will be necessary in the future. Now that all programs are operational, more attention will need to be given to evaluation of programs and adjustments in allocation of resources. The suggested schedule is a meeting of the Executive Board at six to nine month intervals with a meeting of the full Board at twelve to eighteen month intervals. It is recommended that the Technical Committee meet at the same time as the Board and that it pay for its travel costs from the budget provided for the respective programs.

The selection of meeting dates within these time frames would be based on the accumulation of topics that need Board and Technical Committee attention.

External Evaluation

Involvement of the External Evaluation Panel in the program has been quite minimal to-date. Only the Peru portion of the N. C. State program has undergone a full study; the others have had a one-person review on one occasion. There has not been a visit by a member of the Panel to the University of Hawaii campus on official SM-CRSP business.

Limited involvement by the Panel to-date has been justified because of the start-up delays in all but the N. C. State program. However, these obstacles have been overcome and thus greater assistance from the Panel can be effectively utilized.

Significant participation is recommended by the Panel in evaluation and prioritizing of extension proposals and assessment of the progress on those which have been funded. Such activities will require annual meetings in the U.S. as well as periodic on-site visits to the research sites. The budget in Table 3 reflects this increased involvement.

Communications

Unquestionably, the most serious weakness in the SM-CRSP is communications. While it is true that quality performance is the lifeblood of the program, effective communications are essential to its flow. There is, at best, a cloudy perception of our activities and accomplishments, due primarily to our failure to communicate.

Steps have been taken and progress is being made to remedy this unsatisfactory condition. A capable editor has been employed who has not only the essential technical skills, but also the personal attributes and interest in the program to interact effectively with all participants. The editor has visited two of the primary research sites, Niger and Brazil. The news organ, "TropSoils Communiques," has been

Projected Cost for Meetings of the Board of Directors

Object	Year 4	5	6	7	8	Total
	x $1,000					
Travel	15	15	20	20	20	90
Indirect Costs	6	6	8	8	8	36
Total	21	21	28	28	28	126

Projected Costs for External Evaluation Panel

Object	Year 4	5	6	7	8	Total
	x $1,000					
Travel	17	20	25	30	40	132
Consulting Fees	15	18	20	25	30	108
Indirect Costs	9	15	18	22	28	92
Total	41	53	63	77	98	332

Projected Cost for Communication Activities

Object	Year 4	5	6	7	8	Total
			x $1,000			
Salaries	28	31	34	39	43	175
Fringe Benefits	6	6	7	8	9	36
Temporary Labor	2	2	2	2	2	10
Printing	25	26	27	28	29	135
Other Direct Costs	4	5	5	6	6	26
Travel	6	6	6	6	6	30
Indirect Cost	29	31	33	36	39	168
Total	100	107	114	125	134	580

improved and is being issued on a regular basis. A triennial report for broadscale reader understanding is in the advanced stage of preparation. Other communication outlets and mechanisms are under consideration.

The editor position is currently funded only in part (70%) by the Management Entity. It is recommended that full funding of the position be initiated, that he travel to the Indonesia and Peru research sites and that a full communications program be implemented -- all within the earliest feasible time. The budget in Table 4 reflects the funding necessary for these activities.

Special Projects

The projects within the agroecological zone programs of the participating universities are the dominant component of the SM-CRSP. There is a need, however, to utilize other opportunities which can contribute significantly to our goals at minimal cost. Such sources include university faculty not otherwise involved in the program, collaborating country institutions with underutilized potential and other organizations with developing country agricultural interests. The projects may operate either within or outside the administrative framework of the current participating universities in TropSoils.

The perception is that with a relatively small level of funding, primarily for research operational support, research projects can be either initiated or expanded which would provide soil management related information at a favorable cost/benefit ratio. Such projects would be targeted toward specific activities and with a finite duration.

The total annual amount recommended for this activity is $50,000 per year. Prior to implementation a detailed plan for the conduct of the program will be developed and submitted for approval to the Board of Directors. It will specify that all Special Projects will require a review by the Technical Committee and approval by the Executive Committee of the Board of Directors.

Summary

The proposal for extension of the Management Entity operations will result in closer involvement with individual programs enhance their accomplishments. The underlying philosophy is one of continuing the traditional role as a support organ while fulfilling the responsibilities assigned by the primary funding agency.