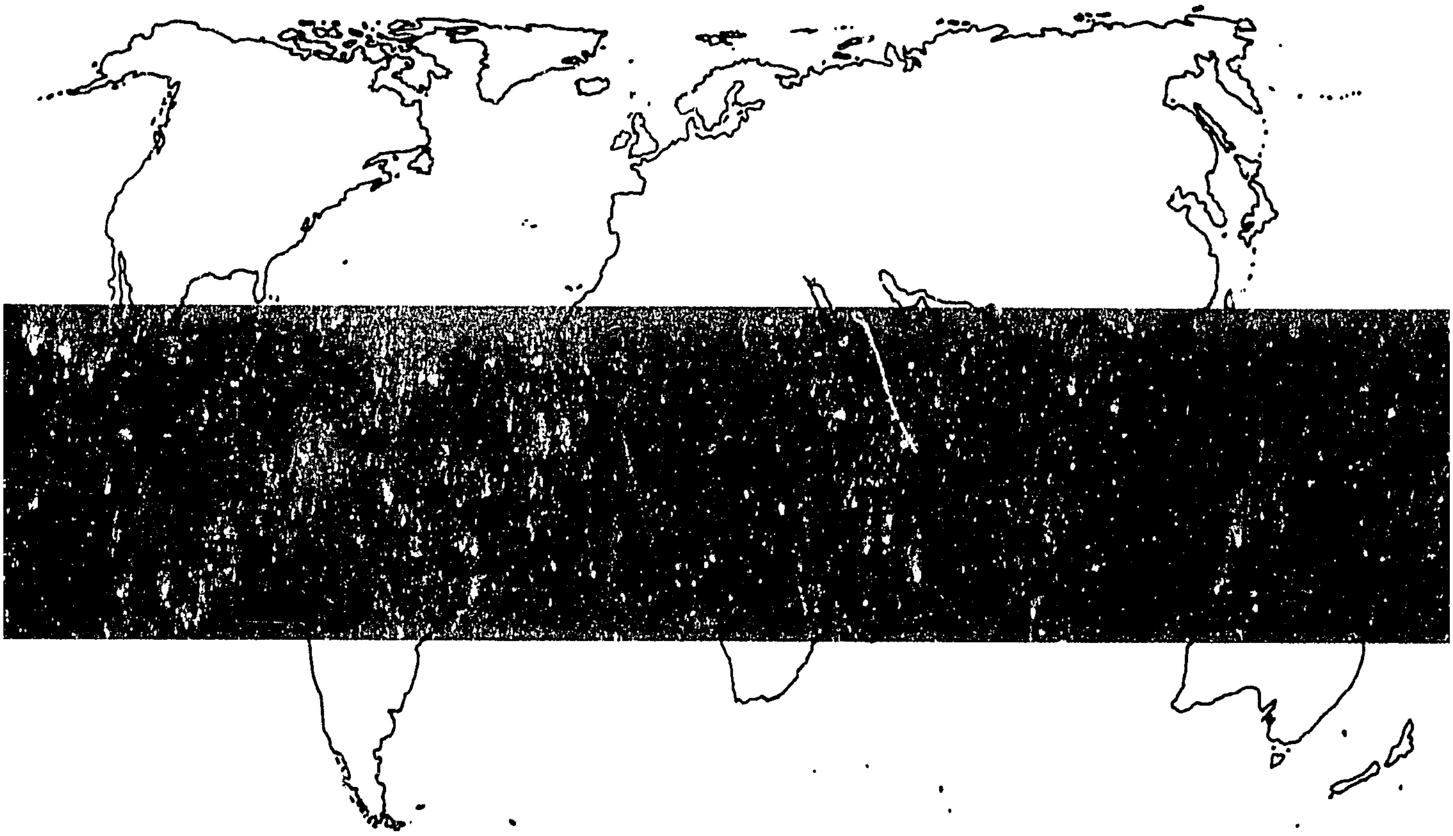
TROPSOILS



TROPSOILS

TRIENNIAL TECHNICAL REPORT

1981-1984

Charles B. McCants, Editor

January, 1985

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

Primary funding is provided by the U.S. Agency for International Development through Grant DAN 1311-G-SS-1083-00. This action is in support of Title XII "Famine Prevention and Freedom from Hunger" of the Foreign Assistance Act.

The formal collaborators 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'Economic Rural-Mali; Instituto Nactional de Investigacion y Promocion Agraria-Peru; International Crops Research Institute for the Semi-arid Tropics-India; North Carc[illegible] State University-USA; Texas A&M University-USA; University of Hawaii-USA.

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GOAL AND ORGANIZATION

The need to increase world food production for the present and foreseeable future is an accepted fact if famine is to be prevented, hunger alleviated and minimum dietary needs met. The actions necessary to meet this challenge are clear: increase production on existing fields and bring new lands into the system. For either approach to be successful, limitations to be plant growth caused by soil constraints must be minimized. The goal of TropSoils is to address this issue. Formally defined, it is to develop and adapt improved soil management technology which is agronomically, ecologically and economically sound for developing countries in the tropics.

TropSoils is an acronym for the Soil Management Collaborative Research Support Program. It is one of several programs developed to implement Title XII, "Famine Prevention and Freedom from Hunger" of the U.S. Foreign Assistance Act. This legislation sets forth the framework for a collaborative research program involving: (1) U.S. Agency for International Development, (2) U.S. universities, (3) international agricultural research centers and (4) developing country institutions. Within TropSoils, adherence to the principle of collaboration has been a requirement and maximizing the collaborative effort from all the participants a major goal. Identifiable inputs by all components have been substantial and have had a major impact on the structure, operations and accomplishments of the program.

The TropSoils approach is to focus segments of its program on specific agroecological zones, with primary and secondary research sites within each zone. The zones are: the humid tropics with primary sites in Peru and Indonesia and a secondary site in Brazil, the semi-arid tropics with a primary site in Niger and a secondary site in Mali, the acid savannas with the primary site in Brazil and the steeplands, which currently is inactive. This approach evolved from the two-year planning process which preceeded its implementations.

The leadership for detailed program development and for project execution is provided by four U.S. universities. Their identification and the agroecological zone of activity follow:

Cornell University - acid savannas
University of Hawaii - humid tropics (Indonesia)
North Carolina State University - humid tropics (Peru, Brazil, Indonesia)
Texas A&M University - semi-arid tropics

TropSoils was officially initiated in September, 1981. The dates at which individual programs became fully operable varied considerably due to the time required to complete the necessary administrative actions with collaborating institutions. The humid tropics program in Peru utilized an existing activity and thus was the earliest to become fully operational. The approximate time at which the different programs came on-stream are:

Humid Tropics (Peru): September, 1981
Semi-Arid Tropics (Niger): February, 1983
Acid Savannas (Brazil): June, 1983
Humid Tropics (Indonesia): June, 1983

The fact that TropSoils is a new program which involves collaborative research on complex problems, operates primarily in the field and under difficult situations in developing areas and has been functional for a maximum of three years at one site and less than eighteen months at the others, has necessarily limited its technical output to-date. Nevertheless, a broad base of well-conceived and scientifically-sound projects have been designed and initiated. Many of them already are having an impact on local actions.

The purpose of this report is to describe the individual TropSoils research projects that are active and to provide a rationale for their place in the program and their current status. Inclusion of data intentionally is omitted because it was not necessary for the purpose of the report and such citations would be premature for most of the projects.

ADMINISTRATION

Administrative philosophy and procedures for TropSoils reflect the collaborative nature of the program. Thus, it involves identifiable and significant inputs by all participants.

The Agency for International Development has delegated overall program and fiscal responsibility for performance to the Management Entity, an administrative unit prescribed in the organization of all collaborative research support programs. It receives guidance and recommendations on policy issues from a Board of Directors and on technical matters from the Technical Committee. The Board of Directors is composed of an administrative official from each participating university and collaborating country institution. The university representatives compose an Executive committee of the Board. The Technical Committee is formed from the Program Coordinators from each university.

Research projects are developed by Program Coordinators in collaboration with campus and field-based faculty and in consultation with research and administrative personnel from the collaborating country institution. Advice and concurrence is requested from the respective USAID office to insure that the objectives are consistent with its goals and priorities.

Program reviews are conducted periodically by an External Evaluation Panel composed of persons with international agricultural development experience and with no affiliation with any of the participating institutions. Its reports are used by the Management Entity, the Board and the Technical Committee in assessing needs for adjustments or revisions in objectives and approaches.

The following persons have had a major involvement in the administration of TropSoils:

Management Entity Office

Charles B. McCants, Director	NCSU
Kim S. Stevens, Administrative Assistant	NCSU
Neil Caudle, Editor	NCSU

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Morris Bloodworth, Chairman (until 10/83)	TAMU
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Goro Uehara	UH

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David Bathrick	USAID/Lima
Allen R. Hurdus	USAID/Jakarta
Adolfo Jurado	USAID/Lima
Howard Lusk (after 1/83)	USAID/Brasilia
S. K. Reddy	USAID/Bamako
Samuel Taylor (until 12/82)	USAID/Brasilia
Wilbur Thomas (until 7/83)	USAID/Niamey
Frederick Vigil (after 7/83)	USAID/Niamey

HUMID TROPICS

INDONESIA

HUMID TROPICS PROGRAM **** INDONESIA

ORGANIZATION

Lead Institution

University of Hawaii

Support Institution

North Carolina State University

Collaborating Institution

Center for Soils Research

Linkage Institutions

Bogor Agricultural Institute
Centro Internacional de Agricultura Tropical
International Board of Soil Research and Management
International Fertilizer Development Center
International Rice Research Institute
Sukarami Research Institute for Food Crops

Research Site

Sitiung, West Sumatra, Indonesia

Principal Investigators

Lead Institution

Goro Uehara

Support Institution

John J. Nicholaides, III

Representatives on Board of Directors

Lead Institution

Ada Demb

Collaborating Institution

M. Sudjadi

HUMID TROPICS PROGRAM **** INDONESIA

TECHNICAL PERSONNEL

Name, Degree	TropSoils Responsibility	Affiliation
Goro Uehara, Ph.D.	Soil Physics[1/]	UH
John J. Nicholaides, Ph.D.	Soil Fertility[2/]	NCSU
Cahyono, B.S.	Soil Conservation	CSR
D. Keith Cassel, Ph.D.	Soil Physics	NCSU
Carol J. Colfer, Ph.D.	Anthropology	UH
Carl Evensen, M.S.*	Soil Science	UH
Robert L. Fox, Ph.D.	Soil Fertility	UH
Dan W. Gill, M.S.*	Soil Fertility	NCSU
Ronald F. Guyton, Ph.D.	Agronomy	UH
Heryadi, B.S.	Soil Fertility	CSR
Eugene J. Kamprath, Ph.D.	Soil Fertility	NCSU
A. Karim Makarim, M.S.*	Soil Physics	NCSU
Harold McArthur, Ph.D.	Anthropology	UH
E. Santoso, B.S.	Biochemist	CSR
D. Santoso, M.S.	Soil Fertility[3/]	CSR
A. Sofyan, B.S.	Soil Fertility	CSR
Subagio, M.S.*	Soil Classification	CSR
S. Sukmana, Ph.D.	Soil Physics[3/]	CSR
Sutji, B.S.	Meteorologist	CSR
John R. Thompson, Ph.D.	Agronomy	UH
B. Tori, B.S.	Soil Fertility	CSR
Gordon Y. Tsuji, Ph.D.	Soil Physics[4/]	UH
Michael K. Wade, Ph.D.	Soil Management	NCSU
Russell S. Yost, Ph.D.	Soil Fertility	UH

[1/] Also, Principal Investigator, Lead Institution.

[2/] Also, Principal Investigator, Support Institution.

[3/] Also, Principal Investigator, Collaborating Institution.

[4/] Also, Project Manager.

*Enrolled in a graduate program leading to next highest academic degree.

HUMID TROPICS PROGRAM **** INDONESIA

AN OVERVIEW[1/]

The Scope of Work for this activity as set forth in the grant which established the Soil Management CRSP includes the following:

A. Characterize the soil of experimental sites.

B. Test promising methods of land clearing and select one or more appropriate for existing conditions.

C. Monitor the effects of clearing methods on soil physical properties and identify or devise means for correcting undesirable effects.

D. Determine the amounts of fertilizer and lime needed to produce satisfactory crops and to sustain yields at levels profitable for the farmers.

E. Evaluate the potential of grass/legume pasture mixtures in the farming system.

F. Apply and assess the efficacy of soil conservation measures to typical areas.

G. Find management systems which minimize energy needs to the extent possible given local limitations on land, manpower and markets.

H. Assess the likes, dislikes, needs and resources of farmers of the area to guide research along lines likely to be beneficial because of the adoption of results.

I. Disseminate the results of the research to other areas in the humid tropics.

[1/] Prepared by Goro Uehara, Principal Investigator.

The principal goal of the program is to uncover principles which will enable resource-poor farmers to adopt soil management practices that will increase family income and farm productivity and at the same time preserve land quality. The research strategy is designed to insure that social, cultural, economic and environmental factors that enhance adoption of a soil management innovation are made an integral part of the research plan. To achieve its goal, the project conducts a major portion of the soil management research with farmers and in farmer fields.

The Setting:

A 100,000 hectare transmigration site in Sitiung, West Sumatra, Indonesia, serves as the project's research area. Six thousand transmigrant families and 1500 indigenous families live in the area. Large cultural and language differences between the Javanese and Sudanese transmigrants and between the transmigrants and indigenous groups present unparalleled opportunities to study the responses of different ethnic groups to soil management innovations.

The soils of the region range in quality from moderately fertile Inceptisols on river terraces to highly leached and impoverished Oxisols and Ultisols of the dissected peneplain. Mean annual rainfall is 2800 mm and mean annual air temperature is 26°C. The tropical rain forest is gradually giving way to rubber plantations and subsistence farming by new settlers.

The first large group of transmigrants settled in Sitiung in 1976. A modest home, 1.25 hectares of recently cleared land and a year's supply of food, fuel, other living essentials, seed and fertilizer awaited each family upon its arrival. Since then, five additional areas in Sitiung have been settled. Bulldozer crews continue to clear more land to accommodate new settlers from the densely populated Islands of Java and Bali. The productive land on the river terraces has long been settled and the newest transmigrants are being placed on the less desirable lands of the dissected peneplain.

The damaging effect of land clearing by bulldozers is a serious problem on the fragile and infertile soils of the peneplain. In response to rising costs and negative effects of mechanical land clearing, the government currently is leaving the bulk of land clearing to the farmers. The farmers from Java and Bali, however, have no experience in land clearing and regard felling and burning of large trees as dangerous. Even after the land is cleared, the Javanese and Sundanese farmers, accustomed to tilling the soil with a hoe, encounter a root mat too thick for this tool. The indigenous farmer, on the other hand, employs a no-till farming practice and places seeds in holes formed with a pointed stick. The immigrant farmers soon discover that the knowledge and experience that worked so well on the rich volcanic soils of Java and Bali do not necessarily apply in Sitiung. For this reason, they are enthusiastic participants of the TropSoils project.

Developing a Collaborative Project:

Transmigration is a major economic and development goal of the Indonesian government. Sitiung is typical of many transmigration sites in Kalimantan, Sulawesi and Sumatra. It is the intention of the government to transfer soil management and farming systems principles discovered in Sitiung to other transmigration sites in the country. Similarly, TropSoils is also interested in uncovering principles that will enable it to respond to requests for technical assistance for management of tropical soils worldwide.

Sitiung was selected as the research site after detailed discussions between Indonesian agencies and representatives of TropSoils. The site is a representative microcosm of virtually everything that is possible in the humid tropics. To exploit Sitiung's unique biophysical and social setting, the Indonesian government has invested heavily in the program. In addition to the administrative leadership and support from CSR in Bogor, it has committed 15 scientists and technicians to the projects. The senior Indonesian scientist holds a Ph.D. degree; he is assisted by four Bachelor of Science and ten high school level technicians.

In addition to the research and support staff, the Indonesian government has provided equipment, office facilities and living quarters for its staff. The costs of seeds, fertilizer and chemicals are shared among the collaborating units. The installation, monitoring and harvesting of all TropSoils' experiments are done by Indonesian technicians. An operating budget of $88,000 was allocated to the TropSoils project by the Indonesian government in 1983-84 fiscal year. A similar amount has been budgeted for the current fiscal year.

For its component, the U.S. institution provides three on-site senior scientists to the project--an agronomist who also serves as team leader, a social scientist who deals with the farming systems component, a soil scientist--and two graduate students. The project is also assisted by university-based scientists from the U.S. institutions who share research responsibilities with scientists in the field.

The major research sites have been characterized for soil properties and are continuously monitored for climate. The thorough, ongoing soil and climate inventory of the Sitiung area will be valuable in efforts to transfer the technology to other regions of the humid tropics.

Although research is currently conducted on farmers' fields, the Indonesian government has reserved 220 hectares of forested land for development into a permanent research station. It is located on the peneplain and represents the full topographic range of the region. About a third of the area is relatively flat and the remainder varies in steepness. It offers a range of landscapes for conducting land clearing experiments, which will be a primary initial emphasis.

The Indonesian government has structured its project efforts so that a fully-staffed research station will be operating in Sitiung when the contribution of AID and the U.S. institution comes to an end.

Team Building:

To prepare the U.S. scientists for work in Indonesia and to ensure that the group functions as a cohesive unit, a team building and language training course was conducted in Honolulu between November 7 and December 3, 1982. The group met together daily over a six-week period with approximately half of the time spent in language study.

The team building included an introduction to the concepts and methods of farming systems research, seminar sessions with people from a variety of subjects on campus who were invo'ved in complementary research and introduction to conditions in Indonesia and the research site. The team also took a Myers-Briggs personality test which was designed to make explicit some of the differences in approach team members might expect from each other and the particular strengths that each team member brought to the group.

Since the farming systems approach requires continuing collaboration and communication, it was essential that participants overcome the kinds of disciplinary barriers that often interfere with team efforts. The team building period served to acquaint the team members with each other and to set a stage that has facilitated continuing collaboration--both between disciplines and across cultural boundaries.

A trip to Yurimaguas, Peru, was made by the U.S. team members to acquaint them with the valuable and closely related work underway there. This trip also contributed to the team building process, as team members coped together with the challenges of remote areas. Yurimaguas provided a concrete situation in which team members first became alerted to each other's interests and areas of expertise.

The value of the team building has been verified on site in Sitiung. The necessity to prepare housing for themselves, participate in a soil survey and adjust to the new conditions simultaneous constituted a real test of team cohesian. The staff functioned effectively during that critical period and has continued to do so.

Training:

Although Indonesia has quality soil scientists, it lacks the quantity needed to meet the country's development needs. The Center for Soil Research has stated its desire to use the TropSoils project to identify potential candidates for advanced training. The objective is to select from the large staff posted in Sitiung, young people who demonstrate leadership qualities and interest in science. The intent is to select high school graduates for entry into Bachelor of Science program, holders of B.S. degrees for M.S. programs and individuals with M.S. degrees for Ph.D. programs.

As part of this program, the Center for Soil Research is sending two of its staff for Ph.D. training. Mr. D. Santoso, the site coordinator and lead Indonesian scientist for the TropSoils project will be matriculating in an Australian University, and Mr. M. Subagio will be going to North Carolina State University. Mr. Santoso will be replaced by Dr. Soleh Sukmana who holds a Ph.D. degree in soil physics.

The number of Indonesian students qualified to enter U.S. institutions is low because most lack proficiency in English. To overcome this problem, the project has hired a teacher who serves as tutor for the expatriate children and language instructor for the Indonesian technicians. Daily contact with the U.S. project staff adds to the language learning process for the Indonesians.

Research Strategy:

Early in the project, Indonesian and U.S. scientists and administrators agreed on a research plan for TropSoils activities in Sitiung. The plan is summarized as a flow chart in Figure 1.

It calls for an initial attention to survey and characterization of soil resources and farming systems in the Sitiung area. That effort is to be followed by testing of improved, alternative soil and crop management systems on farmer fields.

Owing to serious soil erosion in parts of Sitiung and the need to prevent worsening of the situation, the plan also called for soil management research to reclaim the abandoned, eroded lands.

Since the method of land clearing has a decided effect on land quality, the plan also called for a major effort in identifying suitable land clearing methods that could be successfully transferred to other parts of the humid tropics. Work in this area includes the selection, survey and characterization of 220 hectare land clearing experimental site which the Center for Soil Research intends to use as a permanent research station.

Factors Affecting Progress of the Program:

During the planning process for the Soil Management CRSP, a visit to Indonesia was made by personnel from the Planning Entity and AID/W to discuss with Indonesia administrators and scientists information needs and level of interest in a collaborative research program. The response

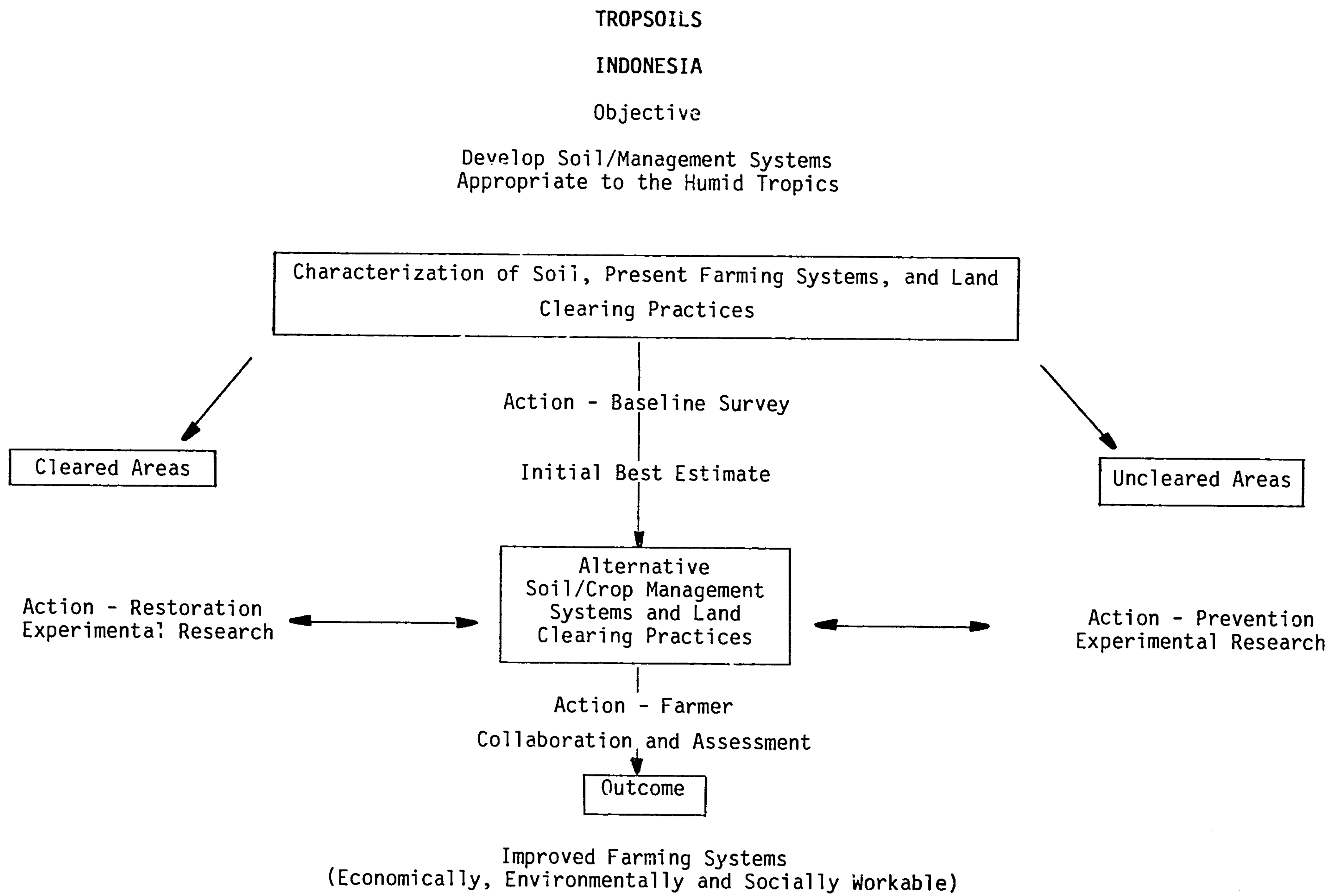

Figure 1. Flow chart of activities for the Indonesia TropSoils Project.

on both issues was positive and enthusiastic. A "Letter of Intention" was signed in February, 1980, by representatives of the Soils Research Institute, the Central Research Institute of Agriculture and Bogor University expressing concurrence with proposed research activities, work location and institutional coordination.

The subgrant from the Management Entity to the University of Hawaii and North Carolina State University to actually implement the program was executed in January, 1982. In March, 1982, representatives from the two institutions and the Management Entity visited Indonesia to discuss formalization of the program and develop the appropriate legal documents. There was anticipation that all necessary approvals would be obtained by August, 1982, and, thus, recruiting of personnel and other plans were initiated by both universities. Difficulties occurred in obtaining the required actions. Considerable uncertainty on timing occurred and resulted in a number of go-stop actions on personnel posting. Final approval was obtained in June, 1983; senior scientists arrived in the country within a few weeks thereafter.

In spite of these developments, with the exception of a six-month period between January and June, 1983, most of the time was used in effective start-up activities.

Major constraints to on-site activities can be linked to isolation of the project area. Isolation results in real and perceived constraints in security, communication, housing, power supply and health.

Security. Concern for the security and safety of team members was a major factor in Indonesian administration's reluctance to permit the team to enter Sitiung prior to formal approval of the Agreement. The concern for security exists to this day, and team members are required to sign in at the District Attorney's office when they leave and return to the area. The District Attorney's office would be in serious trouble with the Central Government if the whereabouts of a team member, injured outside the Sitiung area, were not known to the Office. The security problem is perceived differently by the team members and the district officials. The team feels secure in the village and fields, but the officials are fearful that team members will be harmed by unfriendly people from outside.

Housing. Since original housing reserved for team members was located in Sumani, 2.5 hours from the research area, the team arranged to rent and upgrade homes owned by local settlers. The resulting savings in time and fuel more than compensates for the inconvenience of locating adequate housing.

Communication. There is no direct telecommunication link with the team. The only telephone in Sitiung is located a few kilometers from the team's residences. Cables are received at the post office in Sitiung. A battery operated radio communication system is being developed to link team members with each other and to Padang and Bogor. In cooperation with the IADS group in Sukarami, direct telephone, cables and telex linkages have been established to a one person office in Padang. Messages received in Padang are either called or mailed into Sitiung by the office staff.

Power Supply. There is no municipal electricity or water supply. Except for the kerosene refrigerators and gas stoves, household appliances and lighting are provided by diesel generators. The type of equipment purchased by the project to support a soil characterization laboratory is constrained by lack of steady and reliable power supply.

Health. Two members have been afflicted with unknown ailments. One member of the University-based staff who visited Sitiung in March, 1984, was suspected of having contracted Dengue fever. Although proper precaution can be maintained at home, it is difficult for team members to reject food and drink offered by cooperating farmers. One team member has been ill for over six months and returned to Hawaii for medical help. The doctors suspected a virus and recommended a long rest, but the patient returned to Sitiung after only a short stay.

Although isolation and the constraints that go with it appear formidable, team members treat them as minor inconveniences and continue their work with remarkable enthusiasm. They recognize the reality of working in a developing country is to deal with these kinds of constraints. The connection between soil management and quality of life is not lost because the constraints that affect project activities are the same constraints that face everyone in Sitiung.

DETAIL SOIL SURVEY OF THE SITE FOR LAND CLEARING RESEARCH

Leadership Personnel:

Harijogjo, CSR
Bambang Mahmudi, CSR
Yayat Hidayat, CSR
Anggana, CSR

Date Research Initiated:

May, 1984

Rationale for Investigation:

220 hectare, forested site has been selected to serve as a permanent research station. Instead of simply clearing the land, the land clearing effort will become part of a study to assess land clearing methods (see project on land clearing). A detailed soil and plant inventory of the site will enable the land clearing project to locate suitable research plots and to plan a long term research strategy for the site.

Objective:

To prepare a detailed soil map (1:5,000) of the TropSoils land clearing research site.

Experimental Approach:

This research is conducted in the Sitiung transmigration area of West Sumatra, Indonesia. Transects through the site will be prepared and soil and vegetation type recorded. Soil samples will analyzed in Bogor and the field and laboratory data will be used to classify the soil according to the Indonesian system of soil classification and Soil taxonomy. A large scale map (1:5000) will be prepared.

State of Progress:

A preliminary report has been reported.

Constraints of Progress:

See Overview

Applicability of Results to TropSoils Goal:

Detailed characterization of the land clearing site is necessary to render the research results useful elsewhere in the humid tropics. This site will be one of three "benchmark" land clearing sites planned under a cooperative effort with IBSTRAM.

Training Component:

Soil survey and classification is a continuing training aspect of the TropSoils project. Its main training will be in the use and adoption of Soil Taxonomy as a common international language for soil management technology transfer.

SOIL SPATIAL VARIABILITY IN NEWLY CLEARED FOREST LAND

Leadership Personnel:

Bruce Trangmar, UH
Goro Uehara, UH
Djoko Santoso, CSR

Date Research Initiated:

July, 1982

Rationale for Investigation:

A typical farm in the transmigration area varies in productivity from bare spots to green strips. The bare spots are sterile subsoil exposed by the bulldozer and the green strips correspond to the ash lines of burnt trees. This type of variability is a problem for the farmer and researcher. In farmers' fields, the bare spots are the first to erode. Bare spots produce nothing and, therefore, are neglected. Erosion feeds on neglect, and the land is eventually abandoned.

If a farmer applies lime and fertilizers uniformly over a field, too little is applied to the bare spot and an overdose is given to the green strips. But because the Sitiung farmers spread farm chemicals by hand, they are in a position to vary the application rate according to need. The farmer must learn or be taught to recognize various forms of variability that causes inefficient use of scarce resource.

The researcher needs variability but wants a field with minimum natural variability so that the effect of the treatment variable will be clearly expressed. In Sitiung the range of natural soil variability is almost always as large as the imposed treatment range. The aluminum saturation of the surface layer of a freshly cleared and burnt forest ranges from 0 to 90%. This is the same range a researcher would impose in a liming experiment to assess the effect of aluminum toxicity on crop performance.

Fortunately, a new technique for dealing with soil variability is now available to soil scientists. This technique, called geostatistics, enables soil scientists to estimate the value of a soil property at unsampled locations from an analysis of neighboring samples.

Objectives:

A. To assess soil variability in a small field and measure its influence on crop performance.
B. To identify the soil, chemical and physical properties most responsible for yield variability.
C. To test the occurrence of structure in the variance of soil, chemical and physical properties by means of geostatistical methods.
D. To establish the relationship between soil spatial variability and spatial variability in crop performance.

Experimental Approach:

This research is conducted in the Sitiung transmigration area of West Sumatra, Indonesia. 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 semivariogram 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.

State of Progress:

The results show that natural soil variability can be exploited to answer key agronomic questions. Examples are available to illustrate the variability of aluminum saturation in an experimental plot and its corresponding effect on the rice crop. The data show that rice yields were significantly higher on burn sites than on exposed subsoil. A more detailed analysis shows that difference in organic matter, phosphorus and nitrogen accounted for less of the yield increase than differences in aluminum saturation, calcium, magnesium, potassium or zinc. Thus, geostatistics enabled project scientists not only to map spatial variability of soil properties to extract from the data set agronomic information that relates soil productivity to soil properties.

The same technique has been employed to map agronomically important soil properties for the entire 100,000 hectares research area. The spatial variability of the amount of lime needed to correct aluminum toxicity in the Sitiung area illustrates how geostatistics can be used to identify soil constraints.

Constraints to Progress:

See Overview

Applicability of Results to TropSoils Goal:

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.

Training Component:

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 arrives in Hawaii. Two Master of Science candidates from Indonesia have been proposed for matriculation in the University of Hawaii.

RECLAMATION OF UNPRODUCTIVE, ABANDONED LAND

Leadership Personnel:

Karim McKarim, NCSU
D. Keith Cassel, NCSU
John J. Nicholaides, III, NCSU

Date Research Initiated:

September, 1983

Rationale for Investigation:

Many transmigration areas in Indonesia have been hastily planned and administered. The consequence is degraded landscapes that cannot produce sufficient food crops. Sometimes even cassava will not grow. These areas were improperly cleared and improperly protected. Thus, topsoil and organic matter have been pushed and/or eroded away. A major challenge facing the government agencies is how to reclaim these barren lands. This research is an initial step in identifying what must be done, both chemically and physically to rectify the situation. This process, of course, is partially site and soil specific, but what will work in one area will give clues to what may work in others.

Objectives:

A. To identify soil management practices that will improve chemical and physical properties of degraded soil.

B. To study the effect of lime and fertilizer on crop performance at low and high critical levels for lime and nutrients.

C. To study the effect of various tillage methods on soil physical properties and crop yields.

D. To study the effect of green manures on crop yields and soil chemical and physical properties.

Experimental Approach:

The research is conducted in the Sitiung transmigration area of West Sumatra, Indonesia. A two pronged approach was developed to reclaim the damaged soils by modifying both chemical and physical properties. To alleviate suspected compaction and infiltration problems, the following treatments were installed: (1) hoeing to 15 cm, (2) hoeing plus applying mulch to the soil surface, (3) hoeing with incorporation of organic matter, (4) turning the soil by spading fork to 30 cm depth, (5) spading in alternate 40 cm strips to the 30 cm depth and (6) rototilling to 15 cm. Three subplot treatments of the following soil fertility levels were included on each main plot: F0, no lime and fertilizer; F1, application of lime, N, P, K, Mg, S, Cu and Zn at rates of 1500, 120, 40, 72, 70, 93, 1 and 4.5 kg/ha, respectively; and F2, the application of the above nutrients at rates of 6840, 150, 572, 144, 140, 187, 2 and 6 kg/ha, respectively.

The experiment is a randomized complete block design with a split-plot arrangement of treatments with four replications. The study site will be continuously cropped for two years. Soil physical and chemical properties will be monitored periodically throughout the study.

State of Progress:

The first two crops (rice and soybeans) of the first cycle have been harvested. The rice crop responded dramatically to lime and fertilizers. The unamended soil was nearly barren. Application of low rates of lime and fertilizers resulted in moderate yields. The high rates increased yields on the average by 17%. Green manuring, incorporated 12.5 T/ha of fresh calapagonium sp, showed a very substantial increase in rice yields at all three levels of fertility compared with the nonmanured plots. Low rates of lime and fertilizers with green manure produced considerably more than high rates without green manure. There was little difference among tillage methods, except for the strip tillage which was not as effective as the others.

The soybean crop, which is much more sensitive to low P and high Al responded quite differently than the rice. Again, no amendments meant no yield, and even the low rates produced rather poorly. The high rates, however, yielded very well, on the order of three times the low rates. With this crop the green manure was not reapplied and there was no residual effect on the bean yield. Deep spading produced a marked positive effect on yields at low rates, but gave a negative effect at high rates of lime and fertilizers.

Deep spading had the most favorable effect on compaction, bulk density and water infiltration. Organic matter additions generally improved the soil physical condition compared to simple hoeing but not as dramatically as the deep tillage.

Soil chemical analysis of the fertility main plots after the first crop of rice showed that the low rates of lime and fertilizer increased bases and P, while reducing Al to about 50 per cent of ECEC. The high rates completely eliminated exchangeable Al and brought available P to a very high level. The dramatic soybean response reflects this favorable nutrient status.

Constraints to Progress:

Equipment for measuring soil physical properties is needed but is currently unavailable in Sitiung.

Applicability of Results to TropSoils Goal:

The Center for Soil Research, as the national soil institute of the Ministry of Agriculture, will be (and is) called upon to recommend practices that will prevent soil degradation and reclaim land that is eroded. This research provides information that will assist it in developing a strategy for soil conservation and reclamation. This project also helps the U.S. institutions by providing information on the basic principles involved in what amounts to "rebuilding" a soil. We see firsthand the soil forming processes at work in a dynamic and dramatic situation, unlike perhaps any field condition that can be found in the U.S.

Training Component:

Karim Makarim is an Indonesian who is a candidate for the Ph.D. degree at NCSU. This research will be used, in part, for his doctoral thesis. He is gaining valuable research training and will return to Indonesia.

MANAGEMENT OF ORGANIC MATTER IN INDONESIAN FARMING SYSTEMS

Leadership Personnel:

Carl Evensen, UH
Russell Yost, UH
John Thompson, UH

Date Research Initiated:

October 1984

Rationale for Investigation:

Organic matter is an important soil component, especially in highly leached and weathered tropical soils. Soil organic matter is associated with increased cation exchange capacity, improved soil structure, and is a 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 Indonesia 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 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.

Objectives:

A. To 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 the soil.

B. To identify optimum farming systems for the management of organic materials.

C. To identify the major groups of soil organisms involved in organic matter decomposition in Sitiung and to study the effects of management factors on their numbers and activities.

Experimental Approach:

The field investigations will be conducted in the Sitiung area of West Sumatra, Indonesia. The research will 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, fertilizers, 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 understood better.

State of Progress:

Project just initiated.

Constraints:

See Overview.

Applicability of Results to TropSoils Goal:

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 organic matter in similar sites. Of particular interest will be the identification of useful tree and cover crop species and determination of their interactions with intercropped food crops.

Training Component:

Management of organic matter will be part of the farming system and will be incorporated in training aspects of farming systems research. The data arising from this project will also be used in training for nutrient dynamics and nitrogen transformation in crop modeling.

POTASSIUM DYNAMICS IN CROPPING SYSTEMS OF WEATHERED SOILS OF WEST SUMATRA, INDONESIA

Leadership Personnel:

Dan Gill, NCSU
Eugene J. Kamprath, NCSU
John J. Nicholaides, III, NCSU
Mike K. Wade, NCSU

Date Research Initiated:

June, 1984

Rationale for Investigation:

The soils in Central Sumatra are quite acidic with aluminum saturations of 80 to 90 percent and have very low levels of potassium and other bases. 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. Such losses can be reduced to some extent by neutralization of 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.

Objectives:

A. 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 West Sumatra.

B. To determine the effect of different levels of base saturation on the retention and movement of K applied at various rates.

Experimental Approach:

The research will be conducted in the Sitiung transmigration area of West Sumatra.

Two cropping systems will be used: (1) corn, soybeans and mung beans and (2) rice, peanuts and cowpeas. Lime rates will be equivalent to 500 kg $CaCO_3$/ha and rates that will give 50 and 0 percent aluminum saturation. The rates of K applied, as KCl, to each crop will be 0, 20, 40, 80, 120 and 240 kg K/ha.

Plant leaf samples will be taken at flowering to determine the K, Ca, Mg and N concentration. Total plant content of these nutrients in the harvested grain and yield of grain will be determined at maturity. Soil samples will be taken at 15 cm intervals to a depth of 60 cm after each crop to determine the movement of K and the basic cations. Laboratory studies will be done on the quantity-intensity relationships of K in these soils.

State of Progress:

The plot area is being prepared and lime treatments are now being applied. The first crops will be planted in September, 1984.

Constraints to Progress:

The lack of equipment for conducting field experiments such as drying facilities, plant choppers and small hand operated tractors could hinder the quantity and quality of research.

Applicability of Results to TropSoils Goal:

Potassium availability and reserves in the weathered soils of the humid tropics are generally very low. Addition of fertilizer K is the only means for supplying the needed K. These studies will provide needed information as to the amounts of K required and the soil K levels that will result from given rates of fertilizer K.

The results of this study will be important for developing a soil management program which provides for the efficient use of K fertilizers in highly weathered soils.

Training Component:

Mr. Gill is a candidate for the Ph.D. degree at North Carolina State University and is interested in pursuing a career in international agricultural research. This research will be used for his doctoral thesis.

PHOSPHORUS RATES AND METHOD OF APPLICATION

Leadership Personnel:

Mike K. Wade, NCSU
Djoko Santoso, CSR

Date Research Initiated:

January, 1984

Rationale for Investigation:

Current transmigration policy is to supply triple superphosphate (TSP) at the rate of 100 kg/ha twice per year, irrespective of soil type, soil analysis, or crop 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. This research will aid in the development of a soil test correlation data bank that can assist scientists and policy makers in making scientifically-based decisions for P fertilizer rates and distribution.

It has been observed that farmers generally have poor P fertilizer management practices regarding method and timing of application. The current recommendation is that P fertilizer be banded, a very labor intensive operation that farmers are reluctant to follow. A more labor efficient application method that can achieve equal or better crop production is surely needed; especially for these farmers who do all field operations with a few simple hand tools.

Objectives:

A. To determine optimum rates of TSP fertilizer on a newly cleared clay loam Ultisol

B. To determine cost:benefit ratio of various methods of applying TSP fertilizer

C. To study long-term effects of various P management schemes

D. To determine critical P soil test values for rice, peanut and cowpea

Experimental Approach:

The research is conducted in the Sitiung transmigration area of West Sumatra.

On-farm, researcher-managed, low input trials are used. Three replications, of the following treatments were applied.

- No P
- 20 kg P/ha broadcast and incorporated
- 40 kg P/ha broadcast and incorporated
- 80 kg P/ha broadcast and incorporated
- 20 kg P/ha banded
- 40 kg P/ha banded
- 80 kg P/ha banded
- 20 kg P/ha placed in dibble hole 5 cm to the side of the seed hole
- 20 kg P/ha placed in hole with seed
- 20 kg P/ha banded inbetween every other row
- 80 kg P/ha broadcast and incorporated plus 2T lime, 50 kg K and 100 kg $MgSO_4 \cdot 2H_2O$ per ha

The source of P was triple superphosphate

It is hypothesized that if Al tolerant crops are grown (prior to treatment the soil had 40% Al saturation), then P would be the major nutrient limitation. Therefore for this low input approach only P fertilizer has beer applied, except for one 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.

State of Progress:

There was a marked response to P, as yields increased from about zero to nearly a ton/ha at the highest rate. There were no significant yield differences between the banded and broadcast treatments. Three additional methods of applying the fertilizer were tested at the 20 kg rate. Again there was no significant difference among the methods.

Yield levels were low, even with high inputs. The response curve did not reach plateau yields, indicating P may still be limiting. In addition, the variety (locally obtained from new transmigrant farmers) did not appear to be well suited to this region. At flowering and early pod set stages, the crop suffered from both leaf and wilt diseases.

The current crop is mungbean. Because peanut did not show a plateau yield, all P treatments were reapplied prior to planting. Unlike peanut, this crop is exhibiting considerable within-plot variability. From other experiments we now know that mungbean is quite Al sensitive, and it is suspected that soil acidity is responsible for the variability.

Soil test levels of P increased with P rates. The relationship indicates little initial P fixation and that predication of available P should not be difficult.

Constraints to Progress:

This experiment requires rapid turnaround on soil and plant analyses to better predict or evaluate the rates of lime and fertilizer should be used on subsequent crops. Growing three crops a year with virtually no break puts great and constant demand on laboratory facilities. We have a small functional lab (approx. 20 samples per day of pH, bases and P) for soils. This must be upgraded if it is going to meet the local demand. Also equipment for doing plant samples is very much needed.

The peanut crop was strongly affected by an apparent poor choice in variety selection. There is a serious shortage of developed or improved varieties of all the upland crops. Sometimes seed is even difficult to find in Bogor. It appears that the best solution to this problem is for us to have our own seed storage facilities. High oil content seeds such as soybeans and peanuts will maintain good viability in ambient conditions for only 2-3 months.

The peanuts did not nodulate. We had no inoculant at planting time for peanuts. Only soybean inoculant is regularly produced in-country. No other seed or forage legume inoculant is available.

Applicability of Results to TropSoils Goal:

This research can help build a nationwide P soil test correlation data bank for making site-specific P fertilizer recommendations.

Current national production programs usually call for a blanket P rate for all growers, ignoring soil test levels and soil type. Such a practice is inefficient as some soils need little or no P fertilizer, while others need large doses. Accurate methods to predict optimum rates of P will encourage farmers to use fertilizers and to use them effectively.

More labor efficient methods of P application are needed for these non-mechanized farmers. The experiment showed that the currently recommmended banding method required 275 person-hours/ha of labor, while broadcasting took only 40. Nearly all Javanese farmers hoe their land between crops anyway, so incorporation is not additional labor. Even if no tillage is done, the method of adding fertilizer in the seed hole only required 80 person-hours/ha and was equally effective as banding in improving yields (at the 20 kg P/ha rate).

Training Component:

This project is helping to train CSR personnel involved in methods of determining fertilizer rates. Pre-treatment lab incubation studies, post-harvest soil analyses and correlation with treatment and crop yield exhibit the process involved in choosing and evaluating P fertilizer rates. The foundation for soil test correlation is being laid.

General use of the laboratory in P determination and incubations is training the technicians in useful techniques that can be expanded and carried-on in future years.

SOURCE AND METHOD OF LIME APPLICATION

Leadership Personnel:

Mike K. Wade, NCSU
Agus Sophian, CSR

Date Research Initiated:

September, 1983

Rationale for Investigation:

The Indonesian government has made a new commitment to developing their "palawija" crops, i.e., food crops other than paddy rice. To provide information for this objective, a large scale liming program was initiated in 1983. At present the most common, if not the only, available source of lime in many areas is burned lime. It has certain advantages as liming material: (1) It can be produced as a home industry with little or no capital investment (an earthen or dug kiln and firewood), (2) it is very reactive and therefore relatively low doses are adequate to reduce toxic level of Al and (3) it is an established industry in many places (although its end-use has not been for agricultural purposes). Its main disadvantage may be in its short residual effect. The other possible or likely source of lime is ground limestone, either calcitic or dolomitic. The advantages of ground lime are: (1) it has a longer residual effect and (2) it ultimately may be cheaper if produced on a large scale. Its principle disadvantage is that it takes a fairly significant capital investment to purchase the grinding equipment. Also, quality control may be more difficult as just about any rock can be ground and not visually distinguished from lime. Only two carbonaceous materials can be heated and subsequently slaked by hydrolysis.

Farmers use a variety of means to till their soil, and due to the differing reactivity of these lime materials, it would be beneficial to know if one or some methods were superior to others in bringing about incorporation and subsequent reaction of lime in the soil.

Objectives:

A. To compare burned lime and ground limestone for effectiveness in neutralizing soil acidity and improving crop production

B. To compare the residual effect of the two liming materials

C. To study the effect of tillage on effectiveness of lime

D. To study the effect of tillage on crop growth and soil physical parameters

Experimental Approach:

On-farm, researcher-managed trials are used in the Sitiung transmigration area of West Sumatra.

The treatments are:

A. Lime Source
   1. none
   2. burned lime
   3. ground limestone

B. Application method
   1. surface broadcast - no till
   2. hoe incorporation - 15 cm
   3. cattle drawn plow - 15 cm
   4. rototiller - 15 cm
   5. deep spading - 30 cm

The burned lime was applied at 1.2 x exch. Al (1.33 t/ha), while the limestone, due to low solubility, was applied at 1.5 x exch. Al (2.25 t/ha). For the deep spading treatment the lime was applied at 2x the above rates as incorporation was to 2x the depth of the other treatments. In the no-till plots, 1/3 the lime rate was applied before planting of each crop. Three crops were grown during the season (rice, peanuts and mungbeans) and thus the same annual amount of lime was used.

State of Progress:

Rice did not respond to lime or tillage treatments. Initial soil reaction was pH = 4.8 with 55% Al saturation. Upland rice is expected in most cases, to tolerate such levels of acidity.

Peanuts are not as tolerant to soil acidity as rice but this crop too showed little response to lime or tillage. Although there were no significant differences ($P > .05$) the limed plots generally gave higher yields than the no-lime treatment. The deep tillage (spading) treatment tended to give higher yields but again, no significant differences among tillage treatments were obtained. Yield level of all plots was quite low. The rice straw from the previous crop was used to mulch the peanuts. However, rainfall during the 85 day growing period of the peanuts was almost 1000 mm. The combination of high rainfall, mulch, and drainage from higher areas kept the soil almost constantly saturated. The peanuts did not grow well, looking stunted and yellow from apparent lack of oxygen throughout the growing cycle. This may well have suppressed a lime response. The deep tillage treatment may have permitted better drainage and explains the somewhat higher yields under this treatment.

The final crop of the 1983/84 season was mungbeans. This crop is very sensitive to Al toxicity and showed a strong response to lime. Harvest is currently under way, so no data is available. However, most no lime plots are bare or at best have very stunted and low- or non-producing plants. Visually the no-till treatments are the poorest and the deep tillage are the best. Subsequent soil chemical and physical property measurements should help explain why these responses occurred.

Soil samples are being taken at 0-5, 5-10, 10-15 and 15-30 cm depth every 6 months. The pending analyses will allow monitoring of lime reaction and distribution of source by tillage.

Constraints to Progress:

The primary constraint of this experiment is laboratory facilities. The sampling with depth produces 180 samples per crop. Although this is not so many by itself, coupled with the other experiments a backlog of samples are developing. On-site facilities are capable of analyzing a maximum of 20 samples per day, when there are no chemical or personnel shortages. Frequent interruptions due to other responsibilities prevent the technician from doing more than about 50-60 samples per week. Also lack of plant sample preparation and analysis creates a serious problem in having available plant tissue analysis data in-hand.

Applicability of Results to TropSoils Goal:

This research is aimed at testing the effectiveness of the two most common sources of lime in Indonesia. It will also test the importance of tillage or method of incorporation on lime reaction. Soil analysis will show the distribution and movement of lime within the soil as affected by source and tillage. Liming agricultural land is a relatively new practice in Indonesia. This study should provide information for deciding on the kind of lime processing that should be developed. The general characteristics of both types are known, but field data are needed to quantify the relative reactivity and residual effect of the two sources. Burned lime may not be an economically feasible source in the U.S. or other developed countries, but can be rendered potentially competitive in Indonesia as a home or small-scale industry. This has obvious benefits for a country with high unemployment, and low investment funds.

Training Component:

This experiment provides the opportunity for the personnel to gain both field and lab experience with these two major sources of lime. It also allows them to experience and consider alternative tillage operations, which is a very important question for the farmers. This is in opposition to conventional research station experience where tillage is usually done by hand or wheel tractor.

RESIDUAL AND MAINTENANCE RATES FOR LIME

Leadership Personnel:

Mike K. Wade, NCSU
Eugene J. Kamprath, NCSU
Djoko Santoso, CSR

Date Research Initiated:

September, 1983

Rationale for Investigation:

Soils in the Sitiung area, as well as many in the outer islands of Indonesia in general, are quite acid. Most of these unamended soils 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%). To successfully grow such food crops as peanuts, soybeans, mungbeans, and 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.

Objectives:

A. To determine the critical level of soil acidity parameter(s) for optimum production of upland rice, soybeans, and mungbeans

B. To determine a method of predicting lime rates necessary to achieve a specified level of soil acidity

C. To determine the annual lime application rate required to maintain a specified level of soil acidity

D. To monitor the residual effect of various rates of one-time lime applications on a rotation of annual food crops

Experimental Approach:

The general procedure involves on-farm, researcher-managed studies in the Sitiung transmigration area of West Sumatra. It is designed for a minimum duration of three years.

The experiment is 2-factor factorial with 4 replications. The treatments are:

Lime rates

1. 0 T/ha
2. 1/2 T/ha (3/8 x exch Al)
3. 1 T/ha (3/4 x exch Al)
4. 2 T/ha (1 1/2 x exch Al)
5. 4 T/ha (3 x exch Al)

Lime maintenance

1. Residual only
2. Annual application to maintain first crop levels of Al saturation.

The source of lime was burned limestone.

All plots receive a blanket application of N, P, K, Mg and S at rates estimated to eliminate deficiencies.

State of Progress:

Upland rice, the first crop grown, showed little yield increase due to lime. Unlimed plots averaged 1.6 T/ha while all limed plots yielded 2.0 T/ha. However, this difference was not statistically significant at 5% level of probability and there was poor correlation between yield and soil acidity parameters such as percent aluminum saturation, pH or Ca + Mg. This is not surprising, as upland rice is known to tolerate acid soils. The unlimed plots had an average pH of 4.6, with acid saturation of 66%.

Soybeans, the second crop, showed a marked response to lime, as it is much more sensitive to acid soil.

Mungbeans, the third crop, has been grown and recently harvested. Although this crop responded sharply to lime, it grew poorly and yields are low even at high rates of lime. Marginal rainfall and leaf disease seemed to be contributing factors.

The residual effect of the lime treatment when burned lime is the form applied appears to be relatively short. Seven months after its application there was a decrease in the available soil Ca and Mg and an increase in the exchangeable Al and Al saturation. The residual effect of calcitic and dolomitic lime will probably be longer because of more coarse materials being present compared with the powdered form of the burned lime. Thus, in areas of high rainfall and potential for leaching of Ca and Mg ions, the limestone should probably contain some coarser fractions in addition to some fine particles to provide a longer residual effect.

The soil analysis for the final crop in the rotation, mungbeans, are pending. Based on those analyses, estimates will be made for maintenance doses to re-achieve first crop acidity levels in the designated maintenance plots. Then the second year's rotation will begin with a comparison of the lime response on residual vs. maintained rates. The rotation will be the same as the first year, i.e. rice, soybeans, mungbeans.

Constraints to Progress:

In addition to the need for improved soil analytical facilities and the creation of plant analytical facilities, more and better information on crop protection is needed. Disease in the rice and insects in the soybeans caused reduced yields. Low yields were achieved in mungbean without any clear cut problem being positively identified.

As with varieties, crop protection for upland crops is under the jurisdiction of the Food Crops Research Institute. But it is, as is our collaborating CSR, relatively new in working in these upland, acid and infertile soils of the humid tropics. Much progress has been made in the central producing areas of Java, but materials and methods used there don't necessarily work here. We have good contact and rapport with the West Sumateran Food Crops people from Sukarami, but do not have tried and proven management practices yet developed.

Applicability of Results to TropSoils Goal:

This experiment is providing information to begin building a database for correlating soil acidity parameters with crop growth. Eventually, we hope to define critical values for the major crops of the area so that more precise recommendations for correcting soil acidity can be passed on to government agencies.

The red-yellow podzolics (Ultisols and Oxisols) are prevalent on many transmigration sites throughout Indonesia. It is expected that these results, i.e. critical values and lime rate predictions, can be extended to other areas of similar soils. Once sufficient data are collected, CSR can develop a lime recommendation scheme for growers through national commodity production programs. Our results can be compared with findings from other acid soil regions to establish or confirm acid soil/lime/crop management principles.

Training Component:

The researchers involved in the experiment can learn about the dynamics of lime application; its effect on soil parameters and its reaction and movement in the soil. Once again the importance of simple lab procedures in quantifying and predicting lime requirements are being learned by the researchers and technicians involved. Also, this serves as another example of how to define and establish crop yield and soil test correlations as well as critical levels. As a service to their farmers and government agencies, this is probably one of the most lacking aspects of CSR's work. If the value of such information can be seen, then expansion and development of a nationwide program can begin.

PASTURE GRASS AND LEGUMES FOR THE HUMID TROPICS

Leadership Personnel

John Thompson, UH
D. S. Gunawan, CSR

Date Research Initiated:

January, 1984

Rationale for 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. 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.

Objectives:

A. To evaluate germplasm in a range of environments representative of the humid tropics.
B. To identify suitable cover crops for eroded lands.

Experimental Approach:

This research is conducted in the Sitiung transmigration area of West Sumatra, Indonesia. 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, palatability, productivity and survivability.

State of Progress:

These experiments were previously arranged through contacts with CSR and CIAT personnel. Jose Toledo, Coordinator of the forage and pasture project for CIAT, provided seedstocks of several species of grasses and legumes.

James Spain, pasture agronomist from CIAT, has observed the growth and was much impressed with the performance of several of the species being evaluated. His wife, who is a microbiologist, collected several samples for classification of mycorrhizae. This adds to the information on mycorrhizae in the Sitiung area which Russell Yost and his graduate students in Hawaii are compiling.

About two months ago the team also had the opportunity to discuss the native legumes of Sumatra with Ranier Schultz-Kraft who is the legume germplasm collector for CIAT. Schultz-Kraft was much impressed with the broad range of forage legumes in Sumatra and promised to return for a detailed collection and classification of local legumes. The team will be working closely with him and may utilize some of these species in the legume evaluation in Sitiung.

One grass and four legume species show promise as cover crops to reclaim eroded land and at the same time serve as animal feed.

The grass species which performs very well is Brachiaria dietyoncura. The legumes are:

- Aeschinamene histrix - This is a very vigorous legume with quick recovery. It should be compatible with a vigorous grass such as Brachiaria.
- Centrosema maerocorpem; C. Pubescence and C. sp. - Both appear to be well-adapted and vigorous.
- Pueroria phaseolides - In spite of some insect problems, this species now appears to be well-established.
- Desmodium ovalifolium - This legume was slow to establish but it now appears to be well-established. Some of the Stylosanthes and Zornia species also appear to be well-adapted to the Sitiung area.

Constraints to Progress:

See Overview

Applicability of Results to TropSoils Goal:

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.

Training Component:

Pasture grasses and legumes serve as training elements in erosion control, green manuring, biological nitrogen fixation, ecology of mycorrhizae, animal feeding, land reclamation and ground cover for rubber plantings. 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.

SOYBEAN VARIETY EVALUATION

Leadership Personnel:

Mike K. Wade, NCSU
Heryadi, CSR
Martono, CSR

Date Research Initiated:

February, 1984

Rationale for Investigation:

Soybean is one of the major food crops in Indonesia. Any research, soils or otherwise, will be affected by variety used. Improved soybean varieties suitable for the low elevation humid tropics are relatively scarce. Soybean varieties are notorious for site specificity and few data are available from trials under soil and climate conditions similar to those in Sitiung. It is deemed quite beneficial to use tested varieties in our soil management trials. To lose an experiment due to poor yields or erratic response because of an unknown or poorly chosen variety is very costly in both human and financial resources. It is perhaps ultimately more beneficial to actually screen varieties and lines for Al and/or low P tolerance. However, this initial trail is needed to help select good genetic stock for use in research.

Objective:

Test available soybean varieties in the Sitiung area under high input technology.

Experimental approach:

Preliminary screening of common soybean varieties in a thrice replicated trial on an Oxisol was conducted in the Sitiung transmigration area of West Sumatra. It was limed to 1.5 times the exchangeable Al (3.25 T/ha) and received 40 kg P and 100 kg K/ha. Seed was inoculated with rhizobium received from NIFTAL.

State of Progress:

Six varieties were tested. Wilis, obtained from the old Benchmark project, produced very well. It grew very well vegetatively, matured in 90 days, and had large seeds. A line (B-3038) from Food Crops in Bogor grew well also, even taller than Wilis, but the seed was very small and yields were lower than Wilis. Orba, the most common improved variety in Indonesia, did poorly.

The Wilis variety was subsequently tried at another location that previously had been limed and fertilized and planted to Orba. Orba growth had been poor and yield was less than 500 kg/ha. Early vegetative growth of the Wilis, with no additional lime or fertilizer, was markedly superior to what Orba had been (height at 30 days was 28 cm for Orba and 45 cm for Willis).

The variety trial is completed, but will be repeated as more varieties are collected from whatever sources for testing in Sitiung.

Constraints to Progress:

Availability of good quality varieties is quite limited even on a research level. Contacts with other Indonesian agencies and projects need to be improved. Better yet would be contacts with international sources, such as INTOSOY, AVRDC, etc., to help introduce and test more germplasm in Indonesia.

Applicability of Results to TropSoils Goal:

Varieties that perform well in Sitiung would be possible candidates for other analogous areas of Indonesia, as well as humid tropical areas of South America and Africa. Initial screening here can help select varieties suitable for testing in other tolerance-type trials such as soil infertility, insects, diseases and water stress which can be an effective means of increasing production. Also using tried and proven varieties in our management trials can help insure good yields, which, in turn, improves the credibility of our research results.

Training Component:

Conducting variety trials is a relatively simple matter but has two important functions. One, it teaches those involved how to analyze a crop. The close observations usually made in variety trials, e.g. date of flowering, days to harvest, rate of growth, fruiting characteristics, forces the researchers to observe a crop closely at all its development stages. This provides a useful background for later evaluating the performance of the crop in other type trials, such as a fertility trial. Second, variety trials usually exhibit the large differences that may occur among varieties. It illustrates the importance of knowing and choosing good varieties for our research, and it shows how the variety chosen can seriously affect or influence the results and conclusions of a given experiment.

FARMER AND RESEARCHER DESIGNED AND MANAGED CROPPING SYSTEMS

Leadership Personnel:

Mike K. Wade, NCSU
Carol J. P. Colfer, UH
Djoko Santoso, CSR

Date Research Initiated:

October, 1983

Rationale for Investigation:

Part of the philosophy of the TropSoils/Indonesia program is utilization of the FSR approach, which infers close involvement of both agricultural and social scientists with each other and with farmers. When working in our own culture, especially those with a farm background, there is usually an inherent understanding of the farm culture. However in a foreign setting, that situation does not necessarily exist. In a strict agricultural research sense it does not matter, as we can conduct experimentation on the research station that deals with soil management problems. But such an approach can have shortcomings. Since the ultimate recipient of our agricultural research is the local farmer, it seems that in order to develop effective and acceptable technology for him, we must gain an understanding of his situation, economically, agriculturally, culturally, and his thinking, goals, conflicts, government influence, etc. Such information can then help the agricultural research develop in a way that will hopefully help optimize our work toward development of effective and acceptable technology.

This research project then is not aimed so much at answering scientific questions, but is done to enhance interaction with the new transmigrants. A few treatments have been selected to test various input packages that might be used by the transmigration program. These are done on farmers' fields and managed by the farmers to see how well the packages perform under "real world" conditions. We have a good idea of what to expect of these on a station with researcher management but now we test them by the user.

Last, but not least, the interaction of the farmers and researchers allows the researchers to learn from the farmer as well as vice-versa. His years of experience have been a good teacher in how to manage his land, and we should be able to learn from it.

Objectives:

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

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

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

Experimental Approach:

On-farm, farmer-managed trials are conducted with 19 participating farmers, in the Sitiung transmigration area of West Sumatra. There is one replication per farmer; the plot size is 10 x 20 m^2. The initial plan is for a one year study, 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. Four packages tested are:

1. no inputs
2. government supplied fertilizer, i.e., 100 kg urea + 100 kg TSP/ha
3. 800 kg rock phosphate/ha + government supplied fertilizer
4. 2.5 T lime + 100 kg urea + 200 kg TSP/ha.

State of Progress:

An intercropping pattern was used consisting of rice with relay planted cassava. After the rice harvest, peanuts and chili peppers were planted between the cassava. To date only the rice harvest is complete.

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.

Although tillage was not a factor in the four treatments, it turned out to be a very critical management decision. There was no increase in production by fertilizers when the land was hoed. However if not hoed, the lime treatment was considerably better than the other packages. In the non-limed treatments, hoeing gave an approximate 50% yield increase. The area for this trial was all newly cleared land, i.e., first planting. Hoeing was very difficult due to the thick mass of roots from the previous forest. But, apparently, incorporating the forest litter (there was no general burn) had a fertilizing effect that was even greater than the urea and TSP and rock phosphate. Most of the Javanese farmers thought it best to hoe, as they traditionally do in Java. However, the root barrier deterred some of them. Also, the local (Minang) transmigrants traditionally slash and burn for upland rice cultivation and they advocated not hoeing. They did not think it was detrimental, merely a waste of time. However the situation here was somewhat different from the usual slash and burn. This forest had been felled in the rainy season and not burned. The farmers arrived and cleared the felled trees several months later during the following dry season. By then there was little dry leaf litter or twigs suitable to fire a generalized burn. Thus they had to hand cut and pile the limbs and logs.

Currently peanut and cassava harvests are being completed. Pepper failed mostly due to disease and infertility. Plans are being made to amend and continue the treatments. Next year's cropping pattern will be a simple rotation of rice and soybeans or peanuts.

Constraints to Progress:

Because of the nature of the FSR, with farmers managing the plots, the work is not particularly demanding. We only do annual soil analysis and measure only crop yields so facility demand is also minimal. The main constraint is having time to observe the plots and interact with farmers in their fields or homes. No fixed schedule is used and so this is done at our convenience when not involved in other research activities.

Applicability of Results to TropSoils Goal:

This research offers 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.

Training Component:

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 useable technologies that can be of immediate use to other new transmigrants in neighboring or similar areas. By the close association with them, 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.

COOPERATOR FARMER INTERVIEW SERIES

Leadership Personnel:

Carol Colfer, UH
Barbara Chapman, EPC
Veronica Kasmini, CSR
Bartholomeus Wied Apriadji, IPBNP
Liek Irianti, IPBNP

Date Research Initiated:

November, 1983

Rationale for Investigation:

The principle of matching the requirement 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.

Objectives:

A. To monitor characteristics of the farming families with whom the team is working.

B. To compare their lives with those of a randomly selected group of "control" farming families.

Experimental Approach:

This research is conducted in the Sitiung transmigration area of West Sumatra, Indonesia. 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 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 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 what would be useful.

State of Progress:

The most relevant benefit of this particular interview series was to provide the team with timely, focused information that relates to ongoing agricultural experimentation in the community. In the future the team expects to use this method to ascertain the profitability of the soil management innovations recommended to and adopted by the farmers.

Constraints to Progress:

See Overview

Applicability of Results to TropSoils Goal:

The applicability 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 straight-forward 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.

Training Component:

The primary training impact of this series to date has been periodic input from Colfer into decisions about agricultural experimentation.

NUTRITION/DIET/INCOME SURVEY

Leadership Personnel:

Carol Colfer, UH
Barbara Chapman, EPC
Liek Irianti, IPBNP
Bartholomeus Wied Apriadji, IPBNP

Date Research Initiated:

April, 1984

Rationale for 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.

Objectives:

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

Experimental Approach:

This research is conducted in the Sitiung transmigration area of West Sumatra, Indonesia. 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 actual food consumption data would be as accurate as practical and relying as little as possible on memory. 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.

State of Progress:

The results showed Sitiung I and II to be grouped together, incomewise, at the top and bottom of the ladder. Sitiung V was generally in the middle, from an income standpoint. Incomes range from approximately $8.00 to $200.00 per month. Nutritional status was marginally adequate. The lack of variety in the diets was suggested as a possible contributor to their nutritional deficiencies. Virtually no meat was consumed by the people in any of the locations. The nutritionists warned the team of a danger in focusing on high value crops, the reason being that the people will sell them rather than consume them to improve their nutritional status. They also suggested that the team introduce some of the variety of seeds for edible plants available in Java.

Contraints to Progress:

See Overview

Applicability of Results to SM-CRSP Goal:

The applicability 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.

Training Component:

Training activities were limited to the informal interaction that occurred between team members and the visiting researchers. Some team personnel were alerted to nutritional inadequacies and possible agricultural solutions; but the regular seminars that had been planned could not be arranged due to Colfer's illness.

TIME ALLOCATION STUDY

Leadership Personnel:

Carol Colfer, UH
Atin Kurdiana, CSR
Edi Santoso, CSR
Veronica Kasmina, CSR

Date Research Initiated:

September, 1983

Rationale for 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 corresponds to farmer needs.

Objectives:

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

Experimental Approach:

This research is conducted in the Sitiung transmigration area of West Sumatra, Indonesia. 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.

State of Progress:

The data are currently being entered into the computer to form a data base from which specific soil-management-related questions can be asked related to people's usual activities. The large number of observations and their random nature permit reasonably accurately generalizations to the general populace. The fact that two very different transmigration sites were used, one representing a long-established one and the other a newly-settled site, allow the team to ascertain important differences based on length of residence. These data will also provide a measure of the changes that occur over the course of the research.

The team has already had cause to question the frequency with which people must search for grass for their cattle and goats, the division of agricultural labor between the sexes, the incidence of off-farm employment, monthly variation in productive activities of adults, among others. When the data are fully entered into the computer system, they will be much more accessible to team members.

Constraints to Progress:

Refer to Overview

Applicability of Results to TropSoils Goal:

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.

Training Component:

The training of CSR personnel in this kind of study can contribute to a more people-oriented research agenda for the future, as well as teaching soil scientists one of the techniques for maintaining awareness of community concerns and interests. A number of CSR personnel have been involved in data collection for this study. This provides a mechanism by which they regularly interact with farmers, becoming attuned to their concerns, constraints and goals. This in turn effects their decisions about the kinds of experimentation that are likely to yield agricultural technology that can be used by farmers.

HUMID TROPICS

PERU AND BRAZIL

HUMID TROPICS PROGRAM **** PERU **** BRAZIL

ORGANIZATION

Lead Institution

North Carolina State University

Collaborating Institutions

Instituto Nacional de Investigación Agropecuaria
Unidade de Execucao de Pesquisa de Ambito Estadual de Manaus

Linkage Institutions

Centro Internacional de Agricultura Tropical
Centro Internacional de la Papa
Corporación de Desarrollo de Loreto
Empresa Brasileira de Pesquisa Agropecuaria
International Council for Research in Agroforestry
International Fertilizer Development Center
International Institute for Tropical Agriculture
Instituto Interamericano de Coorperación para la Agricultura
Instituto de Investigaciones de La Amazonía Peruana
Instituto Veterinario de Investigación del Tropico y Altura
Potash and Phosphate Institute
Proyecto Especial Alto Huallaga
Proyecto Especial Madre de Dois
Proyecto Especial Pichis Palcazu
Red de Investigación Agroecologica para la Amazonía
Rockefeller Foundation
Universidad Nacional Agraria - la Molina
Universidad Nacional de la Amazonía Peruana

Universidad Nacional de la Selva - Tingo María

Research Sites

Primary:

Yurimaguas Agricultural Experiment Station, Yurimaguas Peru

Secondary:

Unidade de Execucao de Pesquisa de Ambito Estadual de Manaus, Manaus, Brazil

La Esperanza Experiment Station, Pichis Valley, Peru

IVITA Principal Tropical Station, Pucallpa, Peru

Tulumayo Experiment Station, Tingo María, Peru

Puerto Maldonado Experiment Station, Madre de Dios, Peru

Principal Investigators

Pedro A. Sanchez

John J. Nicholaides, III

Representatives on Board of Directors

Lead Institution

Robert H. Miller

Collaborating Institution

Victor Palma

HUMID TROPICS PROGRAM **** PERU **** BRAZIL

TECHNICAL PERSONNEL

Name, Degree	TropSoils Responsibility	Affiliation
Pedro A. Sanchez, Ph.D.	Soil Management[1/]	NCSU
John J. Nicholaides, Ph.D.	Soil Fertility[1/]	NCSU
Julio C. Alegre, M.S.*	Soil Physics	NCSU
Miguel A. Ara, M.S.*	Soil Management	NCSU
Luis Arévalo, M.S.	Soil Chemistry	INIPA
Miguel A. Ayarza, M.S.*	Soil Management	NCSU
Andrés Aznarán, B.S.	Agric. Engineering	INIPA
Dale E. Bandy, Ph.D.	Soil Management	NCSU
Joaquim B. Bastos, M.S.	Soil Management	EMBRAPA
José R. Benites, Ph.D.	Soil Management	NCSU
Stanley W. Buol, Ph.D.	Pedology	NCSU
Eber Cárdenas, B.S.	Pastures	UNAS
Rafael Chumbimune, M.S.	Soil Fertility	INIPA
D. Keith Cassel, Ph.D.	Soil Physics	NCSU
Jose Carlos Correa, M.S.	Soil Management	EMBRAPA
Charles B. Davey, Ph.D.	Forest Soils	NCSU
José R. Davelouis, M.S.*	Soil Management	UNA
Dennis del Castillo, Ph.D.	Soil Management	NCSU
Rolando Dextre, Ing. Agri.	Soil Management	INIPA
Helmut Elsenbeer, M.S.*	Soil Physics	NCSU
Martha Gallo, Ing. Agr.	Soil Fertility	INIPA
Expedito U. Galvao, M.S.	Crop Science	EMBRAPA
Marco Gávez, Ing. Agr.*	Agronomy	INIPA
Mwenja P. Gichuru, M.S.*	Soil Fertility	NCSU
Robert E. Hoag, M.S.*	Pedology	NCSU
Hemilce Ivazeta, Ing. Agr.	Pastures	INIPA

Lisa B. Katz, M.S.	Soil Fertility	NCSU
Jonathan López, Ing. Agr.	Agronomy	INIPA
Robert E. McCollum, Ph.D.	Soil Fertility	NCSU
Jane Mt. Pleasant, M.S.*	Weed Control	NCSU
Ruben Mesía, Ing. Agr.	Extension	INIPA
George C. Naderman, Ph.D.	Soil Management	NCSU
Laurie R. Newman, B.S. *	Pedology	NCSU
Marco A. Nureña, Ing. Agr.	Extension	INIPA
Cheryl A. Palm, M.S.*	Soils-Agroforestry	NCSU
Jorge R. Pérez, Ing. For.	Agroforestry	NCSU
Beto Pichanasi, Ing. For.	Agroforestry	INIPA
Melvyn Piha, M.S.	Soil Fertility	NCSU
Antonio Polo, Ing. Agr.	Agronomy	INIPA
Carlos Pomareda, Ph.D.	Economics	INIPA
Martti Poutannen, B.S.	Agroforestry	IDSF
Jamie Powell, B.S.	Soil Chemistry	NCSU
Alfredo Rachumí, Ing. Agr.	Agronomy	INIPA
Kenneth Reátegui, M.S.	Pastures	NCSU
Olga Rios, M.S.	Soil Chemistry	UNP
Alcibíades Sanchez, Ing. Agr.	Perennial Crops	PEPP
Rodolfo Schaus, Ing. Agr.	Soil Management	NCSU
Paul C. Smithson, M.S.	Soil Chemistry	NCSU
Thomas J. Smyth, Ph.D.	Soil Fertility	NCSU
Lawrence T. Szott, M.S.*	Agroforestry	NCSU
Johannes Van Diepen, M.S.	Soil Management	NCSU
Jorge Vela, Ing. Agr.	Pastures	INIPA
Manuel Villavicencio, Ph.D.	Soil Management[2/]	INIPA
Adelo Vivanco, Ing. Agr.	Soil Fertility	INIPA

[1/] Also, Principal Investigator.

[2/] Also, Director YAES.

* Enrolled in a graduate program leading to next highest academic degree.

HUMID TROPICS PROGRAM **** PERU **** BRAZIL

AN OVERVIEW[1/]

This program is rooted in the experiences, results and infrastructure developed during the preceding 12 years of collaborative soils research in Peru and other countries in Latin America. A recognition of the relationships, organization and operational procedures which evolved from these activities is important to an understanding of this TropSoils

Since 1971 The Tropical Soils Program at NCSU has operated as the international component of the Soil Science Department for teaching, research and extension. Although it has its own office and laboratory facilities, its activities are woven through the fabric of the Department, with participation of faculty members who carry both domestic and international responsibilities. Of the 41 present faculty members in the Department, 20 have had significant involvement in the Tropical Soils Program. Approximately 38 percent of the M.S. and Ph.D. degrees awarded by the Soil Science Department from 1973-1981 are based on thesis research related to tropical soils. Many of these graduates occupy key leadership positions in soil science around the world.

Field research started in 1972 with the establishment of cooperative experiments at primary sites in the humid tropics (Yurimaguas, Peru), acid savannas (Brasilia, Brazil) and the volcanic highlands of Central America (Turrialba, Costa Rica). Cooperative relationships were

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[1/]Prepared by Pedro A. Sanchez and John J. Nicholaides, III, Principal Investigators.

developed and formal agreements were signed with the predecessor agencies of INIPA in Peru, EMBRAPA in Brazil and CATIE in Costa Rica. The Central American program produced the first multiple cropping research focus in this region and led to the farming systems program of CATIE. Work in the Cerrado of Brazil, conducted jointly with Cornell University, developed basic soil management technology for savanna Oxisols and was instrumental in establishing the research program at EMBRAPA's Cerrado Research Center.

The humid tropical component of the program has operated for 12 uninterrupted years in spite of funding shortages and political upheavals. A strong commitment by the Peruvian research institutions, the Office of Agriculture of AID/Washington and NCSU, permitted an opportunity for continuous direct involvement of NCSU at one key location, Yurimaguas, Peru. Core funding for the program has been provided by AID through Contract AID/csd 2806 "Agronomic-economic research on tropical soils" from 1970 to 1975, by Contract AID/ta-C-1236 "Discovery of new management systems for tropical soils" from 1976-1981, and from the Soil Management CRSP since 1981.

As NCSU's Tropical Soils Program became better known, several institutions requested assistance in various ways. A change in government priorities in Peru towards development of the Selva prompted USAID/Lima and various Peruvian institutions to request our involvement in country programs involving research, extension and training in tropical soil management. The question of whether the Yurimaguas technology is applicable to the drier humid tropics in Brazil prompted a cooperative project in Manaus jointly funded by the Rockefeller Foundation, the Potash-Phosphate Institute and EMBRAPA. The emergence of REDINAA carried a request to develop an Amazon-wide soils project. A similar development for IBSRAM led to involvement in designing a worldwide acid tropical soils network.

Funding availability necessarily limited the extent to which a favorable response could be given to such requests. Thus, a decision was made to seek other sources of funds to supplement those provided by the CRSP. Several donors responded positively, some granting funds directly to NCSU and others to our counterpart national institutions such as INIPA. The "collaborative" word in the CRSP became a reality in terms of funding. What formerly was a single donor-sponsored program, therefore, became a multi-donor program. Because all funds are for programs that support TROPSOILS objectives, funds from the Soil Management CRSP are considered as "core," while those from other donors are considered as "special projects." In addition to INIPA and EMBRAPA's core budget contributions, the other donors supporting this program are USAID/Lima, the Rockefeller Foundation, Potash-Phosphate Institute, Corporacion de Desarrollo de Loreto, Proyecto Especial Pichis Palcazu, and the International Development and Research Centre.

Stages of Program Development:

NCSU's Tropical Soils Program activities in the humid tropics have gone through several stages characterized by technical focus, involvement of collaborative institutions and funding. A summary of this development is shown in Table 1.

Stage 1: The establishment phase took approximately two years between contract awarding and the initiation of field experiments. Much of the effort was geared towards reviewing the available literature and extensive travel through the Latin American tropics to establish the research priorities and a work plan. This effort culminated in a state-of-the-art publication, "A Review of Soils Research in Tropical Latin America," published in 1973 in English and Spanish.

Soil characterization to understand the properties and variability of Amazon soils was also a major undertaking. The selection of the Yurimaguas Station was a consequence of such studies. Time has proven that it is indeed a site representative of the kinds of climatic, soil, vegetation and socioeconomic constraints of the humid tropics. The degree of expression of these constraints, however, varies widely within the region. During this stage, the Fertility Capability Classification (FCC) system emerged as a means for interpreting Soil Taxonomy data for agronomic purposes.

Stage 2: The field phase started with the posting of NCSU staff at Yurimaguas in July 1972 with work on mapping, land clearing and

Table 1. Stages of development of NCSU's Tropical Soils Program in the humid tropics.

Stage and dates:	I Establishment 1970-71	II Continuous Cropping 1972-79	III Management Options 1980-85
Focus	Establish program	Text continuous cropping hypothesis	Develop different options for soil-landscape-infrastructure situations
Main activities	Priority development Site selection Agreements	Soil characterization Land clearing Fertility dynamics Multiple cropping	Stability of high input systems Low input technology Legume-based pastures Agroforestry Paddy rice for alluvial soils
Main accomplishments	Review of soils research in tropical Latin America Yurimaguas Station established	Feasibility of continuous cropping proved, with proper land clearing, fertilization and liming	Quantified long-term effects on soil properties Developing promising options for low input cropping, pastures and agroforestry Paddy rice technology applied
Research output	FCC concept	Basic understanding of dynamics after clearing rainforest attracts international attention	Long-term effects on soil properties Managed fallow concept Components of different options FCC gains wide acceptance
Extrapolation	None	San Ignacio, Bolivia Around Yurimaguas	Manaus, Sumatra INIPA Selva Program REDINAA network development IBSRAM network development

Table 1. (continued)

Stage and dates:	I Establishment 1970-71	II Continuous Cropping 1972-79	III Management Options 1980-85
Training	None	Limited to NCSU graduate students	NCSU, UNA and European Univ. Short-term training of research and extension workers
LDC participation	None	Virtually none until 1978 Strong moral support, but no funds	Major Peruvian involvement, also Brazilian, Indonesian, USAID Missions, IARC's
Funding	100% AID-Washington	100% AID-Washington	70% AID-Washington 30% LDC, USAID Mission and Others

continuous cropping. Efforts concentrated on testing the hypothesis that continuous cultivation of annual food crops is possible in acid infertile soils of the humid tropics. Nutrient dynamics were followed and a series of experiments on fertilization, liming, multiple cropping, structure regeneration, land clearing options were conducted. The FCC system as a precursor of extrapolation efforts continued to be tested. Modest extrapolation efforts began in 1978 at San Ignacio, Bolivia, and on farms around Yurimaguas. This phase culminated with the finding that after eight years, continuous cropping is indeed feasible in agronomic terms provided the marketing infrastructure is present.

The main impact of this phase was the elimination of the myth that these soils are not suitable for cropping, a finding that attracted international attention because it provided a new outlook for world food production. Land clearing research provided the basis for fundamental changes in Brazil's land development approach in the Amazon.

Stage 3: The advent of the Soil Management CRSP and the change in Peruvian government priorities towards the Selva cast the Program in a very different light. Worldwide assessments recognized the importance of research on marginal lands vis-a-vis the green revolution approach. Ecological concerns about deforestation in rainforest areas brought additional attention to soil management research.

It became clear that providing the continuous cropping hypothesis with solid, long-term data was a necessary but not a sufficient condition for the utilization of this technology. The program then began to focus on several soil management options suitable for different soil, landscape and infrastructure conditions. A model emerged which considers low input approaches such as use of acid-tolerant germplasm and managed fallows, legume-based pastures and agroforestry (Figure 1). Attention began to be given to the fertile alluvial soils as an important component. The Tropical Soils Program broadened its scope from one option (fertilizer-based continuous cropping) to five.

Participation of Peruvian institutions, both in terms of funding and personnel, mushroomed. Paddy rice research on alluvial soils began with direct support from CORDELOR. INIPA and USAID/Lima assigned significant PL-480 funds to support both the physical plant and operations at the Yurimaguas Station. The strengthening of INIPA under the Integral REE Program financed by USAID/Lima, the World Bank and the Interamerican Development Bank resulted in the development of a National Selva Program with 197 research and extension professionals stationed throughout the Selva of Peru. On-the-job training of 46 Peruvian professionals resulted in an extrapolation program operated on-site and financed from sources other than the CRSP. INIPA and USAID/Lima requested a major increase in the training/extrapolation activities. Outside Peru, two major research sites began to test the Yurimaguas technology on a systematic basis: at EMBRAPA's Manaus Station and at Sitiung in West Sumatra, Indonesia. A third site, the Pichis-Palcazu in Central Peru, started in 1984. In addition to the National Selva Program, two additional networks are at advanced stages of development, REDINAA for the Amazon and IBSRAM for acid tropical soils on a worldwide basis. International testing and adoption of the FCC system is in progress in Asia, Africa, Latin America and the United States.

Current Status of the Tropsoils Work Plan:

The Work Plan presented in May 1982 to the TropSoils Technical Committee was based on the CRSP grant documents, an AID-sponsored review in October 1981 and an NCSU internal review in October 1982. The final version dated 15 February 1983 constitutes our research commitment to the CRSP for the five-year period. The Work Plan includes 72 experiments organized into six projects.

The Work Plan defines the overall purpose of NCSU's Tropical Soils Program as follows: "to develop and transfer, together with national institutions and other TropSoils universities, improved soil management technologies for productive and sustained farming systems in humid tropics and acid savanna ecosystems on an agronomically, economically and ecologically-sound basis."

The Work Plan lists six specific objectives for 1982-1986. A short discussion of the accomplishments and shortcomings at approximately the midpoint of this period follows.

A. Determine the Long-Term Stability of Continuous Crop Production Systems Based on Judicious Lime, Fertilizer and Management Inputs for Soils of the Humid Tropics.

Data on crop performance and soil fertility dynamics during the first eight years of the continuous cropping experiment were analyzed during this period and published in articles in Science and the Soil Science Society of America Journal in 1982 and 1983, respectively. The agronomic and economic data plus a hypothesis on their ecological implications were included. This high input approach was recognized as being limited to areas with ready accessibility to inputs and a good market infrastructure. Examples of such conditions are found in the Alto Huallaga region of Peru and in West Sumatra, Indonesia.

During the 1982 internal review, it was recognized that for such continuous cultivation to be truly stable, it has to be mechanized to provide a realistic management of crop residues, weed control and maintenance of physical properties. Deeper plowing resulted in higher phosphorus requirements caused probably by mixing part of the subsoil with fertilized topsoil. Weed control is being studied for the first time on a systematic basis.

B. Develop Soil Management Practices for Continuous Crop Production Systems Based on Low Lime, Fertilizer and Tillage Inputs.

Concentration on low input technology was strongly recommended by the 1981 AID Review of the previous program. A conceptual paper was developed, together with CIAT, summarizing current information on low input technology for acid soils and providing a conceptual basis for the approach. The paper was published in Advances in Agronomy in 1981 and the Spanish translation in 1983 by the Colombian Society of Soil Science. The strategy is based on selection of acid-tolerant cultivars, minimum tillage and fertilization, weed control and managed fallows. The more immediate potential applicability of this approach to small farmers in the humid tropics resulted in major efforts directed toward this objective since the CRSP was initiated.

Several key components have come to fruition in the past two years. Upland rice and cowpea cultivars from IITA that combine high yields and acceptable tolerance to pests and diseases with tolerance to high levels of Al saturation have been identified and are now being widely tested through our INIPA collaborators. We have failed, however, to obtain similar results with corn, soybeans, peanuts or winged beans. Screening continues and peanut work is now involving specific crosses made in North Carolina which are tested in Peru. Work with minimum tillage, residue management and their fertility interactions have yet to provide clear evidence of the superiority of minimum or zero tillage, unlike what has happened on Alfisols of IITA. The promotion of faster downward movement of Ca and Mg is being tested. Fertility-weed control interactions are now being studied. A farm level low input central experiment has shown the feasibility of upland rice-cowpea rotations starting with forest clearing with zero tillage, proper spacing and only small rates of N and K have produced a total of 10.3 tons/ha of rice and 2.1 of cowpeas during the first two years.

We suspect that the low input system, however, is unstable as far as continuous cropping is concerned. It may last for more than two years but then a decision will have to be made about the permanent role of the field. Alternatives are high input cropping, managed fallow, grass-legume pastures, or agroforestry. One way to maintain a "continuous" low input system is to rotate one or two years of crops with one to three years of legume fallow.

C. Develop Soil Management Practices for Different Landscape Positions, Including Legume-Based Pastures, Agroforestry and Flooded Rice on Alluvial Soils.

The pasture project has provided very positive results. Three years of grazing trials using germplasm from CIAT have demonstrated the high productivity and persistence of mixtures of acid-tolerant grasses and legumes such as <u>Andropogon gayanus-Stylosanthes guianensis</u> and <u>Brachiaria decumbens-Desmodium ovalifolium</u>, with annual liveweight gains of 700 kg/ha with rotational grazing management and with minimal fertilizer inputs. This provides a promising alternative for degraded pastures in the udic tropics with low animal productivity which decreases and leads to overgrazing and subsequent soil erosion. Pasture establishment problems have been alleviated by experience and better seed sources. Regenerating degraded Panicum maximum pastures on farmer fields was simply accomplished by broadcasting Bayovar rock phosphate.

The principal problem seems to be the low nutritional quality of some grass:legume mixtures which is reflected in relatively low liveweight gains per animal. Initial work in this direction has identified high tannin content as a constraint. Phytotron work in Raleigh is testing the hypothesis that sulfur deficiency may be responsible. Plans are underway to validate initial observations of incipient nutrient recycling in well managed grass-legume pastures at Yurimaguas. The question of whether to use legumes at all is to be studied in a nitrogen transfer experiment.

Research on agroforestry continues to increase. After observational trials on Gmelina arborea intercropping and peach palm (Guilielma gasipaes)-legume interrows, work has centered on establishing the nutrient response patterns of Gmelina and peach palm on a systematic basis. The first, to our knowledge, fertilizer trial of peach palm in acid soils shows a very strong N response and also to other nutrients. Germplasm collection of this valuable species is taking place, as Yurimaguas is one of its centers of origin. These studies have led to the awarding of an IDRC grant through ICRAF for agroforestry research in Yurimaguas.

Alley cropping work began in 1983 with the overall purpose of finding species that can do in acid soils what Leucaena leucocephala does in high base status soils. One trial with several promising species is ongoing and germplasm collection from sources in the Amazon, Africa and Southeast Asia continues.

The question on how fallows regenerate soil productivity is being evaluated on a preliminary basis and more intensive research is now being done in the library to develop hypotheses and future plans.

Flooded rice production on high base status alluvial soils has been an unqualified success. Five crops of irrigated rice have been grown during two years with an average production of 16.5 tons/ha/yr. Replacing transplanting with pre-germinated broadcasted seed depressed yields by 20% but decreased labor input for crop establishment from 20 to 3 man-days/ha.

D. Extrapolate, Validate and Adapt Research Results to Other Humid Tropical Areas, Including the Peru Selva Network, Manaus, Indonesia and REDINAA Soils Network.

The request for assistance in the Selva of Peru resulted in consideration on the adaptation of the Yurimaguas results to special project areas. We expressed the need to validate the results first to make sure that local adaptations could be incorporated. It became apparent that research workers needed prior training to validate and transfer the results in a sound manner. The frequent request for short-term (1-2 weeks) training made it necessary to make on-the-job training a formal activity. During 1982 and 1983 a total of 58 professionals received on-the-job training at Yurimaguas. The 51 Peruvians came from most areas of the Selva and include researchers, extension specialists, farmers and representatives of native communities. Other training activities include graduate students from Argentina, Finland, Germany, the Netherlands and the United Kingdom. Ten NCSU graduate students are in different stages of conducting their theses research at Yurimaguas or in adjacent areas.

Participants of the 1983 Tropical Soils Management Course designed validation trials for their regions. As a result, a network of 29 cooperative trials were established throughout the Selva, on specific soil management options the participants considered appropriate for their localities (Figure 2). These trials are now coordinated through INIPA's newly established National Selva Program. NCSU staff has assisted INIPA in the development of two additional components of the National Selva Program: the National Tropical Pastures Network and the Agroforestry Project. Internationally recruited staff from CIAT and ICRAF will participate in these projects.

In 1980 an agreement was reached between EMBRAPA, IICA and NCSU to post an NCSU senior scientist at EMBRAPA's Manaus Station to test some

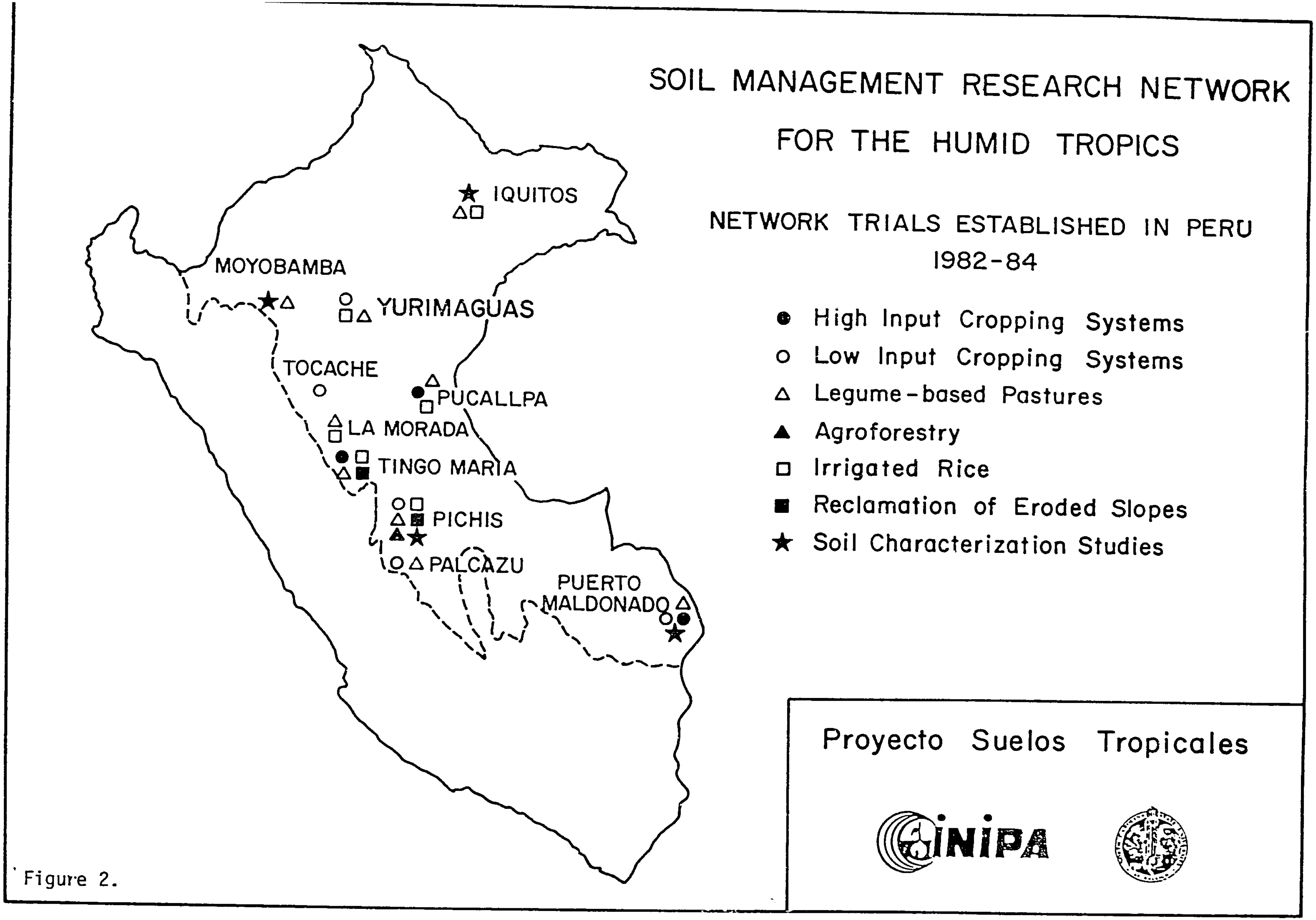
SOIL MANAGEMENT RESEARCH NETWORK
FOR THE HUMID TROPICS
NETWORK TRIALS ESTABLISHED IN PERU
1982-84
High Input Cropping Systems
Low Input Cropping Systems
Legume-based Pastures
Agroforestry
Irrigated Rice
Reclamation of Eroded Slopes
Soil Characterization Studies
IQUITOS
MOYOBAMBA
YURIMAGUAS
TOCACHE
PUCALLPA
LA MORADA
TINGO MARIA
PICHIS
PALCAZU
PUERTO
MALDONADO
Proyecto Suelos Tropicales
INIPA

Figure 2.

of the Yurimaguas experiences in the different environments of Central Amazonia. The forest ecosystem differs in Manaus in terms of a strong dry season, clayey Oxisols vs. sandy Ultisols, the clearing of primary forests and a more developed infrastructure. Results show differences in ash content, fertilizer response and soil dynamics in this different environment.

In 1984 a similar agreement was signed in the Proyecto Especial Pichis Palcazu (PEPP) with funding from the Interamerican Development Bank to post a soil physicist and a pasture specialist in the Pichis Valley of the Central Selva of Peru. This High Jungle location also differs from Yurimaguas in terms of 50% higher rainfall, virtually no dry season and rolling to steep topography. A series of trials have been designed to test the Yurimaguas results under this environment.

REDINAA and IBSRAM are about ready to become fully operational. When they do, additional opportunities for site-specific collaboration may be possible in other Amazonian countries through REDINAA, and in acid tropical soils worldwide through IBSRAM. NCSU is providing the services of the REDINAA Interim Executive Secretary stationed in Lima through a grant from the Rockefeller Foundation.

The overall linkage system of NCSU's TropSoils program is shown in Figure 3. A distinction is made between sites with an active research program, either with NCSU staff on-site or through formal linkages with cooperative institutions. The figure also indicates informal working linkages of different natures. The one with IITA is one of exchange of information and germplasm. Given IITA's extensive networks in tropical Africa, this link could be strengthened to extrapolate TropSoils results to this area and vice versa. Linkages with CEPLAC, and with ESAT at Cardenas, Tabasco, Mexico consist of designing experiments on soil management in their area of action. Strengthened linkages with IBTA-Bolivia, ICA-Colombia, INIAP-Ecuador and FONAIAP-Venezuela are anticipated with the initiation of the REDINAA soils network.

E. To Obtain Additional Soil Characterization Data for Soils of the Humid Tropics and Acid Savannas and Improve the Fertility Capability Classification System.

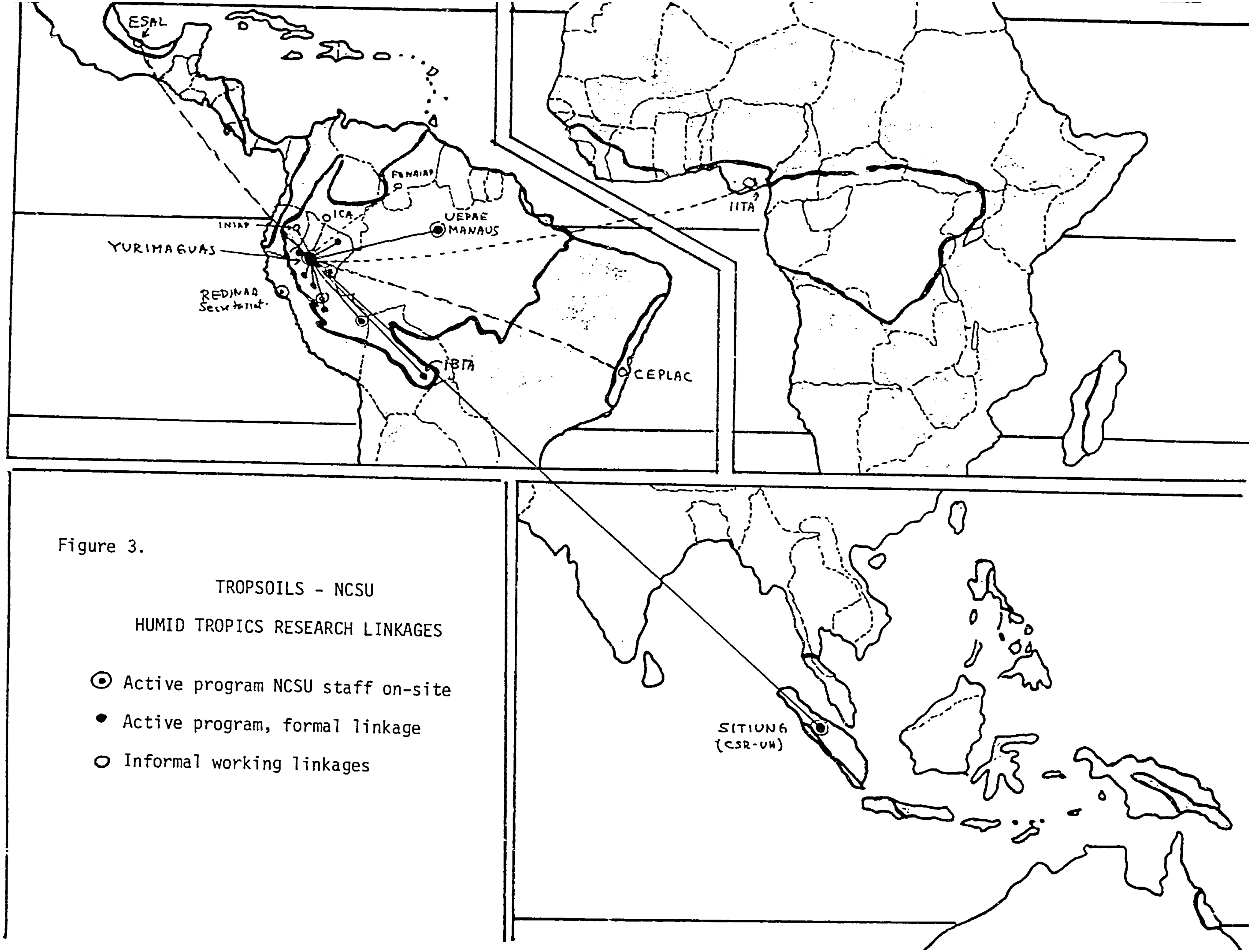

Figure 3.

TROPSOILS - NCSU

HUMID TROPICS RESEARCH LINKAGES

Cooperative research on this topic included active participation in the Soil Management Support Services (SMSS) international committees: ICOMLAS (low activity clays), ICOMAX (Oxisols), ICOMAND (Andisols) and ACOMAQ (wetlands). On-site work is limited to the Madre de Dios region of Peru with apparently more favorable conditions than other parts of the Amazon. A new project at the request of INIPA and IIAP is to characterize the alluvial soils of the Amazon with the hypothesis that variability in native fertility can be predicted from the type of sediments the rivers carry.

Work on FCC includes a second approximation published in Geoderma in 1982, including the use of FAO's World Soil Map and Agroecological Data Bank. In 1984, an adaptation of FCC for wetland soils was performed at the request of SMSS and IRRI. The system is now widely tested by the IRRI-IFDC-INSFERR Network in Asia and in other countries, and also by the Soil Conservation Service in the United States.

Software for keying Oxisols, Inceptisols and Ultisols according to Soil Taxonomy have been developed for personal computers. A similar program for FCC has also been developed.

Outlook

When this program started in 1972, it was viewed by many as a far-out, somewhat quixotic effort. The main interest then was maximizing yields on the best lands through green-revolution type technology. The need for proper management of acid soils of the humid tropics is now widely accepted. Tropical soils research has come of age in the 1980's and is acknowledged both by donor agencies and national research institutions. The benign neglect during the seventies gave us time to develop a foundation and a basic understanding of many principles of soil management in the humid tropics. The demand for this technology now, poses a different set of challenges. Research should at the same time be broader and deeper: Broader, in terms of different management options for specific landscapes and levels of infrastructure development. Deeper, for a better understanding of the changes that take place in the soil under the different options.

Many national research institutions are sharply increasing their efforts in tropical soils research. Some are perfectly capable of conducting systematic research within their boundaries. International networks that directly address soils in the humid tropics are in the process of being developed. We should provide support to these initiatives and at the same time continue generating new information from solidly established bases of operations.

EFFECT OF LAND CLEARING METHODS ON SOIL PROPERTIES AND CROP PERFORMANCE

Leadership Personnel:

Julio C. Alegre, NCSU
Keith Cassel, NCSU
Dale E. Bandy, NCSU

Date Research Initiated:

July, 1980 (under Contract AID/ta-C-1236)

Rationale for Investigation:

There have been many reports about the disastrous effects of mechanical land clearing in the humid tropics. In the early 1970s bulldozer clearing with a straight blade severely compacted soil at Yurimaguas, Peru. Several years after clearing, the land was abandoned. In spite of all of the reports about soil damage caused by mechanical land clearing, few data has documented the specific changes in soil physical and chemical properties affected by various land clearing methods.

Objectives:

A. To determine the rate of change of selected soil physical properties resulting from alternative land clearing-soil management practices.

B. To evaluate crop performance as affected by land clearing-soil management practices of an Ultisol in the humid tropics in Peru.

Experimental Approach:

The study was conducted on a 2.5 ha site on the YAES, Yurimaguas, Peru. The Yurimaguas soil (Typic Paleudult) was covered with a 20-year-old secondary evergreen forest which had 232 m^2 wood per ha.

The experimental design was that of a split plot replicated three times. The six main plot treatments were land clearing--soil tillage combinations and are defined as follows:

A. Slash and burn with tree trunk removal by hand; plant with stick
B. D-6 bulldozer with straight blade; trees immediately windrowed; plant with Planet, Jr.
C. D-6 bulldozer with straight blade; trees immediately windrowed; land chisel plowed; plant with Planet, Jr.
D. D-6 bulldozer with KG blade; vegetation dried on land burned, then logs removed by bulldozer; disk with bulldozer; plant with Planet, Jr.
E. D-6 bulldozer clearing with KG blade; rotovate land with 65 h.p. tractor; plant with Planet, Jr.
F. D-6 bulldozer with KG blade; disk with bulldozer; 14 h.p. rotovator; plant with Planet, Jr.

The main plots minimized the use of large tractors for land preparation following clearing because no such tractors are available in the area.

The disking operation that followed clearing was imposed by the same bulldozer used for the clearing operation. The disking operation cut up the larger tree roots that remained in the soil and incorporated trash left on the soil surface. Subplot treatments were various combinations of fertility and soil management practices and were as follows:

A. Flat planted; no fertilizer or lime.
B. Flat planted; fertilizer and lime added based on soil test.
C. Bedded at 1.1 m spacing; fertilizer and lime added based on soil test.

Crops were planted and harvested according to the following schedule:

Rice	November 28, 1980	March 30, 1981
Soybean	May 27, 1981	September 17, 1981
Corn	September 30, 1981	November 18, 1981
Rice	November 20, 1981	March 23, 1982
Corn	April 6, 1982	July 16, 1982

State of Progress:

A wide range of soil physical and chemical properties were intensively monitored with time. Bulk density in the 0 to 15 cm depth increased for all treatments including slash and burn; increases in bulk density induced by clearing method were greatest in the following order: straight blade > KG blade > slash and burn. Bulk density increased by only 0.1 g/cm^3 in the 15-25 cm depth for both types of bulldozer clearing. The before-clearing infiltration rate of 64 cm/hr was reduced to values equal to only 8 and 14% of this initial rate for the straight blade and KG blade, respectively. Infiltration rate for soil cleared by slash and burn maintained a high infiltration rate of 51 cm/hr.

For all crops, the slash and burn, KG blade plus burn, and straight blade plus chisel treatments had higher yields. The corn, soybean, and the second rice crop responded effectively to chiseling and disking; chiseling without disking was the poorest treatment due to compaction and resulting poor soil physical condition. The effect of the ash was significant for the first crops for those treatments where the vegetation was burned on the land. The yield advantage due to burning decreased with time.

The fertilized, bedded subplot management system was better than flat planted. Bedding promoted very uniform and faster germination; the plants were more uniform and resistant to lodging due to good root distribution. During periods of high rainfall in February and March, corn roots in the bedding system were not subjected to excessively wet soil conditions.

The following conclusions are drawn:

A. Soil compaction in the upper 15 to 20 cm evaluated by bulk density occurred for all clearing methods.

B. infiltration rate was reduced for all land clearing-soil management treatments.

C. Fertilizer nutrient released by burning was available for the first few crops.

D. Bedding increased crop yields.

E. After five crops, the trend is for yield to be of the order: slash-and-burn > KG blade, burn, disk > straight blade, chisel.

Constraints to Progress:

One constraint in initiating the experiment was the difficulty in obtaining the land clearing equipment. At the present time we are constrained by lack of help to complete a few supporting soil chemical analysis.

Applicability of Results to TropSoils Goal:

This research shows that continuous cropping can be achieved on mechanically cleared land if land clearing is followed by appropriate land preparation and soil management.

Training Component:

Julio Alegre, a native Peruvian, has gained valuable research experience conducting this study and will obtain his Ph.D. in 1985.

RECLAMATION OF BULLDOZED LAND

Leadership Personnel:

Julio C. Alegre, NCSU
Keith Cassel, NCSU
Dale E. Bandy, NCSU

Date Research Initiated:

February, 1980 (Under Contract AID/ta-c-1236)

Rationale for Investigation:

Bulldozer clearing has damaged vast hectarages of land in many areas of the humid tropics. Productivity of this land is low and in some situations it has been abandoned to agriculture. Reclamation of this land would allow it to, once again, be used for food production.

Objective:

To develop methodology for reclaiming for continuous cultivation of annual crops those soils which have been damaged by mechanical land clearing.

Experimental Approach:

In February 1980, an experiment was initiated in the YAES, Yurimaguas, Peru, to determine the best technique for reclaiming land previously damaged by mechanical land clearing. The land was damaged in 1972 with a D-6 bulldozer using a straight blade. After clearing in 1972, half of the area was cropped with rice for two years. Soil aeration and infiltration decreased, bulk density increased, and rice yields declined during this time. The other half of the area was planted to guinea grass (Panicum maximum); the land was abandoned after 4 months. Secondary regrowth of the forest was very poor and guinea grass consequently invaded the entire bulldozed area.

Selected soil physical properties were measured in these plots. A compacted zone between 15 to 45 cm depth, as evidenced by an increase in bulk density and penetrometer resistance and a reduction in the infiltration rate, was found.

Land reclamation treatments examined were:

A. Control, no till, cut grass and burn, plant with stick,
B. Control, till, cut and burn, rototill (14HP) and plant with stick,
C. Cut and burn, rototill (14HP) and plant with Planet Jr.,
D. Cut and burn, chisel plow to the 35 cm depth, rototill (65HP tractor), and plant with Planet Jr.,
E. Controlled traffic, cut and burn, rototill (14HP) and plant with Planet Jr. Assignment of pathways for foot traffic inside the plot,
F. Bedding, cut and burn, rototill (14HP) and plant with stick,
G. Digging (simulated subsoiling), cut and burn, rototill (14HP) and plant with Planet Jr., and
H. Mulching, cut and burn, rototill (14HP) and plant with Planet Jr. Mulch applied when seedlings 10-25 cm high.

A completely randomized block design with four replications was used. Rice, the first crop of the sequence was planted in February and harvested in June 1980. A basal fertilizer rate (kg/ha) of 80 N, 44 P, 66 K and 12 Mg and 1 ton/ha of lime were applied. Soybean, the second crop of the sequence, was planted in June and harvested in October 1980. A basal rate (kg/ha) of 20 N, 44 P, 66 K and 24 Mg was applied. Seeds were inoculated with Rhizobium (Nitragin). The crop was hand-weeded once.

State of Progress:

All field and laboratory work has been completed and the data analyzed statistically. Manuscripts are being prepared. A general summary of the experiment and results are presented below.

- Rice yield differences occurred. The lowest yields were on the bedding and mulching treatments. There were no differences among other treatments. The lowest straw yield was from the no-till control. No differences among the other treatments were realized. Drought periods occurred 15, 23, and 44 days after rice planting. It is assumed that the droughts extended the rice vegetative period and thereby reduced yields. The small amount of rain was not enough to maintain proper soil moisture because the potential evapotranspiration was high during the hot (33°C) cloudless days.

For all treatments, bulk density changed being lower than the initial state. The bedding and mulching treatments had the lowest bulk densities, but also gave the lowest yields. The bedding treatment had fewer plants because it had been planted with a tacarpo and the soil occupied by the pathways reduced the nontrafficked growing area. Since the only grass available for mulching at that time was flowering, many grass seed germinated and competed with the rice for water and nutrients. This plus insufficient amounts of mulch applied are the probable reasons for the negative response of rice to these treatments. For the chisel and digging treatments, there were no differences in yields or bulk density.

Since the controlled traffic treatment compared to the tilled treatment showed no differences in rice yields, it can be assumed that surficial compaction was not a problem for rice.

• For soybeans, significant differences at the 5% level were found for both stover and grain yields. The lowest yields occurred for the control no-tilled treatments. The highest yields occurred for the chisel and digging treatments. The soybean crop experienced severe water stress and yields for all the treatments were low. The mulching treatment did not show any advantage over the unmulched treatment. This may be due to the small amount of mulch applied and associated weed problems; moreover, no hilling-up was done when the second and third applications of nitrogen and potassium were applied.

Soil bulk density changed little between the first and second crops of soybeans. Penetrometer resistance was highest in the control-no tilled treatment. The mulching and bedding treatments showed lower penetrometer resistance than the tilled treatments. Surficial compaction in the tilled treatments was not a problem for soybeans.

Based on the date collected for all crops, the following conclusions can be drawn:

A. All treatments involving tillage improved soil physical conditions.
B. Water stress is a critical factor in determining rice and soybean grain yields. Rainfall distribution and soil waterholding capacity are important factors for these soils.
C. Since, before clearing, Guinea grass had grown in the plots for seven years, the topsoil (0-15 cm) had good structure and surficial compaction did not limit rice yields.
D. Significant soybean response to digging (subsoiling) was due to breakup of subsoil which was compacted by bulldozer clearing in 1972.
E. Mulching did not show any advantage over the unmulched treatment.

Constraints to Progress:

The only constraint to completion of this work is finding adequate time to prepare the manuscripts.

Applicability of Results to TropSoils Goals:

This research was directed toward removing soil physical property constraints to continuous cultivation of annual crops. It was successful in meeting this goal.

Training Component:

Julio Alegre, a Peruvian, gained valuable experience in conducting the day-to-day operations of this study. He will gain additional writing experience prior to his return to Peru as he completes the drafts of the manuscripts.

SOIL FERTILITY DYNAMICS AFTER CLEARING A TROPICAL RAINFOREST

Leadership Personnel:

Pedro Sanchez, NCSU
Carlos Valverde, INIPA
Dale E. Bandy, NCSU
Hugo Villachica, NCSU
Cesar Lopez, NCSU
Christopher Seubert, NCSU
Robert E. McCollum, NCSU

Date Research Initiated:

September, 1972 (under Contract AID/csd 2806)

Rationale for Investigation:

The 580 million ha of potentially arable land in the udic tropics with rainforest vegetation is considered the largest available area for expanding the world's agricultural frontier. These lands have no major temperature or moisture limitations, and many have topography suitable for year round crop production. In the Amazon, the main agronomic limitation is the low native fertility of the predominant well-drained soils which are classified as Ultisols or Oxisols. Soil constraints are considered so severe that it is often believed that continuous production of annual food crops is not possible in well-drained rainforest lands. In 1972, NCSU with funding provided by contract AID/csd 2806 and in cooperation with predecessor agencies of INIPA, initiated a research project in Yurimaguas, to determine whether continuous food crop production was possible in an area considered representative of the kinds of climatic, soil, and socio-economic constraints of the Amazon Basin.

Objectives:

A. To determine the agronomic feasibility of continuous production of a rotation of annual crops in acid soils of the humid tropics.

B. To characterize the dynamics of key soil fertility parameters with and without liming and fertilization during the first 8 years after clearing.

Experimental Approach:

Field experimenta were conducted on nearly level portions of the YAES in the Low Selva of Peru. The average annual rainfall is 2100 mm with no pronounced dry season but with occasional drought spells. Standing vegetation was a 30 meters tall secondary forest approximately 17 years of age in 1972. The soil classified as the Yurimaguas series, a fine loamy, siliceous isohyperthermic Typic Paleudult.

Three fields ranging in size from 1 to 2 ha each and approximately 300 m apart from each other, hereinafter referred to as Chacras I, II, and III, were selected in an area having the same soil, geomorphic position, and standing vegetation. The fields were cleared in 1972, 1973, and 1974, respectively, by the slash and burn method. The felled logs were sawed and removed, but tree stumps were left in place. A three crop per year rotation of upland rice, corn and soybeans was planted in treatments without any fertilization or lime (check) and one representing the best judgment of fertilization and liming according to soil tests. This complete treatment was modified periodically as experience and soil test data warranted. Soils were sampled after every harvest and crop nutrient uptake was determined. Data for 8 years was analyzed in 1982 and published in 1983.

State of Progress:

Ash from the burn increased soil pH, available N, P, K, Ca, Mg, and decreased exchangeable Al. Six months after burning, however, the levels of available N and K were reduced, along with sporadic S, Cu, and B deficiencies. Topsoil organic C and total N decreased at an annual rate of 25% during the first year but approached an equilibrium afterwards. The rapid organic matter decomposition probably released organic matter-bound Al which reversed the liming effect of the ash. Phosphorus and Mg became deficient during the second year, Ca within the first 30 months and Zn and Mn during the fourth year. Molybdenum deficiencies occurred sporadically, particularly when locally produced legume seed was used.

Soil chemical properties have improved with continuous cultivation because of liming and fertilizer additions. After 8 years and 21 crops, topsoil pH increased to 5.6, exchangeable Ca increased by 10 times, effective CEC doubled, available P increased from 5 to 39 mg kg^{-1}, and Al saturation decreased from 82 to 1%. The 15- to 50-cm layer of the subsoil has undergone significant increases in exchangeable Ca and Mg and a decrease in Al saturation. This should promote deeper root development. The time at which nutrient deficiencies appeared and the amounts of fertilizer of lime needed to correct them varied substantially between the three fields, despite their close proximity, same preclearing vegetation, geomorphic position, and same soil classification at the family, series and type level.

Constraints of Progress:

Tillage with small rotovators have caused surface soil compaction which can lead to runoff under high rainfall periods. Manual weeding for 12 years have resulted in a significant topsoil removal and buildup of alleyways. Research to overcome this problem with appropriate mechanized means started in late 1982.

Applicability of Results to TropSoils Goal:

This experiment has proven the hypothesis that continuous cultivation of well-drained soils is agronomically possible. This is a central concept of TropSoils objectives in the humid tropics. It is commonly believed that cultivation degrades soils in the humid tropics, often irreversibly. These results, however, indicate that high-yielding continuous crop cultivation with adequate fertilization and lime improves soil properties. Changes in topsoil chemical properties from prior to clearing to after 8 years of continuous cultivation indicate a more favorable chemical environment in terms of soil acidity, base status, availability of most nutrients, and even ECEC. This is directly a consequence of the fertilizers and lime additions.

Perhaps just as important is the improvement in subsoil base status and the accompanying decrease in subsoil Al saturation.

When continuous cultivation is attempted without proper fertilization, the absence of a vigorous crop canopy results in surface soil compaction and, thus, exposure to erosion. This has occurred in the check plots of the experiments reported in this article.

Continuous cultivation without proper fertilization and other appropriate agronomic practices, therefore, is likely to cause a deterioration of soil physical properties and will result in exceedingly low yields. Continuous cultivation with proper fertilization and other agronomic practices produce just the opposite results, improving chemical soil properties and maintaining soil physical properties. The management of physical properties and weed control with mechanization is the next goal of this project. The historical plots will continue to be grown and monitored.

Training Component:

This project has involved training for one MS and two PhD degree students at NCSU. In addition, plots are used for on the job training at Yurimaguas. Data have been widely used in other humid tropical areas and in the world literature.

Reference:

Sanchez, P. A., J. H. Villachica, and D. E. Bandy. 1983. Soil fertility dynamics after clearing a tropical rainforest in Peru. Soil Sci. Soc. Am. J. 47:1171-1178.

CONTINUOUS CROPPING OF ANNUAL CROPS

Leadership Personnel:

John J. Nicholaides, NCSU
Pedro A. Sanchez, NCSU
Dale E. Bandy, NCSU
Robert E. McCollum, NCSU

Date Research Initiated:

August, 1972 (under contract AID/csd 2806)

Rationale for Investigation:

Approximately one-third of the world's 1,489 million hectares in the humid tropics ecosystem is contained within the Amazon Basin Nearly 75% of the Amazon Basin is occupied by acid and infertile soils classed as Oxisols and Ultisols (Table 1). The primary soil constraints to crop production in the Amazon Basin are chemical (Table 2).

The initial rationale was to determine whether continuous cropping of the acid and infertile soils of the Amazon Basin was possible following slash-and-burn-clearing. The answer, from 25 consecutive crops each of a rice-maize-soybean and a rice-peanut-soybean rotation averaging 7.5 tons grains/hectare annually for 10 years, was unquestionably yes. However, the need to evaluate these continuous cropping systems over the long-term, according to recommendations of the 1981 USAID terminal review of the Tropical Soils Research Program, dictated the continued monitoring of this experiment's "complete" lime and fertilizer treatments.

Objective:

To define modifications needed in liming and fertilization practices over long-term cropping of acid and infertile Ultisols of the Amazon Basin.

Experimental Approach:

This research was conducted at the YAES, Yurimaguas, Peru.

Soil fertility changes were monitored via soil testing in the "complete" lime and fertilization plots of Chacra I (cleared 1972) ir order to modify the soil amendment requirements (Table 3) for continuous cropping of this soil. Soil test analyses were perfomed in Yurimaguas and Raleigh and appropriate applications of fertilizer made.

State of Progress:

To date no detrimental effect of continuous cropping using judicious lime and fertilizer amendments (Table 3) based on soil testing has been noted on soil properties or crop yields

Constraints to Progress:

None

Applicability of Results to TropSoils Goal:

Improved soil management technology for continuously cropping the acid and infertile Ultisols of the humid tropics is the end result of this research project. Second, third, and fourth generation soil fertility problems occur with cropping. Research must continue to define and alleviate these dynamic problems. The scale-neutral soil-crop management technology being developed offers an attractive ecological alternative to pessimistic forecasts for the humid tropics, in that its use could lead not only to increased food production for that agroecological zone but also to concomitant reduction in deforestation, if wise choices are made by people and their governments.

Training Component:

No graduate students are conducting research on this project at present. However, the training network of Peru's National Selva Program in conjunction with NCSU's program in Yurimaguas offers short-term training to Peruvian and other (Arge na, England, Holland, Germany) researchers, extensionists and farmers In 1982 and 1983, 19 and 34, respectively, received such training in the soil-crop management technology generated by this research project.

Table 1. General topographical distribution of major soils in the Amazon Basin.

Soil grouping	Millions of hectares					
	Poorly drained, level	Well-drained			Total	(%)
		Slope 0-8%	Slope 8-30%	Slope >30%		
Acid, infertile soils (Oxisols and Ultisols)	43	207	88	23	361	(75)
Poorly-drained alluvial soils (Aquepts, Aquents)	56	13	1	-	70	(14)
Moderately fertile, well-drained soils (Alfisols, Mollisols, Vertisols, Tropepts, Fluvents)	0	17	13	7	37	(8)
Very infertile, sandy soils (Spodosols, Psamments)	10	5	1	-	16	(3)
Total	109	242	103	30	484	

Table 2. Gross estimates of major soil constraints to crop production in the Amazon Basin.

Soil Constraint*	Million hectares	% of Amazon
Nitrogen deficiency	437	90
Phosphorus deficiency	436	90
Aluminum toxicity	383	79
Potassium deficiency	378	78
Calcium deficiency	302	62
Sulfur deficiency	280	58
Magnesium deficiency	279	58
Zinc deficiency	234	48
Poor drainage and flooding hazard	116	24
Copper deficiency	113	23
High phosphorus fixation	77	16
Low cation exchange capacity	71	15
High erosion hazard	39	8
Steep slopes (>30%)	30	6
Laterization hazard if subsoil exposed	21	4
Shallow soils (<50%)	3	<1

* Nutritional deficiencies of boron and molybdenum also have been noted in some Amazon Basin soils, but are not quantitatively estimable due to paucity of data.

Table 3. Lime and fertilizer requirements for continuous cropping of a three crop/year rotation of rice-maize-soybean, or rice-peanut-soybean on an Ultisol of Yurimaguas, Peru.

Input*	Rate per hectare	Frequency
Lime	3 tons $CaCO_3$ equivalent	Once per 3 years
Nitrogen	80-100 kg N	Rice and maize only
Phosphorus	25 kg P	Each crop
Potassium	160 kg K**	Each crop, split applied
Magnesium	25 kg Mg	Each crop, unless dolomitic lime is used
Copper	1 kg Cu	Once/year or two years†
Zinc	1 kg Zn	Once/year or two years†
Boron	1 kg B	Once/year or two years†
Mo	20 g Mo	Mixed with legume seed during innoculation

* Calcium and sulfur requirements are satisfied by lime, simple superphosphate and Mg, Cu and Zn carriers.

** Potassium application may go up to this rate depending on soil test.

† Depends on soil test analysis and recommendations.

SOIL NUTRIENT DYNAMICS AND FERTILITY MANAGEMENT FOR SUSTAINED CROP PRODUCTION ON OXISOLS IN THE BRAZILIAN AMAZON

Leadership Personnel:

T. Jot Smyth, NCSU
Joaquim B. Bastos/Manaus
Dale E. Bandy, NCSU

Date Research Initiated:

September, 1981

Rationale for Investigation:

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. Development of agronomically sound continuous cropping systems, such as those developed in Yurimaguas, Peru, has demonstrated that soil fertility management is a dynamic process which requires information on the approximate time after clearing when nutrient deficiencies may be expected to occur. However, differences in the ecosystems between Yurimaguas (secondary forest, Typic Paleudult, fine loamy, siliceous, isohyperthermic) and Manaus (primary forest, Typic Acrorthox, clayey kaolinitic, isohyperthermic) suggested that soil nutrient dynamics and fertility management would also differ between sites.

Objectives:

A. To establish the patterns of soil nutrient depletion as a function of time after clearing for a Central Brazilian Amazon Oxisol under continuous cultivation.

B. To determine the fertilizer inputs required for sustaining continuous crop production on these Oxisols.

C. To compare soil fertility mangement systems of the Manaus Oxisols with those of the Yurimaguas Ultisols.

Experimental Approach:

This research is conducted at the EMBRAPA/UEPAE Station, Manaus Brazil. An area of primary forest in size sufficient to contain replicated treatments of 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 a rice-soybeans-soybeans-cowpeas rotation provided a cumulative grain yield of 7.3 5/ha, as opposed to 1.5 t/a in the absence of any fertilizers.

Constraints to Progress:

Research in Yurimaguas suggested that three crops could be grown per year in Manaus, under similar conditions. Although annual precipitation is similar for both locations, rainfall distribution and differences in physical soil properties have limited the number of crops to two per year. Therefore, the interval between crops and the number of observations obtained in a 12-month period are less than in Yurimaguas.

Applicability of Results to TropSoils Goal:

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.

Training Component:

There is no active training component for this project.

PHOSPHORUS FERTILIZATION ALTERNATIVES FOR CONTINUOUS CROPING SYSTEMS IN AMAZON OXISOLS

Leadership Personnel:

T. Jot Smyth, NCSU
Joaquim B. Bastos, UEPAE/Manaus

Date Research Initiated:

September, 1981

Rationale for Investigation:

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 effect of different P fertilization strategies.

Objectives:

A. To obtain detailed P response curves and soil test calibration data for the main annual crops cultivated in the region.

B. To obtain a description of the residual P fertilizer value.

C. To provide indications of appropriate maintenance P fertilizer rates for sustaining adequate crop yields.

Experimental Approach:

A phosphorus study was established at the UEPAE station at Manaus, Brazil, 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 nonlimiting 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. 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.

Constraints to Progress:

The development of P fertilization strategies and soil test calibrations should include field trials on several of the most representative soils in the region. Physical limitations have restricted this work to the Oxisol at the Station.

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 fertilizer 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 management of these Oxisol ecosystems.

Training Component:

None.

POTASSIUM FERTILIZATION OF ULTISOLS IN PERU

Leadership Personnel:

John J. Nicholaides, NCSU
Dale E. Bandy, NCSU
Melvin I. Piha, NCSU
Manuel Villavicencio, INIPA

Date Research Initiated:

March, 1981

Rationale for Investigation:

Ultisols such as those being cropped at the YAES are characterized by 1) their lack of weatherable minerals which could release K during the weathering process, 2) their lack of secondary minerals structurally able to fix and later release K for plant availability, and 3) consequent K mobility. This situation makes high yielding continuous cropping depend directly on a proper supply of K fertilization at the time the crops need it. Refinement in K rates and time of application, therefore, are critical for sustaining the high yields produced three times a year by continuous cropping at YAES. An enlarged program on K research was developed in 1981 to develop improved soil fertility management practices for continuous cropping on Yurimaguas Ultisols.

Earlier NCSU research had resulted in K rates for the long-term continuous cropping studies being increased from 77 to 107 kg/ha at year 5. From years 5 to 8 in the continuous cropping studies, however, exchangeable K levels in the topsoil sampled at crop harvest from plots receiving the increased K fertililzation never were greater than 0.15 meq/100 cc and many times were one-half that amount. As the K level of 0.15 meq/100 cc is regarded as the critical level for crops grown on these sandy loam soils in Yurimaguas (rice, corn, peanuts, soybeans), there was concern that crop yields were being limited by either the rates themselves or time of application. Contributing to the lack of build-up of soil test K levels was the fact that crop uptake of K exceeded K fertilizer additions on both clearings of the continuous cropping study (Table 1).

Yields of annual crops on the complete fertilization plots have been declining slowly but steadily since 1978. These factors again reinforced the hypothesis that either K rates or time of application were limiting soil test K levels and perhaps crop yields themselves.

Objective:

To determine the proper rate and time of application of K fertilizers for annual crops on Ultisols (Typic Paleudults) of the humid tropics.

Experimental Approach:

Several field trials were conducted at the YAES on soils low in K (0.12 meg/100 cc) in 1981-1982 to meet the above objective for local rice, corn and peanut cultivars. Randomized complete block design with three or four replications was used in each experiment. Treatments involved rates of K up to 240 kg/ha applied at variable times during growth of the plants.

State of Progress:

Highest yields (1.65 t/ha) of upland rice (cv. IR-42) were obtained when all K was applied at planting because 1) the low rainfall produced less leaching of K than would be expected during a higher rainfall period, and 2) the plants were not burned by the K salts as were those receiving partial K applications during growth. Results suggest that for a crop of rice grown during the drier time of year, May-August, it is best to apply all K at planting.

Corn (a Peruvian composite cultivar, Amarillo Planta Baja) was then planted on the plots. Yield results (were more indicative of normal corn yields than were those of rice. The results suggest that 1) K applications at planting are better than split or late applications, and 2) an obvious K deficiency existed in zero K plots.

Results revealed that 1) the highest peanut yields were obtained when 180 kg K/ha were applied, and 2) rate was only advantageous when split applied 1/3 preplant and 2/3 preflowering (probably related to the rainfall pattern during growth). The additional yield of 280 kg shelled peanuts/ha produced by the extra 60 kg K/ha was split applied, produced a rate of return to capital exceeding 300%. Such a rate of return would be attractive to farmers of the area.

Constraints to Progress:

None

Applicability of Results to TROPSOILS Goals:

As K deficiency is one of the factors most limiting crop production on Ultisols of the humid tropics, refinements in rate and time of application of K fertilization for annual crops could provide an important management component needed for continuous cropping of these soils.

Training Component:

The 19 researchers and 34 extension agents receiving short-term training at Yurimaguas in 1982 and 1983, respectively, were given the appropriate K fertilization recommendations for rice, corn and peanuts based on these studies.

POTASSIUM FERTILIZATION FOR ANNUAL CROPPING SYSTEMS IN AMAZON OXISOLS

Leadership Personnel:

T. Jot Smyth, NCSU
Joaquim B. Bastos, UEPAE/Manaus
Expedito U. Galvao, UEPAE/Manaus

Date Research Initiated:

November, 1982

Rationale for Investigation:

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:

A. To establish K response curves and soil calibration data for the main annual crops cultivated in the region.
B. To develop soil K management systems which optimize fertilizer K utilization efficiency.

Experimental Approach:

Potassium fertilization studies have been established in phases at the EMBRAPA/UEPAE station near Manaus, Brazil. 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 (0,13.5,33 and 46.5 Kg K/ha) in factorial combination with three times of application (0,25 and 55 days after planting corn).

State of Progress:

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 in the areas of standing forest. Topsoil K levels in the burned plots declined to the original levels for the standing forest.

Corn yields increased significantly. 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 suggested that K fertilizer inputs 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.

Constraints to Progress:

Limitations on personnel and physical structure have not permitted the expansion for other crops and soils. Alternative sources of K fertilizers need to be investigated.

Applicability of Results to TropSoils Goal:

Results will provide information for K fertilizer recommendations for major crops in the region.

Training Component:

None.

MINIMUM TILLAGE AND PHOSPHORUS, SULFUR, CALCIUM, MAGNESIUM INTERACTIONS

Leadership Personnel:

Mwenja P. Gichuru, NCSU
Pedro A. Sanchez, NCSU

Date Research Initiated:

May 1982

Rationale for Investigation:

This experiment was initiated as part of the low input soil management technology now underway at the YAES. The low input system is based on the philosophy of "adapting plants to the soil constraints" instead of "modifying the soil to meet plants needs." This includes: 1) the selection of acid-tolerant varieties to eliminate liming, 2) use of tillage methods which allow the return of crop residue in order to recycle nutrients not harvested in the grain, and 3) the use of cheaper sources of fertilizers and better methods of application to reduce inputs.

Objectives:

A. To determine efficient rates and source of phosphorus for acid-tolerant crop rotation (upland rice-cowpeas).
B. To study the effect of no-till vs. rotovate tillage on continuous cropping without liming, utilizing acid-tolerant crops.

Experimental Approach:

This study was conducted at the YAES, Yurimaguas, Peru. A split-split plot experimental design was employed. The main plots were tillage methods (no-till and rotovate tillage); the subplots were phosphorus sources (ordinary superphosphate (OSP) and Sechura phosphate rock (PR); and the sub-subplots were phosphorus rates (0, 25, 25/crop, 50, 100 and 200 kg) kg P_2O_5/ha.

State of Progress:

In May 1984 the sixth crop was harvested, three crops (two rice and one cowpeas) per year. The crop varieties used were ideal for the seasons and surrounding areas. During the wet season, upland rice was grown while in the drier season, cowpeas were grown. The rice takes 105-110 days to mature while cowpeas take 65-70 days. The experiment was planted to a seventh crop (cowpeas) in June 1984.

Preliminary conclusions suggest the following:

A. There was no tillage effect on cowpea grain yields, but rotovated plots tended to have higher vegetative growth. Rotovating was beneficial to rice grain yields only in the first harvest; afterwards, no-till was equal or superior. During the sixth crop cycle, rice plants in rotovated plots showed signs of growth retardation. The yields were much lower regardless of P rate. This suggests that rotovating an unlimed soil may be detrimental due to mixing of the nutrient deficient lower layer with the top layer which is higher in nutrients. Field observations showed that the roots in this rice variety are very superficial. The nutrient dilution effect of rotovating may have played a part in reducing plant growth and yields. However, a definite conclusion cannot be made at this time. Further data analysis is needed.

B. Phosphate Rock compared favorably with OSP as a P source. The soil acidity may have improved the solubility of PR to make it more plant available. Phosphorus response was not strong. A response appeared in the third (rice) and fourth (cowpea) harvests but in the fifth crop (rice) no response was noted probably due to lodging that occurred during the grain-filling period. The lack of initial P response may be due to high available P levels (14 ppm by the modified Olsen method) after the burn, which are normal in Yurimaguas.

Constraints to Progress:

Normal to the humid tropics

Applicability of Results to TropSoils Goal:

High yields were attained with fertilizer input levels much lower than originally envisioned when acid-tolerant germplasm was used. This augurs well for lengthening the cropping period in the low input soil management option.

Training Component:

This project constitutes part of Mr. Gichuru's Ph.D. thesis. The project has been used for training 50 professionals from Peru during the Soil Management Training Course held in May 1983.

FIELD ESTIMATION OF PHOSPHORUS RETENTION BY ANDEPTS

Leadership Personnel:

Alfredo Alvarado - Costa Rica
Stanley W. Buol - NCSU

Date Research Initiated:

January 1980 (under Contract AID/ta-c-1236)

Rationale for Investigation:

If field tests are available to predict P retention, site selection for field trials can be more reproducible. Soil surveyors can utilize criteria for predicting P retention into their soil map unit definitions and delineate areas more accurately.

Objective:

The objective of this study was to investigate the relationship between the P retention capacity of Andepts and more easily measured properties in an attempt to develop a method suitable for identifying those Andepts with the greatest P retention capacity during the course of field sampling.

Experimental Approach:

Phosphorus retention potential was estimated by a modification of the method developed by Fieldes and Perrott. The technique consists in adding a few drops of 0.1 M NaF adjusted to pH 8.2 with NaOH, to one gram of soil in a porcelain spot plate. After 10 minutes, two drops of 0.04% thymolphthalein indicator were added to estimate the pH value. The pH change due to the reaction of F^- with the sample was used to estimate the potential for P retention. Results are compared to established laboratory procedures for P retention and mineralogical composition of the sample.

State of Progress:

The Ph.D. thesis of Mr. Alvarado has been completed and a manuscript prepared for review. The following is an abstract from the manuscript:

In a study to develop a field method for soil surveyors and field agronomists to rapidly evaluate whether or not a particular site would retain a large amount of applied P, 59 samples of Andepts from Costa Rica and Guatemala were incubated with rates of P and then analyzed. Phosphate retention ranged from 25 to 99% and correlated quite well with ammonium oxalate extractable aluminum concentration ($R^2 = 0.56$) in a linear model. In samples with <2.4% ammonium oxalate extractable aluminum, the amount of applied P retained was related even better to this measurement, while at >2.4% oxalate extractable aluminum, retention was not influenced appreciably by oxalate extractable aluminum concentration. Phosphate retention was also correlated with pH in NaF. By the methods used, >90% P retention was predicted by an oxalate extractable aluminum concentration of >2.4% or a NaF pH of >10.7.

A quick test was devised to assess soils with extremely high P retention. The method consisted of adding a few drops of 0.1 mol L^{-1} NaF to approximately one gram of soil in a spot plate and, after 10 minutes, checking the pH with two drops of 0.04% thymolphythalein indicator. This technique was found to correctly identify 79% of the samples as having either greater than or less than 90% P retention.

Constraints to Program:

None

Applicability of Results to TropSoils Goals:

Results provide a field evaluation to identify when high P retention soils are present in new experimental or extrapolation areas.

Training Component:

This research served as the basis for Mr. Alvarado's Ph.D. thesis. He is a native Costa Rican and is now on the faculty of the University of Costa Rica at San Jose.

CHEMICAL WEED CONTROL IN UPLAND RICE

Leadership Personnel:

Robert E. McCollum
Jane Mt. Pleasant

Date Research Initiated:

September 1983

Rationale for Investigation:

Rice is virtually the only short-cycle food crop currently grown around Yurimaguas that is of commercial interest to local farmers, and the area planted to nonflooded rice (upland positions) is many times greater than flooded rice. This imbalance is likely to continue for many years. If something resembling a permanent agriculture involving continuous cropping with short-cycle food crops is to evolve in this environment, rice will almost surely be its principal component.

In a continuously-cropped system of management, the maintenance of soil fertility and the control of weeds will likely emerge as the two most pertinent problems. While soil fertility can be maintained with lime and fertilizers, there is as yet no pre-emergence herbicide in general use that will effectively control grass species that germinate simultaneously with rice. The spectrum of chemicals or combinations of chemicals being studied in this experiment should provide a solution to this problem.

Objective:

To test the following hypotheses:

A. Pre-emergence herbicides are more effective than early post-emergence ones because rice and grassy weeds germinate simultaneously.

B. Herbicides other than propanil can be used on rice and will control weeds more effectively.

C. Combinations of two or more herbicides, applied at the same time or in-tandem, are possible, practical, and more effective than single, one-shot herbicides.

Experimental Approach:

This research is being conducted at the YAES. An abandoned field with a wide spectrum of weed species was limed, phosphated, and plowed to 20 cm. Other nutrients as suggested by soil analysis were applied and incorporated during seedbed preparation and the field was planted to rice two times per year. Weed-control treatments, consisting of two checks (hand-weeded and no control) and 13 chemical-control combinations were established immediately after planting. Plots are rated for crop injury due to herbicide and for weediness during early and late season. Weed counts by species, weed biomass, and rice yields are being measured.

State of Progress:

The first rice production cycle was completed in February of 1984, and the data are yet to be evaluated.

Constraints to Progress:

Timely availability of herbicide

Applicability of Results To TropSoils Goals:

Not yet known, but early-season control of grasses that germinate silmultaneously with rice, is a must if the culture of uplant rice is to progress beyond the machete-and-tacarpo stage.

Training Component:

Besides serving as part of Jane Mt. Pleasant's Ph.D. research, the training component of this project is limited to INIPA's soil management training.

WEED POPULATION SHIFTS UNDER HIGH INPUT CROPPING SYSTEMS

Leadership Personnel:

Robert E. McCollum, NCSU
Jane Mt. Pleasant, NCUS

Date Research Initiated:

July 1983

Rationale for Investigation:

Increasing difficulties in controlling weeds, rather than fertility decline, is viewed by shifting cultivators around Yurimaguas as the main reason to abandon fields. Research to date has elaborated methodologies for maintaining adequate levels of most soil nutrients; but, except for the traditional machete technique, the weed-control problem has scarcely been touched. If a permanent and thriving agriculture is to evolve in the humid tropics, a viable weed-control technology must precede it.

The work described is one of three field experiments whose long-term objectives are to provide the weed-control technology(s) for a sustainable agriculture in humid tropical environments.

Objective:

To test the following hypotheses:

A. A given set of weed-control measures, if practiced over time, will cause a change in the spectrum of weed species. With intensive chemical control, a few species will become dominant; and new control measures must evolve with the altered weed spectrum.

B. Effective weed-management programs can be devised for high-input, continuous-cropping systems in the Amazon Basin.

Experimental Approach:

This research is conducted at the YAES. Weed-control measures, including herbicides, hand weeding, and checks are being used in a rice (September-December)-corn (January-May)soybean (May-September) rotation at Yurimaguas. This cropping sequence will continue through at least six biological cycles (approximately two years). The number of weed species found in each crop during each cycle will be tabulated and their contribution to total weed biomass will be quantified; and the effects of weed competition on product yields will be measured.

State of Progress:

The third crop (soybeans) is approaching maturity and some shifts in the spectrum of weed species are already apparent; but, it is still too early to cite concrete data on population changes. On the other hand, observations to-date suggest that DUAL is a near-ideal herbicide for all of the short-cycle food crops grown here (i.e., corn, peanuts, cowpeas, soybeans) except rice. It controls most grasses and has no apparent residual effects on the succeeding crop. DUAL-plus-BASAGRAN is also a promising combination when DUAL alone is not sufficient.

Constraints to Progress:

Trained people and good tools.

Applicability of Results to TropSoils Goals:

After one year's experience, DUAL has become the herbicide-of-choice for a large percentage of the experimental work being carried on by INIPA. When used properly, it can virtually eliminate the hand-weeding operations that require large labor inputs.

Training Component:

The results of this research will be used in the doctoral thesis of Jane Mt. Pleasant, who has become the principal weed science resource person in the local INIPA training and extrapolation programs in the Selva.

ALUMINUM TOLERANCE: CULTIVAR SCREENING

Leadership Personnel:

John J. Nicholaides, III, NCSU
Melvin I. Piha, NCSU
Manuel Villavicencio, INIPA

Date Research Initiated:

1980 (Under Contract AID/ta-c-1236)

Rationale for Investigation:

A major limiting factor for crop production on the Ultisols and Oxisols of the humid tropics is Al toxicity. Exchangeable Al levels in the soil often reach 3 and 4 meq/100 cc, while Al saturation ranges from 60-95%. The lime necessary to neutralize these toxic levels of Al, oftentimes is unavailable due to transportation and economic considerations. If crop varieties, or breeding lines for use in developing new varieties, which are tolerant to these levels of Al could be found, then crops could be produced on these soils with lower inputs of lime. Such varieties would have far-reaching potential on the agricultural development of the humid tropics which are dominated by the Al-toxic Ultisols and Oxisols.

Objective:

To evaluate the Al tolerance of varieties and breeding lines of important annual crops for the humid tropics.

Experimental Approach:

Field, greenhouse and laboratory experiments were conducted at the YAES and at various locations in North Carolina. The experiments in both locations built on the earlier research results of Piha, Nicholaides and others. Continued field evaluation of peanut and cowpea cultivars was conducted at YAES. Soybean field evaluation was conducted at two experiment stations in North Carolina. Peanut cultivars based on earlier Yurimaguas work were evaluated in lab and greenhouse at NCSU and promising lines were bred at NCSU. The F_1 progeny and parental lines were then evaluated under field conditions in Yurimaguas.

State of Progress:

- A new method to evaluate not only Al tolerance but also high yield potential under stress conditions has been developed. The Piha-Nicholaides method is accomplised by constructing a figure with relative yield (under Al-toxic vs non-toxic conditions) on the ordinate and absolute yield under Al-toxic conditions on the abcissa. The figure is then divided by a horizontal line arbitrarily set at 85% relative yield for rigorous separation of "tolerant" and "sensitive" cultivars. A vertical line drawn from the point of the average yield of the upper third of the cultivars under non-toxic conditions or even an acknowledged "good" yield, such as 2 t/ha of upland rice, could be used.
  Yield data from the field evaluation are then plotted on the figure. Cultivars in quadrant IV are those with both Al-tolerance and high yield potential. Those in quadrants II and III have some desirable attributes for breeding purposes. Those in quadrant I can be discarded for the purposes of such studies.
- An Al-toxic rice cultivar found by Piha and named "Africano Desconocido" is being planted by small farmers extensively in the Amazon Basin. Request for the germplasm are coming from any other countries.
- Peanut breeding lines identified as Al-tolerant were crossed, in dialle without reciprocals, with an Al-sensitive variety. Field evaluation of the F_1 progeny of the Al-tolerant strain showed that this was a dominant characteristic.

- Critical Al saturation percentages differed for soybean varieties, enabling some differentiation of "Al-tolerant" and "Al-sensitive" varieties, although the soybean generally is Al-sensitive.
- Identification of the cowpea variety Vita 3 as Al-tolerant and subsequent testing in Brazil resulted in UEPAE-Manaus selective Vita 3 as the station variety for all research.

Constraints to Progress:

The primary constraint is lack of graduate students to carry on this work.

Applicability of Results to TropSoils Goal:

Varieties developed or identified as being Al-tolerant when put to use have the potential to increase food production on small farms throughout the humid tropics perhaps more than any other factor.

Training Component:

Two students, Mr. Dan Gill and Ms. Lisa Katz, received M.S. degrees researching Al-tolerance of soybeans and peanuts, respectively. The 19 and 34 researchers and extensionists receiving short term training in 1982 and 1983, respectively, at YAES learned techniques for evaluating, propagating and extending Al-tolerant germplasm of rice and cowpeas.

INTEGRATED LOW INPUT CROPPING SYSTEM

Leadership Personnel:

Jose R. Benites, NCSU
Marco Nurena, INIPA

Date Research Initiated:

August, 1982

Rationale for Investigation:

In 1980, a new thrust towards low input crop production systems was initiated as an alternative to the continuous crop production that was based on fertilizer and liming to overcome soil fertility constraints. A conceptual paper was published jointly with CIAT, which provides a complete rationale for the low input approach which is conceptually quite different to the better understood high input approach. Specific research has provided important information on the key component of low input technology such as selection of acid-tolerant cultivars, weed control and kudzu fallow. The available information was put together in mid-1982 to initiate a farm-level experiment that brings together all these components. The first crop was to be exactly as the farmers presently do it. Innovations were introduced from the second crop onwards, where farmers are likely to abandon the fields.

Objectives:

A. To determine the potential productivity of a low input crop production system based on upland rice-cowpea rotation.

B. To determine the length of the cropping period of such a system and devise alternatives.

Experimental Approach:

The research was conducted at the Yurimaguas, Peru and also in a farmer's field in the area.

A one hectare plot of 10-year old secondary forest fallow was cleared by slash-and-burn and planted to the local upland Carolino variety rice with no fertilization of tillage, using a planting stick. Stumps remained in place. At harvest straw was left in place and the improved acid-tolerant Africano Desconocido variety was planted with a 30N, 50 P_2O (kg/ha) fertilization broadcast, no lime and a herbicide application. Tolerant cowpeas were then planted without fertilization and the cycle was repeated. Labor costs were recorded.

State of Progress:

The low input system is performing better than expected. Four crops have been harvested in 20 months, each one producing high grain yields. A total of 8.7 ton/ha of rice and 1.2 tons/ha of cowpeas have been produced with a total fertilizer input level of 60 kg N/ha, 100 kg P_2O_5/ha and 120 kg K_2O/ha in 20 months. The fifth crop, cowpea was planted without additional fertilization, is looking good and will be harvested before two years are over. The use of acid-tolerant upland rice and cowpea cultivars, zero tillage, deliberately leaving crop residues in the field and herbicides for weed control provide a potential for a low input approach beyond what was expected in terms of the cropping period. Soil pH values remain low and Al saturation quite high.

The rotation will be continued, fertilizing only one rice crop per year until yields decline appreciably. Then several alternatives will be considered, including pasture or tree crop establishment, switching to a mechanized high input strategy or to a managed fallow.

Constraints to Progress:

Delays in data collection from the parallel experiment in the farmer's field.

Applicability of Results to TROPSOILS Goal:

Results so far show much promise for the low input strategy as a totally distinct alternative for acid soils of the humid tropics to the high input option. The low input strategy is likely to have wider immediate impact and has lower market infrastructure requirements. It provides a less drastic way to change from shifting cultivation to continuous agriculture. The question of how long can yields of these selected acid-tolerant crop varieties be sustained is of considerable importance.

Training Component:

The project has been widely used as on-site training by the INIP extension director for the various events, including researchers, extension workers, farmers, politicians and native communities.

MINIMUM TILLAGE X RESIDUE MANAGEMENT X POTASSIUM RATES WITH AL-TOLERANT CULTIVARS

Leadership Personnel:

John J. Nicholaides, NCSU
Melvin I. Piha, NCSU
Manuel Vilavicencio, INIPA

Date Research Initiated:

February, 1982

Rationale for Investigation:

Earlier work by Bandy and Nicholaides showed compost from various crop residues to be lacking in sufficient K for good crop production, yet was sufficient in other nutrients. No compost contained enough Ca and Mg to neutralize the high levels of exchangeable Al in the soil. Farmers in the humid tropics have no experience with or limited access to tillage instruments. It was hypothesized that a combination of Al-tolerant rice and cowpea cultivars with minimum tillage use of crop residues with reduced K fertilization might provide a workable system adapted to the small farmers of the humid tropics.

Objective:

To determine whether there is some combination of minimum tillage, residue management and K fertilization which provides good agronomic and economic yields of Al-tolerant rice and cowpeas.

Experimental Approach:

The research was conducted at the YAES, Yurimaguas, Peru.

The long-term experiment was established on a recently burned secondary forest site. The experiment consisted of three tillage treatments: 1) No tillage, 2) Strip tillage using a hoe (approximately 30% of the area was tilled) 3) Conventional rotovation with a hand operated tractor. Superimposed on this were two residue management treatments (i.e.

residue removed or residue applied to surface) and five levels of potassium fertilization.

State of Progress:

Results from two consecutive crops have been harvested (first crop rice, second crop cowpeas) and results indicate no significant response to tillage, residue management, potassium fertilization or liming. There were, however, noted differences in the management requirements and cost of production as follows:

A. For the minimum tillage systems, preplant weed control with the the use of chemical herbicides was both cheaper and more effective than manual control.

B. For the surface residue recycled treatment, initial preplant weed control was attained via the application of paraquat/2,4-D mixture. The rice was then planted and further weed control was done manually, rather than chemically, as this was considered more economical given the nature of the weed problem (sedges).

C. The second crop (cowpea) was similarly established after applying paraquat to the existing weeds and rice ratoon, with follow-up manual weed control. The total cost of this system of weed control and crop establishment for both crops was 162,000 soles, whereas the all manual systems required 216,000 soles, if one assumes a cost of 2,000 soles/man-day for labor.

D. The rotovated system did not produce higher yields than the no-till system and yet it required the use of machinery as well as the removal of tree stumps (estimated at 120 man-days/ha).

E. As expected, tillage resulted in a more favorable distribution of nutrients within the soil profile and a lower bulk density when compared with no-tillage, but these differences apparently did not affect crop yields.

F. For the first two crops, the system based on no-tillage and residue recycling produced 3.9 t/ha of rice and 1.7 t/ha of cowpeas. This system required the least inputs, gave excellent weed control and maximum recycling of residues, as well as was probably effective against soil erosion. Considering that no other treatments produced significantly higher yields, this system should be recommended to small farmers wishing to start using continuous culture techniques with these crops.

Constraints to Progress:

None

Applicability of Results to TropSoils Goal:

The system developed, and still being researched, can be recommended to small farmers who want to start continuous cropping with low inputs. The system is both agronomically and economically sound and, when implemented, should result in increased crop production in the humid tropics.

Training Component:

The 19 researchers and 34 extension agents who received short-term training in Yurimaguas in 1982 and 1983 learned the system developed by this research and are researching it and extending it in other areas of the humid tropics.

DOWNWARD MOVEMENT OF CALCIUM AND MAGNESIUM IN SOILS

Leadership Personnel:

Mwenja P. Gichuru, NCSU
Pedro A. Sanchez, NCSU

Date Research Initiated:

May 1982

Rationale for Investigation:

Acid Ultisols and Oxisols have a chemical barrier that restricts root growth in the subsoil due to toxic levels of aluminum and low levels of basic cations. It may adversely affect crop production during short-term dry spells when the soil has a low water-holding capacity. The movement of bases into the subsoil may alleviate the Al problem and improve the growth environment. High rainfall would promote the downward movement of bases when soluble sources are used. The method and rate of application may influence the rate of movement. These techniques have worked well in Oxisols under high input technology. The question is whether similar principles could be adapted to low input technologies.

Objectives:

A. To promote the downward movement of basic cations into the subsoil using gypsum and dolomitic limestone.

B. To determine the effect of tillage methods on rates of movement.

Experimental Approach:

This research was conducted at the YAES, Yurimaguas, Peru. A split-split plot design was used. The main plots were tillage methods (no-till, strip-till, and rotovate tillage); the subplots were calcium source (gypsum and dolomitic limestone); and the sub-plots were calcium rates (0, 33, 100, 300, and 600 kg Ca/ha). The gypsum was supplemented with magnesium sulfate.

State of Progress:

Five crops were harvested in two years. Soil samples have been taken to 1 m depth and are being analyzed for basic cations.

Soil analyses are not available but grain yields show the effects of tillage and calcium source. However, the effects are not consistent. Tillage had no effect on the grain yields of the first crop (cowpeas) but in the second crop (rice) rotovated plots yielded more than either no-till or strip-till plots. In the third crop (rice), tillage had no effect. However, in the fourth crop (cowpeas), both rotovated and strip-till plots had higher grain yields than no-till. This was due to poorer germination in no-till plots. The soil was extremely dry during the season. The use of the planting stick (tacarpo) tended to reduce soil-seed contact under no-till whereas under strip-till and rotovate tillage, the soil tended to fill the tacarpo hole and over the seed. Normally, a heavy rain after planting would have improved the soil seed contact under no-till but during this particular season, the rainfall failed.

No calcium source effect has been observed but increasing Ca levels resulted in higher yields. These results suggest that calcium nutrition may be more important than the acidity of the soil when acid-tolerant crop varieties are used. Further analyses of the data are being conducted

Constraints of Progress:

Normal to the humid tropics.

Applicability of Results to TropSoils Goal:

The use of acid-tolerant crop varieties may improve the food production potential for the humid tropics without the need for high rates of lime application provided Ca nutritional requirements are met.

Training Component:

This project is part of Mr. Gichuru's Ph.D. thesis research. It has been used in training for tillage techniques for low input systems.

MANAGED KUDZU FALLOW

Leadership Personnel:

Dale E. Bandy,NCSU
Pedro A. Sanchez, NCSU

Date Research Initiated:

1975 (Under Contract AID/csd 2806)

Rationale for Investigation:

Secondary forest fallows improve soil properties in shifting cultivation systems although the mechanisms involved are not well understood. Increases in population pressure often prevent a proper length of forest fallow estimated to be on the order of 12 years. It was hypothesized that an artificially leguminous fallow may be able to exert similar positive effect on soil properties in a shorter period of time. Previous research on managed fallows in the humid tropics has been limited to high base status Alfisols in which a considerable recycling of bases from the subsoil was observed.

Objectives:

To compare the effects of kudzu (Pueraria phaseoloides) and 25-year old fore· fallows on soil properties and crop yields.

Experimental Approach:

An experiment was initiated in 1975 at the YAES evolving planting Pueraria phaseoloides in plots continuously cultivated for different years in a way that by 1980 different treatments were 5, 4, 3, 2 and 1-year under kudzu fallow (KF). These treatments plus adjacent 25-year old secondary forest fallow (FF) were slashed and burned or slashed without burning and grown to a corn-rice-peanut rotation without lime or fertilizers. Slashed, burnable biomass and ash contents were determined prior to and after burning, as well as yields and selected chemical soil properties in the profile. After harvesting the third crop, the entire area was allowed to go fallow to determine the regrowth of both kudzu and forest fallows of identical age.

State of Progress:

- Kudzu fallow biomass accumulation was maximum after two years, but reached only 27% of easily burned biomass accumulated by a 25-year forest fallow.
- Kudzu fallow ash had higher contents of P, K, Mg, Mo, Cu, Zn, B, and Mn but lower N contents than forest fallow ash.
- Due to a 10-fold greater ash deposition in the forest fallow, the nutrient contribution of the kudzu fallow ash was less than that of the forest fallow.
- Resting continuously cropped land for 1 to 3 years in kudzu fallow can subsequently produce about 80% of the crop yields produced by clearing a 25-year old secondary forest fallow.
- On cropped land not previously fertilized or limed, subsequent crop yields increase linearly with length of kudzu fallow up to the 4th year.
- Clearing a kudzu fallow by slash-and-burn is 1/3 as expensive as clearing a 25-year old forest fallow.
- Clearing kudzu fallows by slash and mulch produced slightly better yields than by slash-and-burn.
- The residual effects of fertilizer applications during the preceeding cropping period were evident after kudzu fallow periods and affected subsequent crop yields.
- Kudzu fallows did not recycle bases from the subsoil as in Alfisols, because of the very low base status of the Ultisol's subsoil.

Constraints to Progress:

The second phase of this experiment had to be terminated when a wild fire swept through parts of Chara II during the unusually dry period of August 1983. The variability imposed by the fire rendered further data invalid. A new managed fallow experiment was initiated in 1983.

Applicability of Results to TropSoils Goal:

This experiment showed the value of 1-3 years of kudzu fallow as a viable alternative to a mature forest fallow. This is an important finding for the humid tropics as it provides an important component for the transition between the shifting and permanent cultivation. It also provides an important component for the low input option. The experiment also shows that little base recycling will take place in Ultisol, unless the nutrient stock of the soil has been increased by liming or fertilization.

The experiment also has raised many questions about the mechanisms involved and the changes in physical properties under fallows.

Training Component:

The data, as well as the present field are used for training and demonstration in courses and farmer visits. The use of kudzu fallow is now recommended in many parts of the Selva by the INIPA extension service.

WEED CONTROL FOR LOW INPUT SYSTEMS

Leadership Personnel:

Robert E. McCollum
Jane Mt. Pleasant

Date Research Initiated:

July 1983

Rationale for Investigation:

Control of weeds is a minor managerial problem for about one year after cutting and burning well-forested jungle. Weed infestation increases rapidly thereafter, however, and is perhaps second only to fertility decline among the several reasons for abandoning partially-cleared land to forest regrowth.

Since traditionally-cleared land cannot be tilled effectively until stumps decay, the principle weed-control methodology to-date is hand weeding which not only is very labor intensive but also inadequate. The solution to-date has been to abandon the weedy chacra and start afresh by felling more forest. This is shifting agriculture.

If the transition from shifting agriculture to a more permanent management system is to succeed, effective and affordable weed control measures for bridging the "year two-to-year five" gap are needed.

Objectives:

To develop low-chemical-input management methodologies for controlling weeds on recently-cleared land so that it can be farmed continuously and profitably with short- and medium-cycle food crops. Two hypotheses will be tested:

A. Post-clearing tillage methods, dates (and rate) of canopy closure, and management of plant residues affect a crop's competitive ability against weeds as well as weed population dynamics.

B. Effective weed control, with minimal reliance on costly herbicides, can be achieved via the right combination of soil and crop management practices.

Experimental Approach:

This research is being conducted at the YAES. Land under recently cut-and-burned secondary forest is cropped three times per year in a rice-rice-cowpeas rotation. Imposed variables are: 1) tillage (some-versus-none); 2) residue management (incorporated-versus-surface mulched); 3) plant density (relative rice population = 1.00 and 1.43; and 4) weed-control method (none-versus-hand weeding-versus-chemicals). The experiment will continue through at least six biological cycles (approximately two years). Dependent variables include: 1) the weed spectrum; b) weed biomass by species or family; and c) product yield.

State of Progress:

As of August 1984, the first year of this two-year project is nearing completion. Hence, data accumulation and analyses are incomplete. Two observations made during the first rice crop are relevant: a) Propanil applied 14 days after rice emergence killed some weeds, but it also injured the rice fairly severely; and 2) several genera of Cyperaceae were by far the most prevalent weeds during the first biological cycle.

Constraints to Progress:

Soil heterogeneity, trained people, and good tools.

Applicability of Results to TropSoils Goal:

Too early to elaborate, either locally or elsewhere.

Training Component:

This experiment is part of a thesis project for Jane Mt. Pleasant. No other training activities are foreseen.

PASTURE GERMPLASM ADAPTATION TO ACID SOILS OF THE HUMID TROPICS WITH MINIMUM INPUTS

Leadership Personnel:

Pedro A. Sanchez, NCSU
Dale E. Bandy, NCSU
Miguel A. Ara, NCSU
Rodolfo Schaus, NCSU
Kenneth Reategui, INIPA
Jose Toledo, CIAT
Carlos Sanchez, INIPA
Hemicle Ivazeta, UTM

Date Research Initiated:

May, 1978 (Under Contract AID/ta-c-1236)

Rationale for Investigation:

A major thrust of the NCSU program consists of developing stable, persistent grass-legume mixtures that are tolerant to acid soil constraints with minimum inputs in humid tropical landscapes, in order to increase and stabilize cattle production systems. The first step in this process involves the section of grass and legumes cultivars adapted to very acid, infertile soils with fertilizer inputs generally limited to 25 kg P/ha/yr and 50 kg K/ha/yr. Ecotypes that grow well under these conditions in clipping experiments and do not exhibit major insect and disease attacks are then selected for the next phases of research encompassed in other projects.

Objective:

To select grass and legume ecotypes adapted to Yurimaguas that grow and produce seeds under severe acidity and low fertility stresses under clipping conditions.

Experimental Approach:

The studies were conducted at Yurimaguas, Tingo Maria, Puerto Maldonado, La Morada and Puerto Bermudez, Peru.

Four B type CIAT regional trials were planted at Yurimaguas on a topsoil value of pH 4.0, 80% al saturation and 5 ppm avail. P. Accessions of specific interests to TROPSOILS objectives were included in the latter two trials. Each trial lasted for one year an followed standardized methodology for percent ground cover, dry matter productions, and ratings for insect and disease attacks.

In 1982 similar trials were established in Tingo Maria, La Morada, Puerto Maldonado, Tarapoto and Puerto Bermudez in cooperation with CIAT's Tropical Pasture Program.

State of Progress:

A total of 39 grass ecotypes of the genera Adropogon, Axonopus, Brachiaria, Panicum and Paspallum have been evaluated for at least one year each, fertilized with 22 kg P/ha/yr, 41 kg K/ha/yr and 100 kg N/ha/yr. With the exception of the N rate, a total of 9 legume ecotypes of the genera Aeschynomene, Calopogonium, Centrosema, Desmodium, Leucaena, Macroptilium, Pueraria, Stylosanthes, and Zornia, were evaluated under same conditions.

The grass ecotypes Andropogon gayanus 621, Brachiaria decumbens 606, Brachiaria humidicola 606 were selected for grazing trials and wide testing in extrapolation trials. The legumes Desmodium ovalifolium 350, Desmodium heterophyllium 349, Stylosanthes guianensis 136 and 184, Centrosema hybrid 438 and Zornia latifolia 728 were similarly selected for further testing.

Several ecotypes well adapted to other tropical environments failed at Yurimaguas. Among them are: Panicum maximum, because of fertility stress, Leucaena leucocephala and Macroptilium sp. 135 presumably because of soil acidity stress, and Stylosanthes capitata because of low growth vigor.

New promising accessions include Brachiaria dictyoneura 6133, Centrosema macrocarpon (4 accessions), and Desmodium ovalifolium 3666 and 3784.

Constraints to Progress:

There is little doubt that there is plenty of acid tolerant germplasm for the humid tropics. The main constraints now are insect and disease resistance and in the case of legumes high tannin contents. The most dangerous insect pests for grass, the spittle bugs attacking Brachiaria, is being tested in a 32 accession trial in cooperation with CIAT entomologists. A similar trial for anthracnose tolerance of 20 accessions of the genera Stylosanthes is being conducted in cooperation with CIAT plant pathologists, to select new accessions more tolerant to Colletotrichum gloeosporoides. New accessions of D. ovalifolium, selected for lower tannin contents at CIAT are being evaluated, as one way to alleviate the palatability problem.

Lack of a national pasture seed production capacity in the Selva causes increasing difficulties in propagating promising material.

Applicability of Results to TROPSOILS Goals:

Identification of grasses and legumes capable of growing well under extreme acid soil stress and considerable insect and disease stress provides us the basic tool for devising soil management practices for legume-based pastures in the humid tropics.

This work, along with INIPA research in Tarapoto and IVITA's in Pucallpa led INIPA to release Andropogon gayanus on November 19, 1982 as "Pasto San Martin".

With the advent of the National Selva Program, further pasture germplasm testing will be the responsibility of INIPA, allowing TropSoils staff to concentrate on soil-pasture relations.

Training Component:

Three Peruvian soil-pasture specialists, Ings. Ara, Schaus and Reategui were trained at CIAT to conduct these trials. The trials have served to train more than 50 research and extension specialists in pasture species identification and evaluation methodology.

GRASS-LEGUME MIXTURES UNDER GRAZING

Leadership Personnel:

Pedro A. Sanchez, NSCU
Miguel A. Ara, NCSU
Rodolfo Schaus, NCSU
Kenneth Reategui, INIPA
Miguel Ayarza, NCSU
Rolando Bextley, INIPA

Date Research Initiated:

July 1980 (under Contract AID/ta-c-1236)

Rationale for Investigation:

An important step in the pasture production option is to evaluate the productivity and persistence of mixtures of the most promising acid-tolerant grasses and legumes under actual grazing conditions. Since clipping trials are useful only to estimate adaptation to the environment, soil management practices must be tested under actual grazing conditions where the grass and legume compete with each other and are subject to the selective grazing, trampling and nutrient recycling of the animals.

Objectives:

A. To measure pasture and animal productivity on different associations, in terms of daily weight gain (g/animal/day) and annual production (kg/ha/year).
B. To evaluate the compatibility and persistence of the different grass-legume mixtures under grazing.
C. To evaluate changes in soil properties as a consequence of long-term pasture production.

Experimental Approach:

An experiment was planted at the YAES to study grass-legume mixtures with grazing animals on a site previously cleared and grown to crop for two years. Three associations were investigated: Andropogon gayanus/Stylosanthes guianensis, Brachiaria decumbens/Desmodium ovalifolium, and Panicum maximum/Panicum phaseoloides. Two other associations (Andropogon gayanus/Colletotrichum pubescens and Brachiaria humidicola/Desmodium ovalifolium) were established in 1981 and 1982, giving a total of five treatments, with two replications each.

Under continuous grazing, an imbalance developed in some grass-legume mixture which threatened the persistence of the grass. Alternate grazing was initiated in October of 1981 with 42 days on and 42 days off. The number of animals carried was adjusted each time relative to the amount of forage present. Pasture dry matter and animal weights were measured every 42 days. Soil samples were taken every six months. Annual maintenance fertilization consisted of kg/ha: 25 P, 42 K and 8 Mg. Topsoil properties at the beginning of grazing were: pH of 4.1, 4 ppm Olsen P and 61% Al saturation.

State of Progress:

Continuous grazing worked against the grass-legume balance in all mixtures. The higher palatability of the grasses decreased their stand; furthermore, the absence of a resting period severely hindered their recovery. Unlike other ecosystems, our concern became the persistence of the grass species in view of the very aggressive behavior of the legumes Centrosema hybrid 438, Desmodium ovalifolium and kudzu. Alternate grazing, however, improved the grass legume balance in B. decumbens/D. ovalifolium but not with other mixtures. After four years of this experiment, the most persistent mixtures appear to be Brachiaria humidicola/Desmodium ovalifolium; Brachiaria decumbens/Desmodium ovalifolium; Andropogon gayanus/Stylosanthes guinensis.

Although the liveweight gains per hectare indicate a beef production potential of six to eight times that of the native pastures, the daily gains per animal suggest a pasture quality problem. Analyses of samples collected right before first grazing indicate low in vitro digestibility, and low cell wall disappearance rate in D. ovalifolium as compared with other species. Values for kudzu, believed to be a low quality forage, are similar to those of guinea grass. Of the four species analyzed, Brachiaria decumbens had the higher digestibility values.

The nutrient composition of the four species prior to initiation of grazing appear to be within normal levels for the species except for low protein contents of legumes. The above data suggest a quality problem.

Constraints to Progress:

Low viability of grass seeds has been a problem. Unavailability of botanical seed of some species forced time consuming vegetative propagation.

Applicability of Results to TropSoils Goal:

The recognition that grasses, rather than legumes, are more fragile in mixed pastures in humid tropics is an important finding for the ecosystem. Most of mixed pasture work in the tropics has been done in acid savannas or semiarid tropics. To our knowledge this is the first formal experiment in which mixtures of the acid-tolerant germplasm is being tested in the humid tropics. In other ecosystems, the value of legumes is mainly as forage during the dry season when the grasses completely dry out. The role of legumes in an environment where grasses remain green throughout the year bears further examination. The palatability problem of legumes also poses implication. Low palatability means high litter and low litter decomposition rates. The influence of these factors in nutrient cycling will continue to be investigated.

Training Component:

This project is part of non-degree training of three Peruvian pasture specialists (Ing. Ara, Schaus, Reategui), as well as other research and extension workers for INIPA, the Universities at Iquitos, Tingo Maria and Pucallpa.

The experiment has been effectively used as a demonstration of the high potential productivity of legume-based pastures by INIPA, not only to scientists but also at high government offices including Ministers of Agriculture and the President of Peru.

FERTILIZER REQUIREMENTS FOR PASTURE ESTABLISHMENT

Leadership Personnel:

Miguel A. Ara, NCSU
Pedro A. Sanchez, NCSU

Date Research Initiated:

May, 1982

Rationale for Investigation:

Previous studies have demonstrated that a very important limiting factor is the establishment of acid tolerance grasses, because legumes establish themselves rapidly. Establishment difficulties are probably related to soil fertility status, degree of land preparation, seedling vigor, and ability to compete with rapidly growing weeds, all typical conditions of humid tropical ecosystems.

Objectives:

To determine rates and placement of fertilizers to promote faster pasture establishment.

Experimental Approach:

A fertilizer experiment was installed, in May 1982, at the YAES, Yurimaguas, Peru, on a degraded Andropogon bicornis pasture subjecting Andropogon gayanus, and other species to varying rates of P, K, Mg, S, Ca, Zn, B and Mo.

State of Progress:

Results suggest the optimum levels for establishment are 50 to 100 kg P_2O_5/ha as ordinary superphosphate and 50 kg K_2O/ha, both incorporated in bands adjacent to the seeding row. There was no observed response to other nutrients in the establishment phase.

Constraints to Progress:

None

Applicability of Results to TropSoils Goal:

Recognition that only banded application of ordinary superphosphate and KCl apparently provide sufficient P, K, Ca and S to attain proper establishment of Andropogon gayanus and other species, confirms similar observations in acid savannas. Care should be given to other important factors such as a rough, corrugated seedbed, and weed control.

Training Component:

None

NITROGEN CONTRIBUTION OF LEGUMES IN MIXED PASTURES IN THE HUMID TROPICS

Leadership Personnel:

Miguel A. Ara, NCSU
Pedro A. Sanchez, NCSU
Jorge Vela, INIPA
Silos Gonzalez, IVITA
Hector Huaman, IVITA

Date Research Initiated:

August 1984

Rationale for Investigation:

Grass-legume pastures in acid soils of the humid tropics have high potential productivity under alternate grazing as has been proven in Yurimaguas. The need for legumes is often questioned and the mechanisms for nitrogen contribution in tropical areas with no strong dry season are not understood. Many of the best adapted legumes have low palatability; consequently, they are consumed in low proportion and thus the N contribution via animal excreta to the grass is likely to be low. This high tannin content suggests a low rate of litter decomposition and consequently, limited N may be added to the associated grass by this other mechanism of N transfer in mixed pastures. In ustic soil moisture regimes the main contribution to the legume is to provide green forage to animals during the dry season, when the grasses are dried or dead. Its role in the humid tropics deserved investigation, as there is no previous research on this subject under grazing conditions in this ecosystem.

Objectives:

A. To estimate the N contribution of two adapted pasture legumes, Centrosema sp. CIAT 438 and Desmodium ovalifolium CIAT 350, to their respective mixtures with Brachiaria decumbens, in terms of N availability to grazing animals.

B. To assess any difference in the N contribution between both legume species.

C. To evaluate the effect of increased grazing pressure on the N intake in the mixture B. decumbens-D. ovalifolium.

D. To quantify the N contribution in terms of N fertilizer necessary to obtain the same level of N availability.

Experimental Approach:

A. Hypotheses:

1. There is a contribution of the associated legume to N availability to the grazing animal. This contribution can be estimated by comparing mixed pastures with pure grass pastures at various N fertilizer rates.
2. Centrosema sp. is more palatable than D. ovalifolium. A higher legume utilization and hence more N availability is expected in the treatment Centrosema sp.-B. decumbens than in D. ovalifolium-B. decumbens.
3. As grazing pressure increases, selectivity between species by the grazing animal is reduced. Doubling the grazing pressure in D. ovalifolium-B. decumbens will increase the relative contribution of the legume to animal N intake.

B. Experimental:

A 7 ha grazing experiment is proposed to test the above hypotheses. This is to be conducted at IVITA's Pucallpa Station on a Typic Paleudult, as part of INIPA's National Selva Program. The choice of Pucallpa is due to the better infrastructure available for research with cattle in the Amazon of Peru. The seven treatments are:

1. B. decumbens-D. ovalifolium at a grazing pressure of 9.0 kg forage available dry matter/100 kg animal liveweight
2. B. decumbens-D. ovalifolium at a grazing pressure of 4.5 kg forage available dry matter/100 kg animal liveweight
3. B. decumbens-Centrosema sp. at the same grazing pressure like (1)

4, 5, 6, and 7. B. decumbens alone with 0, 100, 200, and 400 kg N/ha/yr respectively.

The design is randomized complete block, thrice replicated, plot size: 0.33 ha. Rotational-variable stocking grazing system. Animals will rotate among replications (30 day resting, 15 day occupation periods). Grazing pressure will be adjusted to 9.0 kg forage available dry matter/100 kg animal liveweight for all treatments except (2). Zebu steers of 150 kg will be kept as grazers until they reach 250 kg, then changed. Two oesophageal fistulated animals will graze permanently with the grazers and will be included in the grazing pressure calculatons.

Mixtures will be planted 1:1 grass:legume. Before planting pastures 259 kg/ha of $Ca(OH)_2$ will be incorporated in the topsoil if Al saturation is above 80% or if exchangeable Ca is below 1.5 me/100 cc soil. Initially and annually: 50, 100 and 20 kg/ha of P_2O_5, K_2O and MgO. Actual rates will vary with soil test values. N source will be urea. Legumes will be inoculated with Rhizobium.

C. Variables to be measured are:
   1. Forage dry matter yield and forage available prior to and following grazing periods.
   2. Growth of the pasture during the grazing periods.
   3. Relative botanical composition, N content of each component, total N content of the extrusa and In Vitro dry matter digestibility (IVDMD) of the intake.
   4. Fecal output
   5. N in the forage
   6. Dry matter animal intake
   7. N consumed (available).

State of Progress:

Arrangements are being made for the trial to be established at Pucallpa.

Constraints to Progress:

None at present.

Applicability of Results to TropSoils Goal:

Expression of the effect on N availability of the legumes in terms of N applied will help in econcmic considerations when comparing grass-legume mixtures with N-fertilized grasses in the humid tropics. Results also would indicate if it is possible to increase the N contribution of legumes in mixtures. For example, a positive effect of treatment #B.2, above, would indicate that N intake can be increased witha change in grazing pressure.

Results will help to assess the not-well-understood role of legumes in tropical pasture systems. Tropical grass-legume mixtures have been often questioned due to the difficulties in management involved in the maintenance of an appropriate species balance. Assessing the N transfer from soil-plant to animals and the effect of legume species and some management practices on this important pathway of the N cycle in pasture systems is the expected contribution to the scientific community.

Training Component:

This project will contribute the main portion of Miguel Ara's Ph.D. thesis research as well as the main responsibility of his counterpart assigned by INIPA, Jorge Vela.

DYNAMICS OF POTASSIUM AND NUTRIENT CYCLING IN PASTURES UNDER GRAZING

Leadership Personnel:

Miguel A. Ayarza, NCSU
Pedro A. Sanchez, NCSU

Date Research Initiated:

July 1984

Rationale for Investigation:

Potassium is the most likely nutrient to be lost by leaching in soils with low cation exchange capacity and high rainfall. Soils of Yurimaguas (Typic Paleudults) meet these two characteristics. Agronomic trials have shown that high yielding forages also require high additions of K (yields between 30 and 40 tons dry matter/year are observed). The importance of K losses due to leaching in these soils is widely recognized. However, the magnitude of leaching losses in pastures under grazing may be different than in crops. It is hypothesized that the high efficiency of adapted forages plus their dense root network allows only low amounts of potassium loss by leaching.

Objectives:

A. Quantification of leaching losses of K in pastures under clipping and grazing.
B. To monitor the effect of K levels on productivity of the pasture and on the dynamics of K in the soil.
C. To estimate the effect of K return by animal excretions.
D. To compare estimated K losses with crops grown in the same area.

Experimental Approach:

The research will be conducted at the YAES, Yurimaguas, Peru.

- Monitoring changes in soil properties with time in grazing experiment.

- Characterization of chemical and physical factors dealing with retention and leaching capacity of soils in Yurimaguas. Soil columns and lab work.
- Study of K requirements and efficiency of recovery of K of Brachiaria decumbens and Desmodium ovalifolium in a pot experiment.
- Evaluation of leaching losses in a mixture of B. decumbens and D. ovalifolium with three levels of K and grazing activity.
- Clipping experiment to evaluate the effect of K on productivity and efficiency of recovery of the same species.

State of Progress:

Selected properties were monitored in a B. decumbens-D. ovalifolium pasture for four years in an initial assessment of major soil nutrients. This pasture has been grazed for three years and fertilized annually with 22 kg P, 42 kg K, 10 kg Mg plus a one time addition of lime (500 kg/ha). On the average, the stocking rate of the pasture has been 4.4 animals/ha. In general, an improvement of most of the soils properties with time has been observed, particularly between 0 and 20 cm. This may suggest that the dense root network produced by these pastures plus effective nutrient cycling maintains nutrients in that layer and prevents further losses by leaching.

Constraints to Progress:

None except that there are no greenhouse facilities in Yurimaguas.

Applicability of Results to TROPSOILS Goal:

Legume-based pasture production technology development is one of the major goals of TropSoils. Quantification of leaching losses of K in pastures may help to improve the assessment of fertility management in areas devoted to the production of cattle in the humid tropics.

Training Component:

This project will constitute the major portion of Mr. Ayarza's Ph.D. thesis.

EFFECT OF SULFUR ON QUALITY AND PALATABILITY OF DESMODIUM OVALIFOLIUM IN ASSOCIATION WITH BRACHIARIA DECUMBENS UNDER GRAZING

Leadership Personnel:

Miguel A. Ayarza
Pedro A. Sanchez

Date Research Initiated:

May 1983

Rationale for Investigation:

Desmodium ovaliforlium is a forage legume being tested under grazing conditions in many areas of the humid tropics. It is highly adaptable to acid soils low in bases and P and high in aluminum saturation, and is showing excellent yields and persistence under grazing. However, its high content of tannins in leaves leads to low palatability and digestibility of the forage. Consequently, low animal performance is observed. Recent evidence indicated that sulfur may improve *D. ovalifolium* performance by decreasing tannin concentration in the leaves. Based on the assumption that S deficiency may occur in Ultisols of Yurimaguas, a study of the effect of sulfur additions on a mixture of *D. ovalifolium* and *B. decumbens* was undertaken.

Objectives:

A. To assess the relationship between S and tannins.

B. To evaluate the probability of S deficiency of soils in Yurimaguas.

C. To relate changes in tannins with sulfur uptake and soil parameters.

Experimental Approach:

Field research is conducted at the YAES, Yurimaguas, Peru. Pastures of D. ovalifolium and B. decumbens under grazing conditions are sampled. Studies will be conducted in the laboratory and phytotron. A determination will be made of sulfur in soils and evaluation of change in tannins with sulfur additions.

State of Progress:

The low palatability of D. ovalifolium is apparent from field observations which is causing an imbalance in the mixture composition in favor of the legume. Analysis of tannins revealed concentrations of 20% catechin equivalents compared to other foragers that yielded about 2-4%. Percent S in tissue of legume was below the 14% critical level. A phytotron experiment showed maximum dry matter yields were obtained with 10 ppm of SO_4 in solution. Probabilities for S deficiency in the soils of Yurimaguas are not as high as was expected. Topsoil $S\text{-}SO_4$ is about 12 ppm and the B horizon about 2 ppm. Critical levels for some pastures have been set up in 4. No critical level has been established for D. ovalifolium beyond the establishment period.

Constraints:

Nothing unusual.

Applicability of Results to TropSoils Goal:

A legume-based pasture strategy suitable for humid areas is desirable. D. ovalifolium is a valuable legume to combine with aggressive grasses and fits well with this goal; therefore, improvement on its performance would contribute to the legume-based pasture strategy.

Training Component:

This research will be used as part of Miguel Ayarza's PhD thesis.

FOREST AND SOIL REGENERATION

Leadership Personnel:

Larry T. Szott, NCSU
Charles B. Davey, NCSU

Date Research Initiated:

February 1984

Rationale for Investigation:

An understanding of the natural processes involved in the regeneration of the fertility and favorable physical properties of abandoned agricultural land is critical to the design of stable, low input farming systems. This project represents an attempt to quantify the time-course of these changes in soil properties through studies of purmas of various ages and conditions.

Objectives:

A. To study soil and vegetation dynamics following post-agriculture abandonment, especially the importance of soil chemical and physical properties in fertility regeneration.

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

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

D. To experimentally investigate the effect of soil physical and chemical properties on secondary succession by manipulating soil fertility levels and physical properties.

Experimental Approach:

This research is being conducted near the YAES, Yurimaguas, Peru.

Objectives B and C. Locate purmas of the following ages (in years); 1, 3, 5, 10, and 15 to 20, on similar soils, on or near the YAES and measure various chemical physical soil parameters. The results will be used to ascertain the rates at which the various parameters change following agricultural abandonment.

Objective D. Impose treatments involving plant residues, fertilizer, and soil disturbance on a single recently abandoned field. The main plots include: (1) removal of plant residue; (2) removal of plant residue and addition of fertilizer; (3) plant residue left in place; (4) double the amount of plant residue. The split plots include: (1) disturbed soil; (2) non-disturbed soil.

State of Progress:

The land has been cleared from 18-year old secondary forest and used for 1 mixed crop of rice and corn. Plots have been laid out and sampling has begun.

Constraints to Progress:

Obtaining suitable land for the conduct of Objective C. This constraint prevented early initiation of the project.

Applicability to TropSoils Goals:

Development of ecologically- and economically-sound, low-input agricultural systems for the humid tropics requires more knowledge about the dynamics of chemical and physical processes in the soil during the fallow period. This project is intended to provide basic time-course information which will assist in devising new and better low input systems.

Training Component:

This research will be used, in part, by Mr. Szott for his doctoral dissertation.

ALLEY CROPPING

Leadership Personnel:

Larry T. Szott, NCSU
Charles B. Davey, NCSU

Date Research Initiated:

August 1983

Rationale for Investigation:

Shifting cultivation, an ecologically stable system when populations are small, breaks down under increasing population pressures. In more heavily settled areas, improvements are needed to increase the productivity and stability of cultivation systems. One alternative to shifting the use of land in time (i.e. traditional shifting cultivation) is to shift its use in space by alternating areas of woody fallow species with food crop species. This system is referred to as alley cropping. It represents technology with medium inputs and where successful permits both permanent agriculture and a more favorable distribution of labor needs through the cropping sequence than shifting cultivation. Additionally in the traditional shifting cultivation system in the humid tropics, the minimum cropping cycle appears to be four years in jungle fallow for approximately one year of food crop production. Thus the land is in crop production 20% of the time and in fallow 80% of the time. Any alley cropping system that devotes more than 20% of the land to food production represents an improvement over the traditional system.

Objectives:

A. To determine whether tree or woody bush species in combination with food crops can prolong soil productivity.

B. To examine the survival and growth of various nitrogen-fixing tree or bush species in combination with food crops.

C. To assess the effect of the tree or bush species on soil chemical and physical properties and on crop yield.

Experimental Approach:

This research is being conducted at the YAES, Yurimaguas, Peru. The two principal variables to be investigated are the species of trees or woody bushes to use and the spacing between the tree/bush rows. Only nitrogen-fixng tree/bush species are being evaluated.

N-fixing tree or bush species are:

A. Cajanus cajan

B. Cedrelinga catanaeformis

C. Erythrina sp.

D. Inga edulis

E. Leucaena diversifolia

F. Leucaena leucocephala

Spacing between rows:

From 2.0 m to 4.5 m in 0.5 m increments (6 spacings in total). Short rotation food crops will be grown in the area between tree rows, the number of crop rows varying from 2 to 7 in one row increments. Tree prunings will be used as green fertilizers spread as mulches over the crop rows.

Fertility of tree/bush rows:

A. no amendments

B. 2 tons lime/ha

C. 2 tons lime/ha + 100 kg P/ha

Controls include short rotation food crops grown with and without soil amendments but excluding trees or bushes.

State of Progress:

A 3 ha. 10-15 year old secondary forest was cut and burned during August-September 1983. Rice was planted using traditional methods in October and harvested in late February 1984. Trees, raised in the nursery or direct seeded, were established in the field during this same period. All, except Cajanus cajan, needed more time in order to reach a size at which they could be pruned. Cajanus cajan was pruned, the clippings added to the experimental plots. Corn was planted in March 1984.

Soil chemical and physical properties are being monitored. The contribution of nutrients added to the system in the prunings will also be analyzed. Crop yields will be analyzed based on their relationship to the tree/bush rows.

Constraints to Progress:

Initial progress is slow because of the time required to establish the various trees and bushes. Also there was some difficulty in obtaining adequate supplies of quality seed of some tree and bush species.

Applicability of Results to TropSoils Goals:

Alley cropping represents a logical middle technology between the low input systems (traditional shifting cultivation or improved fallows) and high input, intensive, permanent cropping system. Its objectives are to increase crop production, allow permanent use of good crop land, protect the land from erosion, improve the distribution of labor needs, and still require only modest inputs of capital.

Training Component:

If this project is successful, the techniques developed and results should be provided to members of the extension service. It will assist them in advising some of the more progressive farmers in methods of increasing both their crop and income production. Also, Mr. Szott is a Ph.D. candidate at North Carolina State University and this research will be used in part for his doctoral dissertation.

IMPROVED FALLOWS

Leadership Personnel:

Larry T. Szott, NCSU
Charles B. Davey, NCSU

Date Research Initiated:

August 1983

Rationale for Investigation:

The ecological stability of natural and managed ecosystems in the humid tropics is threatened by human population growth. The need for agricultural land has caused widespread deforestation and the shortening of fallow periods of previously cleared land.

An increase in land productivity, per unit area of per unit time, is needed. This study includes an examination of whether the productivity of shifting cultivation systems, per unit time, can be increased through the use of improved fallows.

Objectives:

A. To determine whether the rate of soil fertility regeneration of land formerly used for agriculture can be accelerated by the use of improved fallows.
B. To investigate the effect of high biomass, nitrogen fixing fallow species on soil physical and chemical properties, and subsequently, crop yield, in comparison with natural secondary vegetation.

Experimental Approach:

This research is being conducted at the YAES, Yurimaguas, Peru. The following species have been established in enriched fallows in order to satisfy the stated objectives:

A. <u>Cajanus cajan</u>
B. <u>Centrosema macrocarpum</u>

C. Desmodium ovalifolium

D. Inga edulis

E. Pueraria phaseoloides

F. Stylosanthes guianensis

They are being compared with natural secondary vegetation which usually contains only a few nitrogen-fixing plants per hectare.

State of Progress:

Soil chemical and physical properties are being monitored over time. Special attention is being given to the success of the nitrogen fixing plants. As soon as the previous crop of rice was harvested, biomass of living and dead plant material was determined and subdivided as follows:

A. Live - above ground (lianas, grasses, herbs, tree sprouts, tree seedlings)

B. Live - below ground (roots by depth - 0-5, 5-15, 15-30, and 30-50 cm)

C. Dead - Previous crop residue (rice).
Litter layer (fresh organic residues).
Fermentation layer (decomposing organic residues).

The total biomass exceeded 16 tons/ha.

Constraints to Progress:

Seed of some species that were desirable to test were difficult or impossible to obtain and some that were obtained did not germinate well.

Applicability of Results to TropSoils Goals:

This project represents a very low input modification of the traditional system of shifting cultivation. Thus, if successful, it should be useful locally, regionally, and perhaps with other species throughout much of the humid tropics.

Training Component:

If this project is successful, the results should be provided to members of the extension service. It will assist them in advising subsistence farmers in low input methods for increasing crop production. Also, Mr. Szott is a Ph.D. candidate at North Carolina State University and this research will be used in part for his doctoral dissertation.

NUTRITIONAL REQUIREMENTS OF PEACH PALM (GUILIELMA GASIPAES)

Leadership Personnel:

Jorge M. Perez, INIPA
Robert E. McCollum, NCSU
Charles B. Davey, NCSU
Dale E. Bandy, NCSU

Date Research Initiated:

August 1982

Rationale for Investigation:

Peach palm (Guilielma gasipaes) has become quite important because of the high human nutritive value of the fruit and because the palm heart and fruit can be utilized to make various products. Its management on plantations of the humid tropics is poorly understood, and only in Costa Rica has research been initiated on peach palm destined for the canned palm heart market. The Costa Rican research conducted on high-base status soils indicates that the peach palm requires 200 kg/ha of nitrogen and 100 kg/ha of potassium per year. An experiment was initiated to study the fertilization of peach palm on low base status soils. The intent was to determine what levels of fertilizer caused a response in peach palm diameter, height and fruit yield.

Objective:

To determine optimum fertilizer levels for peach palm production.

Experimental Approach:

This research is being conducted at the YAES. Eighteen fertilizer treatments are arranged in a randomized complete block design with four replications. The experiment is located on a flat Ultisol which was cleared by a bulldozer.

Plants used in this experiment were begun as seed. Germination time averaged 90 days. Transplanting was done at a spacing of 3 m x 3. Fertilizer application was performed in the following manner:

First application: At transplanting, fertilizer was spread over a 0.16 m^2 area and incorporated into 0.048 m^3 soil.

Second application: At three months after transplanting, broadcast over a 1 m^2 area.

Third application: At six months after transplanting, broadcast over a 4 m^2 area.

Fourth and final application: At 12 months, over a 9 m^2 area.

Weed control was done with a mower.

State of Progress:

At 18 months after transplanting, plants are showing a strong response to fertilizer.

Response of both height and diameter to N is almost linear between zero and 100 kg/ha, with diminishing returns being observed from 100 to 200 kg/ha. The check plots showed signs of severe leaf chlorosis. At 50 N/ha, the plants had prominent, although less severe, symptoms of leaf chlorosis. Vigorous plants with green leaves were observed in both the 100 and the 200 kg N/ha plots.

A phosphorus response was obtained for both height and diameter, with the majority of the response occurring between zero and 25 kg P_2O_5/ha. From 500-100 kg/ha, no response was observed.

A large potassium response was observed from zero to 50 kg K/ha, with maximum growth occurring at 100 kg K/ha. Above this rate, however, growth declined.

A strong response to magnesium occurred at rates between zero and 20 kg mg/ha, after which less response was observed. Both height and diameter respond similarly.

A response to lime was obtained for both height and diameter.

Constraints to Progress:

Soil heterogeneity, both natural and induced, is significant. This experiment is on land that was cleared with a bulldozer approximately two years before its initiation. Apparently, a significant amount of cutting and filling was done. A natural drainage-way, and, therefore, soil with poor drainage, also cuts across the experimental site. Some plots will not produce reliable results.

Applicability of Results to TropSoils Goals:

If the present work shows that peach palm can be grown successfully in pure, managed stands, production in sufficient volume and sufficient concentration to support a processing industry could be achieved in a short time.

Training Component:

Not identified.

NUTRITIONAL REQUIREMENTS OF GMELINA ARBOREA

Leadership Personnel:

Jorge M. Perez, INIPA
Robert E. McCollum, NCSU
Dale E. Bandy, NCSU
Charles B. Davey, NCSU

Date Research Initiated:

September 1982

Rationale for Investigation:

The N. C. State University component of TropSoils has a large agro-forestry component. While Gmelina arborea is not native to the upper Amazon Basin, it is reported to be fast-growing in humid tropical environments, and the demand for wood is high (firewood, building poles). Virtually nothing is known about its nutrient requirements for optimal wood production and little about its management in pure stands.

Objective:

To determine recommended fertilizer rates for Gmelina aborea during its establishment period.

Experimental Approach:

This research is being conducted at the YAES. The experimental design consists of 18 treatments arranged in a randomized complete block design with four replications.

The variables include, in kg/ha, N: 0, 50, 100, 100; P: 0, 25, 50, 100; Mg: 0, 70, 20, 40; lime: 0, 1000, 2000; Cu: 0, 1; Mo: 0, 1; 2n 0, 2.

Seeds were procured from Brazil. A spacing of 3 m x 3 m was used for the transplants. Fertilizer application was done in the following manner:

First application:	At transplanting, fertilizer was spread over a 0.16 m^2 area and incorporated into 0.048 m^3 of soil.
Second application:	At three months after transplanting, broadcast over a 1 m^2 area.
Third application:	At six months after transplanting, broadcast over a 9 m^2 area.

State of Progress:

One year and two months have passed since transplanting. During this period, measurements have been taken three times, with the last measurements revealing an average height of 4 m and an average diameter at breast height (DBH) of 3.6 cm over the entire experiment. No response to fertilization has been observed, except that the check plot with no fertilizer is developing slowly and shows nutrient deficiency symptoms. A susceptibility to poor drainage, which slows growth rather noticeably, has also been observed in the second replicate which includes a low spot.

A strong attack by leaf cutter ants has caused damage so heavy that the potential for decimation of many trees exists.

It has also been noticed that Gmelina arborea is susceptible to drought stress and prolonged dry periods (greater than 60 days) cause a general chlorosis and substantial defoliation.

Constraints to Progress:

Soil heterogeneity is limiting the reliability of one replication.

Application of Results to TropSoils Goals:

Not known at this date, but firewood and building poles are high-demand items in Yurimaguas. If the present work shows that Gmelina arborea grows well in pure stands on acid soils, it could replace less-desirable native species in subsequent forestry of agroforestry endeavors.

Training Component:

None identified.

GUARANA FERTILIZATION

Leadership Personnel:

T. Jot Smyth, NCSU
Joaquim B. Bastos, UEPAE/Manaus
Jose C. Correa, UEPAE/Manaus

Date Research Initiated:

February, 1983

Rationale for Investigation:

Guarana (Paullina 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 application 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:

A. To characterize the yield response curves of guarana to rates of N, P, K and Mg fertilization.

B. To establish soil test and tissue analysis calibration data on guarana for these nutrients.

Experimental Approach:

This research is conducted at the EMBRAPA/UEPAE station near Manaus, Brazil. 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 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 58% 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.

Constraints to Progress:

Initial plant mortality problems have restricted plant growth and, consequently, the number of planned observations. Foliar analyses planned for the first year were delayed in order to insure the survival and adequate establishment of the plants.

Applicability of Results to TropSoils Goal:

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 provide opportunities to compare fertilizer requirements between annual and perennial cropping systems on the same soil.

Training Component:

None.

INTENSIVE MANAGEMENT OF ALLUVIAL SOILS

Leadership Personnel:

J. R. Benites, NCSU
Luis Arevalo, NCSU
D. E. Bandy, NCSU
Ofelia Rios, INIPA
Emilio Tejada, INIPA
Kriisttina Hormia, FINLAND
Alfredo Rachiumi, INIPA

Date Research Initiated:

1981

Rationale for Investigation:

About 8% of the Amazon Basin consists of usually flood-free, relatively fertile alluvial soils. The cultivation of irrigated rice on these fertile soils has great production potential in the region. There are in the Peruvian Selva about 4 million hectares of fertile soils on flat topography for the expansion of irrigated rice.

Goal:

To intensify productivity of alluvial soils with paddy rice through adoption of existing technology to site specific conditions.

Approach:

Specific experimental approaches are provided per subproject.

State of Progress:

Paddy rice production on high base status alluvial soils has been an unqualified success. Five crops of irrigated rice have been grown during two years with an average of 16.5 tons/ha/year. Soon after this research began in 1981, a group of migrant farmers of approximately 35 families began production of paddy rice across the Shanusi River. Now about 300 hectares of land on fertile alluvial soils are under cultivation by these farmers who have large expansion plans. The impact of this research in the Peruvian Selva will be to increase the paddy rice area by 90,000 hectares in the next 5 years on soils classed as Eutric Haplaquept and Typic Tropudalf.

Constraints to Progress:

None

Applicability of Results to TropSoils Goal:

See Rationale

Training Component:

The training component within the last three years include on-the-job training in Yurimaguas of 2 Ingineros Agronomos, 3 technicians and one graduate student from Finland. Field days serving as a technology transfer function were held in December 1981 (farmer attendance = 90), August 1982 (farmer attendance = 200+), and August 1983 (farmer attendance = 200+).

Subproject 1: Varietal Selection

Objectives:

1. Selection of rice varieties with most promising yield potential and grain quality.
2. Tolerance of varieties to the prevalent rice diseases in the area: leaf blast (<u>Pyricularia</u> <u>oxyzae</u>), brown leaf spot (<u>Helminthosporium</u> <u>oryza</u>) and leaf scald (<u>Rhinchosporium</u> <u>oryza</u>).
3. Lodging resistance.

Results:

Twenty varieties were selected for planting in Ultisols and cultivated under irrigation. Yields ranged from 0 to 7.5 ton/ha. The ten best varieties selected for the 1982 experiments were Ceysroni, IR 6115, TOX 340, IR 7790, IR 4-2, TOX 514, Colombia 1, ARC 10372, TOX 515 and CR 1113 which were more productive than Carolino, the local variety.

Yields ranged from 1.5 t/ha for IR 8192-115-2 up to 7.8 t/ha for IR 9411-5-3-3, while the local check yielded 2.6 t/ha. It is interesting to point out the high yield obtained with IR 4-2 (7 t/ha). This variety has been successfully used at San Ramon Experiment Station during the last 10 years, as an upland rice with no irrigation.

Most promising varieties in terms of yield were also resistant to Pyricularia, Rhizoctonia, Rhynchosporium and Helminthosporium.

Status:

In 1983, INIPA's Rice National Program took the varietal selection experiment as part of their research program at Yurimaguas.

Subproject 2: Soil preparation and planting methods for rice.

Objective:

To determine the best methods of soil preparation and planting method to achieve maximum yields in rice.

Approach:

Rice is the only major food crop capable of growing in the flooded soils because of its ability to oxidize its rhizosphere. Flooding brings about a series of physical, chemical and biological changes. In order to maintain the water level needed by the rice, puddling - an operation whereby soil aggregates are destroyed - is used to decrease water percolation down through the profile. Puddling thereby can lead to lower levels of nutrients being leached and fewer irrigations, thereby decreasing the cost of rice production.

Treatments:

Soil preparation methods: puddled and non-puddled
Planting methods: transplanting and broadcast seeding
N rate (kg/ha): 0 and 50

Results:

Results from two harvests indicate that transplanting gives superior yields to broadcast seeding, although differences are not great. The plots subjected to puddling and transplanting yielded 450 kg/ha more than those transplanted and tilled dry. This difference in yield was not economically significant.

Results to N fertilization were somewhat contradictory In the second harvest, however, all N treatments out-yielded those without N.

The following preliminary conclusions have been made thus far:

1. Wet tillage (puddling) tends to increase yields.
2. Puddling and transplanting can be recommended initially to level and settle the fields; thereafter, broadcast application of pregerminated seed may be more economically feasible.
3. Differences in yield of transplanted and broadcast seeded plots were minimal.
4. No conclusions can be made concerning N fertilization.

These preliminary experiments form the basis for a technological package for rice production which would include soil preparation by puddling and broadcast seeding with pregerminated seeds. These measures would permit production in the Selva to increase, since they avoid the need for substantial manual labor. Availability of laborers is a serious limitation in the Selva area. However, this package must include a good weed control program, since weed control is the major limitation when rice is broadcast seeded. A weed control study for broadcast-seeded rice is planned for 1984.

Subproject 3: Effects of N,P and K Fertilization (Y-503, Y-504, Y-512

Objective:

To determine when a farmer will need to start applying fertilizer, correct source, amount, and time of application.

Treatments:

Experiment 1: N fertilization and management

A. Soil preparation: puddled and nonpuddled

B. N Rate (kg/ha): 0, 50, 100, 200

C. Application timing*

1. 100% at Tr
2. 50% at Tr + 50% at PI
3. 50% at Ti + 50% at PI
4. 33% at TR + 33% at Ti + 33% at PI

Experiment 2: P fertilization and management

A. P Sources

Ordinary Super P (18% P_2O_5)
Triple Super P (46% P_2O_5)
Rock P (33% P_2O_5)

B. P Rates (kg P_2O_5/ha): 0, 25, 50, 100

Experiment 3: K fertilization and management

A. K Rates (kg K_2O/ha): 0, 30, 60 90, 120, 180

Both N and P trials were initiated in August, 1981; the K experiment in March, 1982. Six cycles of rice have been completed for the N and P experiment, but data are only presented for the last three crops for N and the last four crops for P and K experiments using the 1R4-2 variety.

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*Tr = Transplanting
Ti = Tillering
PI = Panicle Initiation

Results:

Rice generally responds to N fertilization, although the initial crop grown after clearing the land does not usually respond to applied N. On annually flooded soils in Yurimaguas, no significant responses to N application rates and timing have been obtained for three consecutive crops. There has been a response to soil preparation method, however, with the puddling treatment yielding an average of 820 kg/ha more than the nonpuddling over three consecutive crops.

Rice response to P fertilization occurs less often than with other crops, since available P increases under flooded conditions. The residual effect of three sources and four rates of P are being studied, but no significant responses have yet been obtained over four cropping cycles.

No significant response to fertilization has been obtained in the four crops harvested in the K experiment to date.

Subproject 4: Water Management

Objectives:

1. Determine optional irrigation frequency
2. Determine the effect of water level fluctuation on paddy rice seedling

Procedure:

The paddy rice production system developed by the project consists of pumping water with a 9 HP water pump. Water sources can be the river itself or an artificial lake. The pumped water is conducted towards the paddies through an irrigation network.

Treatments:

Experiment 1: Irrigation frequency

Irrigation once a week
Irrigation once every two weeks

Experiment 2: Water level: 0, 10, 20, 30 cm

Results:

The best yields were obtained with irrigation once every two weeks for the three observed harvests. The river caused a loss of 20 m of field, including part of the irrigation once a week treatment.

The effect of different water levels on the continuous crop yield, through three harvests, indicates that the best yields are realized between 10 and 20 cm for the three harvests. At higher and lower levels, yields tend to decrease.

NEW AREAS: CHARACTERIZATION, CLASSIFICATION AND INTERPRETATION OF SOILS IN SOUTHEASTERN PERU - PUERTO MALDONADO

Leadership Personnel:

Stanley W. Buol, NCSU
Laurie J. Newman, NCSU

Date Research Initiated:

April 1984

Rationale for Investigation:

Eastern Peru is thinly populated and communications are often difficult. Soil surveys have been and are being made but usually on a small scale map base with limited ground truth and sample characterization. Soil genesis studies to establish working hypotheses relating soil properties to landscape positions are not common. There is a need to pursue studies that will enable better concepts of the spatial variability soil properties at a scale relating directly to agronomic management practices.

Puerto Maldonado is a major city in the state of Madre de Dios, Peru. Limited agronomic research has been done in the area but it is a natural extension of the ongoing research at Yurimaguas. A new experiment station has been started in the area and it is desirable to establish that the soils on the station both represent the area and are similar to those at Yurimaguas. No detailed soil map exists of the station and this is desirable as research plots are cleared and established.

Also, there are indication that to the north of Puerto Maldonado there may be soils with higher saturation percentages than those at Puerto Maldonado or Yurimaguas. If this is a fact, it will be desirable to establish experiments in that area.

Objectives:

This project was formulated to study the soils of the Puerto Maldonado experiment station in detail to provide characterization and classification data to be used in extrapolating research results obtained at the station to other sites and to provide more characterization of other major soils in the area.

Experimental Approach:

A. Make a detailed soil map of the experiment station near Puerto Maldonado, Peru

B. Sample and then characterize the chemical, physical, and mineral properties of the major soils on the station

C. Make reconnaissance samplings of soils to the north of Puerto Maldonado to determine the magnitude and nature of suspected differences.

State of Progress:

Ms. Newman is on site and has established a preliminary siting of major soil types in the area.

Constraints to Program:

Logistics at the site slow the progress.

Applicability of Results to TropSoils Goals:

Data obtained will permit better communication with extension personnel and allow for "fine-tuning" of management recommendations to remote parts of eastern Peru.

Training Component:

Ms. Newman is obtaining data for a M.S. degree.

NEW AREAS: CHARACTERIZATION, CLASSIFICATION AND INTERPRETATIONS OF SOILS IN NORTHEASTERN PERU

Leadership Personnel:

Robert E. Hoag, NCSU
Stanley W. Buol, NCSU

Date Research Initiated:

May 1984

Rationale for Investigation:

Drainage systems flowing into the Amazon River in Peru and Northern Brazil originate in distinctly different geologic formations. The hypotheses which this study will substantiate or disprove are: 1) soils developing on flood-plains and terraces and may have distinctly different properties as influenced by the type of geologic formation form which the sediments originate, 2) soils developing in sediments originating in areas with limestone formations have near neutral pH values and high base status, 3) soils developing in sediments eroded from formations with acid igneous or metamorphic rocks and volcanic ash are likely to be acidic and have low base status, 4) soils adjacent drainage originating with the basin sediments are acidic and have low base status, 5) sediments along river draining the Guiana and Brazilian shields may be pre-weathered oxidic materials in which the soils may have properties similar to other Oxisols, or 6) the oxidic sediments may have properties dissimilar to the source area if reducing conditions have allowed the conversion of Fe^{+3} to Fe^{2} and subsequent removal by leaching.

Objectives:

To sample and analyze soils developing in sediments derived from four major geologic sources; to determine their physical, chemical, and mineralogical properties and by a comparison of soil properties and drainage systems, develop a means of predicting the occurrence of the contrasting soil properties on floodplain and terrace landscapes within the Amazon Basin.

Experimental Approach:

The research will be conducted in areas of northeastern Peru.

Infrequently flooded sites in farmer fields will be sampled and described to a depth of 2 m. All pedons will be analyzed to determine nutrients and mineralogical composition and classified.

State of Progress:

All samples have been taken and are in various stages of transport and/or analyses.

Constraints to Program:

None

Applicability of Results to Tropsoil Goals:

Results will be used to instruct local extension personnel in the expected local variations expected in soil properties when extrapolating research results.

Training Component:

Mr. Hoag is preparing a thesis for a PhD degree from the data obtained.

FCC REFINEMENT AND TESTING

Leadership Personnel:

Stanley W. Buol, NCSU
Pedro A. Sanchez

Date Research Initiated:

1973 (under Contract AID/csd 2806)

Rationale for Investigation:

The Fertility Capability Classification (FCC) was proposed as a technical soil classification system in 1973. The intent of the system is to provide technical groupings of soils using only those soil property characteristics of concern to soil fertility management decisions. The system has and continues to undergo refinement in response to two stimuli: 1) experience gained from within the TropSoils project, and 2) experience of other groups who are utilizing the system and conferring with the TropSoil staff or reporting the results.

The FCC system for classifying soil is a technical system that uses as criteria physical, chemical, and mineralogical properties from the upper, usually within 50 cm of the surface, part of the soil profile. Other features such as slope and rockiness are also used in certain situations. This differs from natural soil classification systems where emphasis is placed on soil properties that occur deeper in the soil. Category limits in FCC has been selected to reflect soil conditions where soil management practices are changed as one compares different kinds of soil. Because the soil property criteria are selected from near the soil surface, they reflect that part of the soil that can be most easily influenced and altered by management practices. Also, because only a limited number of soil properties are used to define a given group of soils and these properties are selected because of their relevance to management decisions, the groups formed are more homogeneous with respect to management technologies than groups produced by other classification systems. The system has been found to reduce greatly the number of kinds of soils that need to be considered as different within any given area.

Objectives:

A. Test the criteria presently used relative to its applicability in soil management decision.

B. Formulate new criteria, or delete existing criteria where results are not satisfactory.

C. Assist interested collaborators in the adoption of the system into existing soil survey programs.

Experimental Approach:

The existing FCC system is being used by investigators in various countries of the world. As their data are transmitted to the project leaders, the results are evaluated and modifications in the criteria and/or the interpretations are incorporated into the system.

Since the FCC system is designed to evaluate response to soil management practices, data showing response curves related to rate of fertilizer application are of specific value if the initial level of "available" nutrients has been determined by soil test methods. Experiments relating results from band versus broadcast methods, preplant versus side-dress fertilizer placement, benefits from subsurface drainage versus surface drainage and any other experiments that compare management techniques on identified soils are of value in documenting the usefulness of the FCC in technology transfer. Researchers are encouraged to select experimental sites that compare different kinds of soil in the same field, thus eliminating weather variables and focusing on interpretations on soil property variables in comparisons of management techniques.

State of Progress:

A number of publications have included the FCC system. Researchers in Brazil have evaluated the system especially in the Oxisols and associated Ultisols and made suggestions relative to the definition of certain modifier groups. The system has been tested in Indonesia and found to produce more agronomically homogeneous groups than Soil Taxonomy or local classification systems. Taiwan has used the system to select research sites and produced considerable data showing that nitrogen fertilization management practices produce different results in paddy rice on different FCC groups of soil. They also found that the probability of micronutrient problems is significantly higher in some kinds of FCC grouped soils than in others. The salinity criteria has been modified and used for land evaluation in California and Thailand has evaluated its existing soil classification groups in FCC terms. Several other researchers in various countries have requested information on the system and its use. They have designed experiments to evaluate the system.

Presently the system is under intense evaluation by the USDA-SCS for inclusion as a technical interpretation grouping in the National Cooperative Soil Survey reports in the U.S. Microcomputer software has been developed that permits easier use of the system and also provides for both generalized and locally specific interpretations of the FCC group identified. The interactive microcomputer program is easily expanded as local experience becomes available. Copies of the computer program have been supplied to Malaysia, The Peoples Republic of China, and the USDA-SCS at their request. Efforts are underway to accommodate the interpretations to the particular delivery systems utilized by the various users.

Constraints to the Program:

Replicated field sites in diverse locations would be desirable for categoric evaluation.

Applicability of Results to TropSoils Goals:

The FCC system provides technical groups of soil properties. Within groups similar fertility management responses are expected. Management responses are predicted to be different between groups. The groups developed provide the basis for packaging management systems for technology transfer.

Training Component:

Concept and practices are communicated in formal courses and on site instruction.

SOIL MANAGEMENT RESEARCH NETWORK FOR THE HUMID TROPICS

Leadership Personnel:

J. R. Benites, NCSU
NCSU, INIPA, and Special Project Staff

Date Research Initiated:

1981

Rationale for Project:

Several national institutions responsible for research and extension in the Peruvian Selva and other humid tropical regions wish to apply TropSoils technologies. 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 cites are viable in other humid tropics environments.

Goal:

1. To validate and extrapolate available soil management technologies beyond Yurimaguas.
2. To develop the capability of collaborating country personnel to conduct, interpret and report user-oriented soil management research.

Approach:

The Research Network is the mechanism used to validate technology. The on-farm and on-station research done by trainee local scientists was used. Specific approaches were developed for each subproject.

State of Progress:

See specific subprojects.

Constraints to Progress:

The training program requirements place an increasingly difficult burden on the staff. If the training program is to be expanded, the appointment of a full time training coordinator will be essential. The TropSoils program has not allocated funding for such a co-ordinator.

Applicability of Results to TropSoils Goal:

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.

Training Component:

See subproject dealing specifically with this topic.

Subproject 1: Collabortive Research

Objective:

To develop collaborative research with other institutions

Results:

Up to 1980 the Program's research activities in Yurimaguas were marginally involved with and supported by Peruvian research institutions, although these activities were followed with considerable interest and attention by the Ministry of Agriculture and the USAID Mission.

The establishment of INIPA as the national agricultural research and extension entity in 1981 initiated a series of changes that have now resulted in major participation of host country institutions and scientists. Two INIPA Special Projects, "Administracion de Sulos

Tropicales" funded by PL 480 money and counterpart monies from Peruvian Treasury and the other "Estacion Experimental de Yurimaguas," supported with Peruvian money have provided funds for research related to our five year work plan and to the building program, respectively. CORDELOR is providing funds to support research on intensive management of alluvial soils to date and the only crop that we are investigating is flooded rice. CIP has provided, until 1982, logistical support for the Program and in turn conducts potato adaptation and anthropological research in Yurimaguas. CIP's assistance has been a major as well as positive factor in Program operation.

In 1983, INIPA's Rice, Corn, Grain and Legumes National Programs began to coordinate research extension, and training of these commodities at Yurimaguas through the IEE Program with funding from USAID, the Peruvian Treasury, and the PTTSM Project supported by BID. This complementary research in plant breeding is needed to support the project in order to obtain cultivars for acid soil tolerance and other limitations related with the humid tropics environment.

NCSU staff has also been active with development of the (PNIPA under the REE. The PNIPA Selva document is finished and should be officially approved by INIPA in March 1984. It provides the farmwork for the coordination and integration, farmwork INIPA, of the agricultural research and extension components of the various Selva area development projects, each of which has its own administrative mechanism, independent sources of funding, and in most cases separate sources of technical assistance. This project will also interact with the international REDINAA program which is under the development and for which Peru is currently providing the secretariat with funding from the Rockefeller Foundation.

In addition, funds from INIPA, Alto Mayo, Huallaga Central, Alto Huallago, Pichis Palcazu and Madre de Dios Special Projects support extrapolation and training activities outside Yurimaguas.

The technology validation network with INIPA and the Selva Special Projects is an important element through which technology developed at Yurimaguas can be evaluated at multiple sites within the network.

The estimated amount of counterpart funds for 1983 from all sources (IEE, PTTSM, CORDELOR, Administracion Suelos Tropicales and Estacion Experimental de Yurimaguas) was on the order of US $ 320,000. Our projections for the amount of the entire counterpart funds for 1984 will be on the order of US $ 570,552.

In addition to the national linkages described in previous paragraphs, TropSoils-Peru maintains close linkages with the Hawaii-NCSU-CSR TropSoils Program in Indonesia and NCSU operates at the secondary site of Manaus, funded by the Rockefeller Foundation and EMBRAPA.

Informal working relationships are now developed with the following national research institutions working on soils in the Amazon: EMBRAPA and CEPLAC (Brasil), IBTA (Bolivia), ICA (Colombia), INIAP (Ecuador) and FONAIAP (Venezuela). Many of their scientist have visited Yurimaguas in the past two years.

The program has ongoing involvement with other international centers and organizations. The most intensive ones at present are with CIAT's Tropical Pasture Program and ICRAF's agroforestry program. A regular flow of germplasm exists between the TropSoils Program and IITA, IRRI, and ICRISAT for testing under acid soil conditions.

Subproject 2: Tropical Soil Management Training Program

Objective:

Provide a general orientation and opportunity for practical experience of collaborating country personnel to conduct, interpret and report user-oriented soil management research.

Results:

The need for personnel with knowledge of soil management technology in the Humid Tropics is unquestioned. There must be well-trained and competent soil management specialists if there is to be significant long-term improvement in food production.

The training of personnel in soil management has been an integral part of the Yurimaguas program. Since its inception in 1972, six soil scientists have received training leading to the Ph.D. degree, and eight more - Julio Algre, Miguel Ara, Miguel Ayarza, Helmut Elsenbeer, Mwenja Gichuru, Jane Mt. Pleasant, Cheryl Palm, and Larry Szott - are currently involved in the program.

Within the last year we have provided training to 19 visiting professionals for short periods; 19 others participated in a formal short course on tropical soil management; 2 visiting research assistants; 7 special scholarship holders; 4 student scholarship recipients; and 5 practicing students.

The majority of the 56 trainees, including 7 natives from indigenous communities, originated in the Peruvian Amazon. Other countries, such as Argentina, England, Holland, and Germany were also represented.

Most of the trainees are potential cooperators in on-farm research. Consequently we are training our research collaborators in Peru who are adapting and validating the Yurimaguas results. The main output of training is, therefore, research collaborators.

During 1984, the Program within the Soil Science Department will continue to offer training to the Ph.D. degree. Considerable foreign interest in the program has also developed. Requests for training have been received from Finland, Holland, the United States, and the FAO in Rome.

Based on past experience, we have learned that short courses in soil management can be effective mechanisms for technology validation and transfer. Through this means, a great deal of information can be disseminated in a relatively short period of time. Accordingly, we wish to increase our use of this component in our training program. To this end, efforts have been undertaken to finance a series of short courses related to tropical soils management. The IIAP has expressed an interest in financing the course series. We are presently awaiting approval of a joint agreement between IIAP, and INIPA.

Subproject 3: On-Farm Technology Validation

Objectives:

Foster technology transfer via participation in research networks.

Results:

A network of cooperative on-farm and on-station trials was established in January 1983 in collaboration with INIPA; the Alto Huallaga, Pichis Palcazu, Alto Mayo, Huallaga Central and Puerto Maldonado, Central Special Projects, The University of Tingo Maria, and the CORDELOR in Iquitos.

A total of 17 trials have been planted by our collaborators in Iquitos, Pumahuasi, La Morada, Tocache, Pichis, Palcazu, Puerto Maldonado and Moyobamba. Results to date show high (5.5 t/ha) first crop corn yields from high input system in Tingo Maria, wide adaptation of the acid-tolerance rice and cowpea culti-vas in low input systems, as well as several grass and legume ecotypes and the installation of paddy rice pilot farms in Iquitos.

The research at Yurimaguas will be important to the Selva Program under the REE in providing technology that can be adapted broadly in the region in support of the area development projects.

Program staff continues to cooperate in the establishment of the tropical soil research networks and fostering this development of secondary sites according to the overall TropSoils objectives. The main efforts include REDINAA and IBSRAM.

In the past nine years, 1384 visitors from 40 countries are recorded as having come to Yurimaguas to visit the TropSoils Program. This interaction has contributed to the horizontal transfer of transfer of technology and research ideas.

SEMI-ARID TROPICS

SEMI-ARID TROPICS PROGRAM

ORGANIZATION

Lead Institutions

Texas A & M University
Texas Agricultural Experiment Station

Collaborating Institutions and Organizations

Institut National de Recherches Agronomiques der Niger
Institut D'Economie Rurale
International Crops Research Institute for the Semi-Arid Tropics

Linkage Institutions

CARE
Institut de Recherches Agronomiques Tropicales
International Fertilizer Development Center
International Tillage Laboratory, Agricultural University, Wageningen, The Netherlands
Ministry of Agriculture of Haiti
Niger Cereals Research Project (Purdue University)
Office of National de Regeneration des Forests
Sorghum Millet Collaborative Research Support Program
University of Haiti
University of Niamey
Forest Land Use Project, USAID/Niamey

Research Sites

Primary

ICRISAT Sahelian Center, Niger
Maggia Valley, Niger
Guesselbodi Classified Forest, Niger
Various other locations, Niger

Secondary

Cinzano Experiment Station, Mali
Maroua, Cameroon
Jacmel, Haiti

Principal Investigator

Frank G. Calhoun

Representatives on Board of Directors

Lead Institution

E. C. A. Runge

Collaborating Institution

Mamadou Ouattara

SEMI-ARID TROPICS PROGRAM

TECHNICAL PERSONNEL

Name, Degree	Tropsoils Responsibility	Affiliation
Frank. G. Calhoun, Ph.D.	Pedology[1/]	TAMU
Andre Batiano, Ph.D.	Soil Fertility	IFDC
Will Blackburn, Ph.D.	Range Science	TAMU
Elizabeth Bui, M.S.*	Pedology	TAMU
Claude Charreau, Ph.D.	Pedology	IRAT
Robert G. Chase, Ph.D.	Soil Management	TAES
Raymond B. Daniels	Pedology	NCSU
Joe. B. Dixon, Ph.D.	Soil Mineralogy	TAMU
Leslie Fussell, Ph.D.	Agronomy	ICRISAT
James Gardiner, B.S.*	Soil Fertility	TAMU
C. Tom Hallmark, Ph.D.	Pedology	TAMU
John Heermans, M.S.	Forestry	USAID
Michael Klaij, M.S.	Soil Science	Wageningen
Jonathan Landeck, B.S.*	Soil Classification	TAMU
Robert J. Lascano, Ph.D.	Soil Physics	TAES
Pierre Louis, B.S.*	Soil Classification	TAMU
Fritz Marcelin, B.S.*	Soil Classification	TAMU
Frances Mbote, B.S.*	Soil Classification	TAMU
Gandah Mohamadou, M.S.	Soil Physics	INRAN
Arthur B. Onken, Ph.D.	Soil Fertility	TAES
Gene Perrier, Ph.D.	Soil Physics	ICRISAT
Naraine Persaud, Ph.D.	Soil Physics	TAES
Harbi Shadfan, Ph.D.	Soil Mineralogy	TAES
Mamadou Simpara, M.S.	Soil Physics	IER/Mali
M.V.K. Sivakumav, Ph.D.	Agroclimatology	ICRISAT
Charles W. Wendt, Ph.D.	Soil Physics	TAMU
John Wendt, B.S.*	Soil Physics	TAMU
Larry West, M.S.*	Soil Classification	TAMU

Larry P. Wilding, Ph.D.	Pedology	TAMU
Bernard P. K. Yerima, B.S.*	Soil Classification	TAMU

[1/] Also, Principal Investigator.

*Enrolled in a graduate program leading to next highest academic degree.

SEMI-ARID TROPICS PROGRAM
AN OVERVIEW[1/]

The scope of this Program as set forth in the grant which established the Soil Management CRSP encompasses the following:

A. Characterize the soil at experimental and cooperative sites according to the U.S. Soil Taxonomy and the Fertility Capability Classification System.

B. Devise and test methods to prevent or diminish soil crusting.

C. Test and select the most practical means of soil erosion control, measuring losses to water and wind to the extend possible.

D. Develop low input soil management systems to maximize the use of soil moisture.

E. Evaluate crops and Rhizobia for tolerance to high temperatures, drought, low phosphorus and acidity/soluble aluminum or manganese.

F. Determine how to monitor and adjust plant nutrient balances to sustain yield on a profitable basis.

G. Investigate alternatives to the system of shifting cultivation commonly practiced in the semi-arid tropics.

H. Conduct cooperative trials with farmers to obtain assessment of current and modified technology under normal management capability, obtain cost and return data as well as land and labor requirement from the farmers and, finally determine income in either cash or food over a period of years to obtain a realistic evaluation of current and new soil management systems which are introduced.

[1/] Prepared by G. Frank Calhoun, Principal Investigator.

I. Disseminate results of research to other areas in the semi-arid tropics.

The primary goal of this Program 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 semi-arid tropics. The overall research strategy in the early stage of this Program has been one of the primary focus on characterization of the soil-water-atmosphere-plant system in the semi-arid tropics. A secondary focus has been on modification of this system based on principles and knowledge gained from research in other semi-arid agroecological zones. As we gain more information, characterization research will diminish in proportion to modification research.

The Setting:

A. The Primary Research Site - Niger

Most of the TropSoils research in Niger lies within the Sahel bioclimatic zone; an extensive semi-arid belt immediately south of the Sahara Desert. The population density of this part of Niger is about 20 to 25 persons per square kilometer and more than 90% of these people are involved in subsistence agriculture. The primary food crop is pearl millet (Pennisetum spp.) which is often intercropped with cowpeas. Other crops include peanuts, sorghum, maize, rice and manioc. Pastoral grazing of sheep, goat and cattle are another major agricultural enterprise. The growing of crops is almost entirely done by hand labor. The sandy soils are easily tilled and animal or mechanical traction for agriculture is rare.

The climate is characterized by a June to September rainy season and a dry season throughout the remainder of the year. Rainfall is irregular and normally comes in the form of convective storms. As much as 100mm of rain may fall during a single event. There are periods of strong, dry "harmattan" winds which bear dust from the Sahara during the dry season. Potential evapotranspiration is approximately 2000mm annually while annual rainfall is only 300 to 600mm with drastic variability from year to year. Temperature is warm year round and averages 29C in Niamey, the capital of Niger.

Forests in the Sahel are diminishing due to human, environmental and/or grazing pressures. Normal vegetation is grasses and thorny bushes with scattered trees. In many areas barren crusted soils are left where vegetative cover has receded, increasing runoff and elevating soil and air temperatures. The landscape is composed of laterite-capped plateaus and ancient sand-filled valleys. There are many problems associated with the soils on these landscapes. Large areas of soil are high in sand and have low soil water storage. Crops grown in these areas are subject to sandblasting 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. The crusting also causes problems in crop establishment.

Chemically, the soils are also deficient for most crop production. They are acid, low in available phosphorus, calcium, magnesium, nitrogen and organic matter. They are often high in free iron oxides and exchangeable aluminum. Considerable microvariability exists, causing difficulty in interpretation of cropping systems research results.

The climate is harsh and rainfall is erratic and has decreased 30-40 percent during the past decade. Air temperatures commonly exceed 50C and soil temperatures at 5cm depth often exceed 50C. With no inputs, yields of local crop varieties exceed those of introduced varieties. Local varieties have been selected by farmers over time under the soil deficiencies and harsh climate of the area.

B. Secondary Research Sites:

1. Mali: The primary location of research in Mali is at the Cinzana research station located about 100 miles northeast of Bamako on the Niger River - just past Segou. Mean annual rainfall is around 550mm per year and the landscape is vegetated by a savanna woodland. The station is characterized by low relief (6-8 meters) with a toposequence of several distinctly different soils. Soils at the lowest point of the landscape are poorly drained and fine-textured with some shrink-swell properties. Soils on the crests are excessively-drained, coarse textured and yellowish-red in

color. These latter soils are quite similar to the sand-plain soils of Niger.

2. Cameroon: Northern Cameroon has extensive areas of Vertisols which are clayey soils that express considerable shrinking and swelling upon drying and wetting. Such soils are rare in Niger but otherwise extensive in the semi-arid tropics. The Maroua region where TropSoils research has been initiated has annual rainfall of around 800mm which decreases northerly to less than 500mm on the southern shore of Lake Chad. Mean annual temperature is approximately 28C. The parent material of the lowland soils (many of which are Vertisols) is primarily lacustrine sediments deposited when the shore of Lake Chad occurred much further to the south than it does today. Sorghum, millet, peanuts and cotton are the major crops grown in the region.

3. Haiti: The steeplands research site, under partial TropSoils sponsorship is located at the USAID/Haiti ADS-2 watershed project in Southeast Haiti approximately 20km north of Jacmel. The area has two separate rainy seasons (April-June) and (October-December). Corn constitutes the major crop, often with beans, pigeon pea and sweet potatoes intercropped with the corn. The area is underlain by limestone and the soils of the study area are formed from residuum, colluvium and alluvium derived from the limestone. Soils on the summit and footslope positions are Oxisols while those on the side slopes are Inceptisols.

Program Evolution: The Collaborative Process

A. The Planning Phase:

The Planning Entity developed a proposed program which included: (1) a soil physicist; (2) a soil fertility specialist, and (3) a ground cover agronomist. Each of these three positions were to work equally between Upper Volta and Niger. Finally each position was to operate under the ICRISAT umbrella in both countries with ICRISAT to serve as the primary collaborating institution. The arrangement was supported and agreed to by the USAID missions in Niamey and Ouagadougou in 1980.

B. The Implementation Phase:

Two years elapsed from the time that the Planning Entity proposed the arrangements outlined above and the arrival of Texas A&M/ME representatives in West Africa to initiate discussions on implementation of the program. Much had changed in the interim.

Changes in key USAID/Niamey personnel and the resignation of the ICRISAT West Africa coordinator made it necessary to retrace and revise original plans. The initial response from USAID/Ouagadougou was negative toward reinitiation of discussions. Subsequent discussions with ICRISAT, USAID/Niamey and AID/Washington authorities discouraged us from using the original plan to work under the ICRISAT-UNDP umbrella. USAID/Niamey argued strongly that we should work directly with INRAN. AID/Washington indicated that large portions of the ICRISAT perquisite schedule would be unacceptable for reimbursement. It was finally decided among all parties involved that it would be best if TropSoils operated under the AID bilateral agreement with the Government of Niger; however, TropSoils would, at our insistence, develop separate memorandums of agreement with ICRISAT and INRAN. At a very early stage in negotiations with ICRISAT we were asked to fill the soil fertility position first due to a supposed commitment by IRAT to place a soil physicist at the ISC. At a much later stage we were informed that the IRAT commitment had fallen through and that IFDC had placed a soil fertility specialist at the ISC. By early 1982 we had finally arrived at a focus on soil-water research within the farming systems context at the ISC. The memorandum of agreement with ICRISAT was signed in early 1983. Discussions with INRAN focused on similar research needs, that of soil and water. The memorandum of agreement with INRAN was also signed in early 1983.

The TropSoils commitment to both INRAN and ICRISAT for 1983 was to place a senior soil physicist in Niger who would develop a research program shared equally between both institutions. It was further understood that discussions would continue during 1983 to determine the type of position to be filled next.

C. The Operational Phase:

During its early phase we knew that the TropSoils Program in Niger would be too small during its early phase to justify major in-country administrative and logistical support. Thus we arranged a working relationship with Purdue University to provide this support. Purdue is the prime contractor for the Niger Cereals Research Project which provides technical assistance in cereal grain research to INRAN. A memorandum of agreement was signed between Texas A&M and Purdue in which Purdue would provide office support to TropSoils (at a suitable fee) while Texas A&M (through TropSoils support) would interface with the NCR Project in terms of soils research.

The TropSoils soil physicist (Robert G. Chase) arrived in Niger in early March, 1983. Dr. Chase had just completed a four month orientation/preparation period which included one month in Texas (College Station and Lubbock), one month at ICRISAT (Hyderabad) and two months in France for language training. His plan of work included research on soil temperature modification and the effectiveness of a West Texas sandfighter on millet establishment and control of wind erosion. The soil temperature research was to be conducted at the ISC. The sandfighter research was to be done at both the ISC and the INRAN research station at Kolo.

The strategy of splitting TropSoils research between INRAN and ISC the first year ran into immediate problems. TropSoils found itself in the middle of a conflict between ICRISAT and INRAN. The INRAN Director General insisted that no TropSoils research was to be conducted at the ISC. ICRISAT informed us that if TropSoils did not place a full-time soil physicist at the ISC that they would "hire their own". The primary problem was that INRAN was unhappy with the ICRISAT posture in Niger which involved aspects of both philosophy and personalities. The controversy did help us to crystallize our thinking in terms of future staffing for TropSoils. Follow-up discussions with both INRAN and ICRISAT led to the agreement that TropSoils would place a second soil physicist in Niger who would work primarily with INRAN. Dr. Chase would then move full-time to the ISC in 1984 working primarily on soil-water-atmosphere-plant relations. The TropSoils soil physicist attached to INRAN would conduct research in soil and water conservation. Subsequently, the second soil physicist, Dr. Naraine Persaud, was recruited and arrived in Niger in March, 1984. In general, the subsequent overall relationships between TropSoils, INRAN and ICRISAT have been most cordial and mutually supportive.

A recurring concern in all of our discussions with host country administrators and USAID mission officials was clarification of the role of a CRSP. The host country/USAID perspective, in the beginning, was that the CRSP was to function as a "technical assistance project. Our position, of course, was to emphasize the meaning of the words "collaborative" and "support" in the CRSP acronym. We stressed that Collaborative meant that TropSoils and the host country institution would develop research programs of mutual concern, using shared resources. Support meant that TropSoils would bring in additional resources which would accelerate and sharpen on-going soil management research programs in the host country. The concepts of "technical advisor"/"counterpart" relationships inherent in "technical assistance" were not to be part of the CRSP model. TropSoils and host country soil scientists were to work on an equal basis on research of mutual interest. Indications are that this working philosophy is now well accepted in Niger.

Considerable effort, during this start-up period, has been expended in identifying other donor and locally supported programs in Niger which were concerned with soils. This has resulted in either collaborative agreements or linkages with IFDC, CARE, IRAT, the Tillage Laboratory of the Agricultural University of Wageningen/Netherlands, the USAID/Forest Land Use Project, and the University of Niamey.

Research Strategy:

A. Niger:

Our primary research focus is on soil and water management for dryland cropping systems. Essentially all components of the scope of work are presently being addressed in Niger (Figure 1).

Soil fertility and ground cover agronomy research by TropSoils in Niger has been de-emphasized during the first two years because of current IFDC input and that intended by ILCA. TropSoils is involved in some plant nutrient-soil water interaction research in collaboration with IFDC at the Sahelian Center. The interaction of soil fertility and available water is an extremely important component in crop production strategies for the Sahel.

Evaluation of crops and rhizobia for temperature, drought and nutrient stress has not been initiated. INTSORMIL has a stress evaluation program for sorghum and millet, a portion of which is handled by Dr. Art Onken at Lubbock. Dr. Onken is also a collaborating scientist with TropSoils. IITA is placing a cowpea agronomist at the ISC. The cowpea agronomist is backstopped by a strong biological nitrogen fixation program at IITA headquarters in Ibadan, Nigeria. Prior to initiation of rhizobial tolerance research in Niger we wish to discuss needs and strategies with IITA.

Socioeconomic analysis and input in the TropSoils research in Niger has been minimal to date. There are two reasons for this: (1) our major research emphasis during the first two years has been on characterization of the edaphic components of the Nigerien Sahel and (2) our desire to integrate the socioeconomic aspect with the ISC farming systems economist. The interface with ISC economics program was temporarily suspended due to the resignation of the ICRISAT economist. Our windbreak evaluation and agroforestry research activities are tied into larger projects which have a funded socioeconomic component.

Graduate students have played a valuable and important role in Niger. Jonathon Landeck conducted research on the water retention and balance characteristics of the major soils at the ISC. This was an excellent follow-up on the Tropsoils-supported soil survey of the ISC which was conducted under the leadership of Larry West. Jonathon also provided considerable assistance to Bob Chase during his first year in Niger. During the rainy season of 1984 we have two graduate students in Niger conducting research on (1) the soil-geomorphological relationships of sand-filled valleys and (2) phosphorus-soil-water interactions. The first project is in collaboration with INRAN while the second is in cooperation with IFDC. Both graduate students also serve in a support role for the two senior scientists in Niger. A third potential graduate student is working with Naraine Persaud at the windbreak evaluation study in the Maggia Valley. This individual spent a two year Peace Corps assignment in Niger as a forester and is presently employed by CARE specifically for the windbreak project. Fifth year students from the University of Niamey are being worked into the program this year, primarily at the ISC. One of these is continuing the soil-water retention research started by Jonathon Landeck in 1983.

B. Mali:

A memorandum of Agreement has been signed with Mali; however, the plan of work was not approved in time to initiate a research program during the 1984 rainy season. Soil management research at the IER station at Cinzana provides us the opportunity to work with soils that are loamier in texture than the sandy soils of the ISC in Niger. The research effort will focus on the interactions and effects of soil preparation techniques and soil fertility parameters on soil water status and crop yield. The present and future support base for TropSoils research in Mali appears to be very favorable. ICRISAT is presently involved in an AID-supported breeding/cropping systems project with the IER. INTSORMIL is a part of the TropSoils-IER agreement to establish a collaborative research program. USAID/Bamako also has on-line two long-term technical assistance projects in farming and cropping systems research and extension. An additional factor is the apparent political stability in Mali when compared to neighboring countries, especially Upper Volta.

C. Cameroon:

TropSoils involvement in Cameroon represents a target of opportunity. The soil order of Vertisols occupies large areas of the semi-arid tropics; however, this group of soils is not extensive in Niger. Vertisols dominate vast tracts of land in northern Cameroon. Bernard Yerima, a native of Cameroon, had recently completed a masters thesis on the Vertisols of the Pacific Coast of El Salvador. Colleagues of his in the Cameroon Ministry of Agriculture informed him of reforestation problems encountered by ONAREF in northern Cameroon on these soils. We submitted a proposal to ONAREF to conduct a collaborative study on the properties of these soils and interpretations for forest regeneration and agriculture.

Increased knowledge of the reforestation and agricultural potential of north Cameroon Vertisols will have a positive effect on rural development strategies by ONAREF and other agricultural institutions of the region.

D. Haiti:

The final approval for TropSoils funding from AID/Washington, requested that each agroecological program address soil management problems of the steeplands.

The project in Haiti addresses the issue of soil erosion and classification on steeplands for the semi-arid tropics zone. As in Cameroon, TropSoils involvement in Haiti represented a target of opportunity. We were able to link with an existing Texas A&M/USAID project and combine funding support from three other sources. The two Haitian graduate students received stipend, per diem and travel support from the TAMU/Haiti-USAID project. The Texas A&M Strengthening Grant covered all travel costs for the two TAMU faculty involved. TropSoils/Texas A&M covered costs of equipment and supplies needed in Haiti. Finally, salaries for the two faculty and costs of laboratory analyses will be borne by TAMU and TAES.

Organization and Management:

The general organization of the TropSoils/Texas A&M Program for the Semi-Arid Tropics is shown in Figure 1. A listing of faculty and staff involved in backstop and support activities is provided in Table 1. The three principal geographic focal points are College Station, Texas; Lubbock, Texas; and Niamey Niger. College Station is the location of the main campus for Texas A&M University. The Texas A&M University Agricultural Research and Extension Center at Lubbock-Halfway is located several miles north of Lubbock on the Southern High Plains.

A. Texas

1. College Station. The Principal Investigator, Frank Calhoun, is officed in the Soil and Crop Science Department of Texas A&M University. The PI is responsible for the overall coordination of the Semi-Arid Tropics Program. This includes direct responsibility for coordination of secondary research sites and all institutional linkages. He coordinates all junior scientist activities, serving in most instances as co-chairman of degree committees for these individuals. He functions as direct supervisor for the senior scientists in Niger while coordinating activities in soil physics, pedology, crusting research and soil fertility which backstop the program in Niger. The PI is involved as either a project leader or technical backstop on selected projects both in Texas and Niger. The PI office is tied to INRAN and ICRISAT in Niger by telex through Western Union's Easylink.

   There are two primary support components of the Program located in College Station: pedology and crusting research. The pedology component provides soil classification and characterization support to the program in Niger. This is under the leadership of Larry Wilding, Professor of Pedology in Soil and Crop Sciences Department. Other faculty and staff involved in pedology support include Larry West, Tom Hallmark and Will Blackburn.

   The crusting research component is involved in mineralogical, micromorphological and electron microscopic analysis of soil

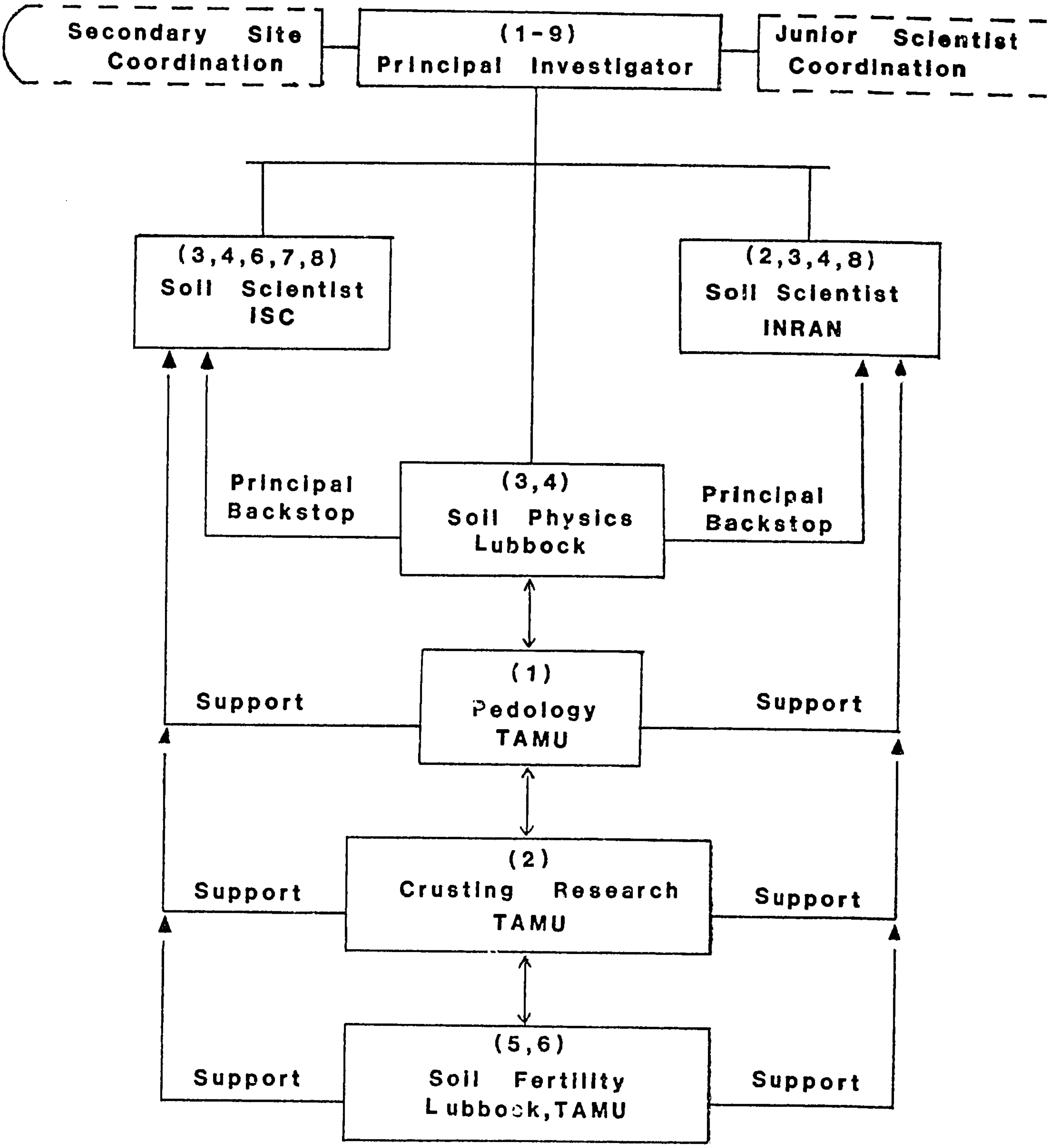

Figure 1. General organization of TropSoils Program at TAMU. Numbers in parenthesis denote research objectives corresponding to A, B, C, etc., in text.

Table 1. Backstop and Support Faculty/Staff at TAMU A&M
As of October, 1984

Name; Position; Institution/Location	Role
Charles W. Wendt; Professor, Soil Water; TAES/Lubbock	Leader of soil physics backstop activities for Niger.
Robert J. Lascano; Post-doc Research Scientist; TAES/Lubbock	Technical backstopping for Niger in soil physics; energy balance studies; windbreaks
Mike Gerst; Research Associate; TAES/Lubbock	Logistical backstopping for Niger in soil physics for Niger; computer programming support
Larry P. Wilding; Professor, Pedology; TAMU/College Station	Leader of pedology support component for Niger.
Tom Hallmark; Assoc Prof, Pedology; TAMU/College Station	Pedology support, Project Leader for steepland research in Haiti, soil characterization
Will Blackburn; Professor, Range Science; TAMU/College Station	Pedology support; soil conservation input for steepland research in Haiti.
Larry West; Research Associate and Manager of Soil Characterization Laboratory; TAES/College Station	Pedology support; field leader of ICRISAT Sahelian Center soil survey, soil classification support in in Niger for crusting and windbreak research.
Joe B. Dixon; Professor Soil Mineralogy; TAMU/College Station	Leader of crusting research support component for Niger.
Harbi Shadfan; Research Associate, Soil Mineralogy; TAMU/College Station	Crusting research support; research on soil hardening, crusting and induration for soils in both Texas and West Africa
Arthur B. Onken; Professor, Soil Chemistry; TAES/Lubbock	Soil fertility support; fertility-water interaction research at Lubbock and in Mali
Frank G. Calhoun; Professor, Tropical Soils; TAMU/College Station	Principal Investigator

crusting and induration in Niger, Mali and Texas. This effort is focused on the ISC, Guesselbodi and sand-filled valley sites in Niger and Cinzana in Mali. Joe Dixon, Professor of Soil Clay Mineralogy is the leader of this support component with assistance from Harbi Shadfan.

2. Lubbock. The TAMU Agricultural Research and Extension Center near Lubbock is located in the semi-arid temperate zone of Texas (~ 450mm rainfall per year). Many of the same soil-environment problems that exist in the Sahel occur also on the Southern High Plains of the U.S. These include drought, wind and water erosion, soil crusting, sand blasting, and seedling burial. Lubbock stands in contrast to College Station which is located in southeast central Texas on the boundary between a humid temperate and a semi-arid climate (~1000 mm rainfall per year). The soil physics and fertility research programs at Lubbock have been, over the years, oriented towards problems which have a more direct bearing on those of the Sahel.

   The soil physics component in Lubbock plays a very active, continuing role in backstopping the research activities with INRAN and ISC in Niger. The Lubbock group is involved in day-to-day programatic and logistical support for the scientists and many of the graduate students in Niger. Program backstopping includes consultation and assistance in research design, work plan development, equipment selection, data analysis and computer programming. Logistical backstopping has entailed equipment purchase, calibration, shipment and installation; custom computer programming and general trouble-shooting. A separate research program in energy and water balance, windbreak analysis, and spatial variability is being conducted by this group. The soil physics research program in Lubbock closely parallels the research in Niger. Charles Wendt is the principal backstop scientist for the Semi-Arid Tropics Program. He is assisted by Robert Lascano (programs) and Mike Gerst (logistics). The Lubbock office has a telex communications link via Western Union Easylink with Niger.

The soil fertility component supports research in fertility water interaction in Niger (with IFDC) and fertility-tillage interactions in Mali (with IER). Art Onken leads this support component and is conducting supporting research in soil fertility at Lubbock.

B. Niger

There are two Senior Soil Scientists stationed in Niger. Bob Chase is assigned to the ISC and Naraine Persaud to INRAN. Until recently administrative support in Niger was provided by Purdue University through the Niger Cereals Research Project. This arrangement worked quite well the first year because only one of Purdue's five long term positions was filled during that time. The Purdue office manager was able to handle the load quite easily. With the arrival of the full Purdue advisor component this situation rapidly deteriorated. In recent months we have decided to establish a separate TropSoils office with an administrative assistant/office manager and a bilingual secretary. The USAID/Niamey mission has been supportive of this decision. Immersing TropSoils in either the ICRISAT or INRAN infrastructure would make it very difficult to maintain visibility and flexibility in Niger.

The operating philosophy vis-a-vis institutional relationships in Niger and the working relationship between the two senior scientists is also based on a collaborative mode. TropSoils must interface with a number of programs and institutions in Niger. It is very important that the perceptions of both the international (USAID, ICRISAT, IFDC, etc.) and host-country (INRAN, University of Niamey and other GON agencies) institutions towards either of the two TropSoils scientists not be compromised. Thus we have asked both scientists to work as a partnership with a division of responsibilities and communications between TropSoils and both the international donor and host country communities.

The working model for this is shown in Figure 2. Operationally this means that Bob Chase is responsible for all liaison with the international community and Naraine Persaud for the host country community. Chase and Persaud maintain close communication with each other through the TropSoils office which has been established in Niamey. This allows both to be the official representative of TropSoils to their respective

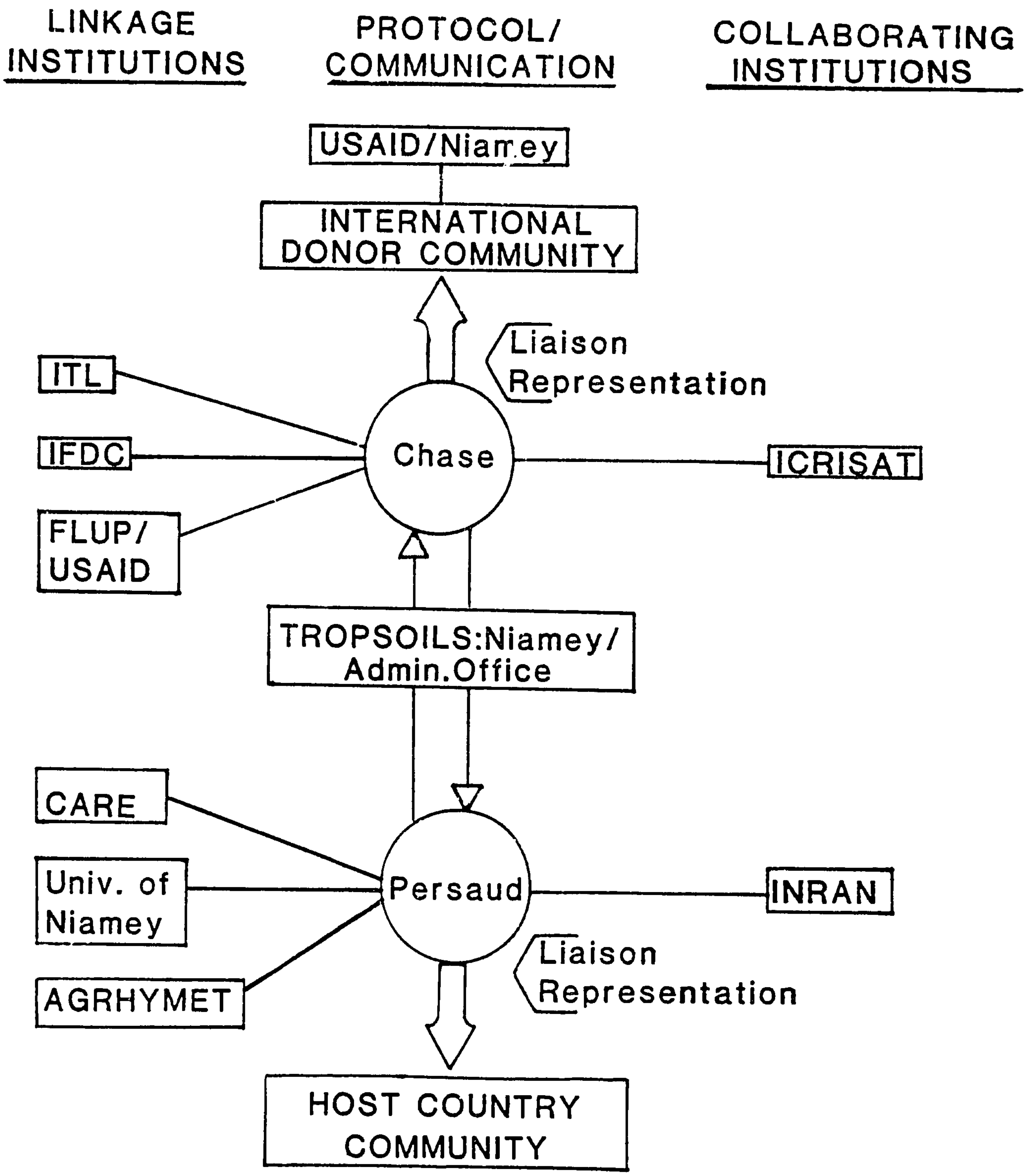

Figure 2. Linkage, protocol and collaborative relationships for TropSoils in Niger.

collaborating institution (INRAN and ICRISAT). It also allows a sharing of protocol duties across the collaborating and linkage institutions.

Factors Affecting Progress of the Program:

A listing of specific constraints to progress of the Semi-Arid Tropics Program would be nothing more than a litany familiar to all who have worked in a developing country or have tried to manage a program that dealt with problems of distance, bureaucracy, logistics and cross-cultural communication. What is remarkable in all of this is the progress and understanding which has taken place over the past two and one-half years.

If this Program has achieved a measure of success to date then it is due to the people involved: scientists, administrators and staff from USAID/Niamey, AID/Washington, INRAN, TAMU, TAES, ICRISAT and many other institutions in West Africa, the U.S. and Europe. Administrators such as Moussa Saley, the Director General of INRAN, and Charles McCants have patiently listened and questioned as we struggled together in developing a research program that finally made some sense. Scientist/administrators such as Mamadou Ouattara have worked hard and learned along with the rest of us the true meaning of a Collaborative Research Support Program. Rudy Vigil, USAID/Niamey, has taken a vigorous professional and personal interest in the success of the Program. Bob Chase has borne the brunt of program establishment in Niger - a feat not easily described in many pages of prose, let alone a sentence. He is to be commended for surviving the first year with sanity intact. Charles Wendt has spent innumberable hours on flights between Lubbock and West Africa. His commitment to the success of TropSoils and his appreciation of the relationship between soil and water problems in the Southern High Plains and the Sahel have been invaluable to the quality and focus of research in Niger. Naraine Persaud quickly grasped the environmental realities of the Sahel and the political nuances of Niger in developing a research program which has broad-based support and respect. The list could go on.

The proposal submitted by Texas A&M in 1980 for involvement in the Semi-Arid Tropics Project argued strongly that TAMU had a comparative advantage over other land-grant institutions in the U.S. The similarities of agro-ecologies between the Sahel and vast regions of Texas led us to believe that Texas principles and technology could be applied and modified in countries such as Niger. The TAMU weakness was lack of cross-cultural experience with francophone Africa. The argument of comparative advantage has already been justified by the sandfighter research -- a technology lifted out of farmer fields in the Southern High Plains and successfully modified for animal traction in southern Niger. The weaknesses in cross-cultural and language skills has not appeared to be an overriding constraint. Our two senior scientists are functional in French while the TAMU backstop and support faculty have found it difficult to build up language expertise within the framework of the TAMU System.

In many ways, the weakest link in the overall strength of this program lies within the structure of the Texas A&M University System. The infrastructure support for international agricultural programs at Texas A&M has lacked stability and organization throughout the life of this CRSP. There have been four directors over the past three years. Only the most recent appointee has had any long-term LDC experience. Fiscal operation and accounting support procedures have not kept pace with the needs of the program. The international programs office has reported directly to the President who is on a different reporting line to the Chancellor from that of the Director of TAES. Because of this, many of our subgrant amendments and MOA's have been significantly delayed because of tortuous sign-off routes. The effect has been to delay the start up of new areas of work and to significantly impede productive activities in others.

STATISTICAL ANALYSIS OF RAINFALL RECORDS

Leadership Personnel:

Naraine Persaud, TAES
Adam Abdoulaye, INRAN
Mahmadou Gandah, INRAN
Also Idrissa, Tapis Vert Project

Date Research Initiated:

May, 1984

Rationale for Investigation:

Rainfall is a critical factor in soil and crop water relations in Niger. Too much or too little, a poor distribution or its spatial and temporal variability have a considerable influence on agricultural production and productivity. Statistical analyses 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 rainfall networks and planning experiments and hydrological projects.

Analyses of recording rain gauge charts provide depth or intensity/duration/frequency relationships and hydrographs. Such information is required for estimating surface runoff and erosion and in the design of channels, levees, spillways, terraces and other conservation works.

Objectives:

A. To determine:
   1. the probability a given day in a year will be wet or dry
   2. the probability a given sequence of wet or dry days will occur at a particular time of the year

3. the probability a given number of days will be wet or dry in a particular sequence of days
4. the probability of occurrence of a rainfall event of given magnitude during a given period of the year
5. the spatial and temporal variability of rainfall in Niger
6. the presence of general trends and periodicities in individual records and correlation relationships between records
7. the frequency distributions of extreme values.

B. To determine the depth or intensity/duration/frequency curves and relationships for the particular sites.

Experimental Approach:

This research is conducted at the AGRHYMET Center, Niamey, Niger.

For objectives A1-A4 inclusive, standard counting probability methods will be used to analyze available long-term records of daily rainfall for all stations in Niger from their origin to 1983. Initially each record series will be examined for consistency and discordant values. Series analysis both in time and frequency domain, spatial analysis and regression analysis will be used for objectives A5 and A6. For objective A7, the Gumbel and other theoretical frequency distributions will be fitted to the empirical frequency distributions of extreme values. Chi square and/or the Kolmogorov-Smirnov goodness-of-fit tests will be used to determine the best distributions.

State of Progress:

All the daily rainfall records for stations in Niger have been assembled and the sheets are being hand-sorted for data entry. The required hardware and software for gaining access to the hard disk storage are in-country, were successfully tested and are currently being installed. Data entry should begin shortly.

Constraints to Progress:

Initial set-up time of TropSoils computer facilities at AGRHYMET has been extensive.

Applicability of Results to TropSoils Goal:

Results can be used directly by other agencies and disciplines and in all aspects of soil and water conservation planning and development. For TropSoils, the results can be used in conjunction with (1) available data on particle size analysis and moisture retention for a large number of soil samples from representative profiles for many soil types in Niger collected by the FAO Soil laboratory, (2) the results of projected work on soil water hydraulics using the rainfall simulator and (3) estimates of potential and actual evaporation existing in the French literature to arrive at hydrological balances, estimates of annual erosion losses and rational design of conservation works.

Training Component:

Hands-on training is provided to Mr. Mahamadou Gandah, soil physicist, in the manipulation and interpretation of meterological data.

MEASUREMENT OF THE PHYSICAL CHARACTERISTICS OF RAINSTORMS

Leadership Personnel:

Naraine Persaud, TAES
Mahmadou Gandah, INRAN
Moussa Adamou, INRAN

Date Research Initiated:

1984 rainy season

Rationale for Investigation:

The rainfall characteristic directly related to erosion is its kinetic energy. Studies have demonstrated the important role of drop impact in inducing detachment of soil particles and their suspension in runoff. In the USLE 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. Furthermore, drop size measurements may help in analysis of results of experiments to measure rainfall erosion in field plots.

Objectives:

A. To measure the drop-size distributions of convective-type natural rainstorms for various rainfall intensities.

B. To utilize these measurements in conjunction with known terminal velocities of water crops in still air to compute the kinetic energy of rainstorms based on physical principles of motion.

Experimental Approach:

This research is conducted at Niamey, Chikal and Tarna, Niger.

The flour-pellet method will be used to make the measurements of drop-size distribution. Preliminary laboratory studies will be made to develop a standardized calibration curve for the flour-pellet method. To do this several experiments will be done to determine (a) optimum mesh size for the flour, (b) possible use of millet flour and sorghum flour for this measurement and (c) possible effect of wind velocity, drop impact velocity and humidity of the flour on the calibration curve.

State of Progress:

Equipment is being obtained, personnel trained and detailed procedures are being developed.

Constraints to Progress:

None

Applicability of Results to TropSoils Goal:

The erosivity of rainfall is directly related to its kinetic energy. The benefit of being able to calculate this directly from basic physical principles and pluviometric data is crucial and would constitute an advance in knowledge that is broadly applicable.

Training Component:

Training in this particular methodology will be provided, hands-on, to staff and technicians from INRAN, the Niger Meterological Service and the University of Niamey.

STUDIES ON SOIL DETECHMENT BY RAINDROP IMPACT AND SOIL TRANSPORT AND DEPOSITION BY OVERLAND FLOW

Leadership Personnel:

Naraine Persaud, TAES
Mahmadou Gandah, INRAN
Ambouta Karimou, University of Niamey
Nikola Thiessen, Tapis Vert Project

Date Research Initiated:

Mid-1984

Rationale for Investigation:

It is recognized that soil loss by rainfall involves a process of shattering and detachment of soil aggregates by raindrop impact and their transport by overland flows towards points of runoff concentration as determined by the microtopography of the field. While the importance of these two processes and their interrelationship has been investigated, they are still poorly understood and quantified. The comparative neglect of this basic aspect of soil erosion research is due partly to the emphasis over the last thirty years on the development of empirical and practical tools for planning soil conservation work. Investigation of these basic processes may help in attaining a better understanding of soil erosion and in development of physically based models for use in estimating losses and designing conservation programs. Such information is especially needed under conditions of Sahelian type rainstorms.

Objectives:

A. To measure the amount of soil detached and splashed per unit area by raindrop compact and the distances to which soil is splashed by impact for various rainfall and soil conditions.

B. To measure the depths of erosion and deposition at various locations in a bare plot during rainstorms.

Experimental Approach:

This research is conducted at Niamey and Chikal, Niger.

The rainfall simulator presently being constructed at TAREC will be used to achieve the first objective. Special tools will have to be designed and tested for measuring soil detachment/unit area and the distances to which detached soil particles are thrown after impact. The second study will be done on a bare plot. Small gauge scour chains will be buried at specified locations in the bare plot. These will be examined after rainstorms to determine the relative depths of erosion and deposition at these locations. A microtopographic survey of this plot will be done at the beginning and end of the rainy season to determine soil redistribution and deposition within the plot.

State of Progress:

The microtopographic survey of the bare plot has been completed. The small scour chains have been purchased and will be installed shortly.

Constraints to Progress:

Timely implementation will depend on availability of rainfall simulator and fabrication of special tools.

Applicability of Results to TropSoils Goal:

There is a lack of knowledge on the behavior of Latosols under rain. These studies will contribute some answers and may help to orient the future course of soil erosion research in Niger. A contribution can be made to a resolution of conflicting opinions on the value and necessity of soil erosion research in monsoonal grassland areas.

Training Component:

Hands-on experience and training is obtained on a regular basis by INRAN, University of Niamey and Tapis Vert Project personnel.

ESTIMATING PERCENTAGE RUNOFF FROM CRUSTED FOREST SOILS

Leadership Personnel:

Robert G. Chase, TAES
John Heermans, USAID/FLUP

Date Research Initiated:

June, 1983

Rationale for Investigation:

Visual observation of crusted soil in barren areas between strips and clumps of vegetation in "tiger"/"leopard" bush areas of the Sahel leads to the deduction that there is nearly 100% runoff from these surfaces. This study was designed to test the hypothesis that there is very little infiltration of rainfall into these crusted forest soils. This baseline data will then be used to evaluate improvement of infiltration due to treatment interventions developed by FLUP and TropSoils.

Objective:

To estimate the percentage runoff from crusted forest soils in a simple, easy manner.

Experimental Approach:

The research will be conducted at the Guesselbodi Classified Forest near Niamey, Niger.

There are serious inherent difficulties in determining infiltration rates in and runoff from crusted soils using standard methods. However, advantage can be taken of the fact that moisture in the sandy Sahelian soils decreases to very low levels at depths of 50 cm or more during the dry season. Therefore, one can determine total soil moisture changes over short periods of time gravimetrically by sampling to the dry subsurface layer. A location was chosen in the Guesselbodi forest where a rain gauge, a deeply plowed (30 cm) field and a crusted surface were in close proximity. Within six hours of each of three rainstorms, rainfall was recorded and soil samples taken to 60 cm (0-15, 15-30, 30-45 and 45-60 cm depths) in the cultivated field and in the crusted soil. These values were compared and runoff estimates made.

State of Progress:

Gravimetric water contents have been calculated for 1983. Results have not been interpreted in terms of percentage runoff estimates.

Constraints to Progress:

Insufficient time to interpret gravimetric water contents in terms of runoff due to tardy completion of laboratory results.

Applicability of Results to TropSoils Goal:

The results of this study will be applicable to those areas of the Sahel where forest degradation has reached the "tiger"/"leopard" bush stage. It will facilitate better design and interpretation of soil management/agroforestry research conducted in such areas in the future.

Training Component:

No formal plans at this time. Informal, hands-on training will be provided on a regular basis for INRAN, ICRISAT and University of Niamey personnel. A University of Niamey senior student may be assigned a portion of this study in the future.

MOISTURE RETENTION PROPERTIES OF SOILS AT ICRISAT SAHELIAN CENTER

Leadership Personnel:

Robert G. Chase, TAES
Frank G. Calhoun, TAMU
Larry West, TAMU
Jonathan Landeck, TAMU
Manzo Moumane, INRAN
Boukari Djibo, INRAN

Date Research Initiated:

May, 1982

Rationale for Investigation:

In semi-arid West Africa, the availability of water is perhaps the most important single factor influencing the distribution of vegetation and the success or failure of crop production. Periods of water stress during the rainy season are a chronic threat to potential crop yields across the Sahel. Highly unpredictable periods of moisture replenishment make the identification of pertinent soil qualities influencing soil moisture use by crops absolutely vital to the formation of acceptable soil management technology. For this reason research must be initiated to elucidate moisture-related characteristics of Sahelian soils.

Objectives:

A. To determine the morphological, physical, chemical and mineralogical properties of four representative soils at the ISC.

B. To assess the field moisture storage and moisture retention capacities of these soils as correlated with laboratory soil-water suction values and in-situ profile moisture measurement.

C. To establish correlative relationships of soil properties with moisture retention and moisture storage capacities.

D. To develop, through inference, appropriate directions for agricultural soil management research in Niger based upon the results of this investigation.

Experimental Approach:

A. Conduct a soil survey of the ISC including characterization of the physical and chemical properties.

B. For four of these soils, identification of moisture retention properties.

C. Through the use of regression analysis, identify the soils' physical properties which most influence the moisture retention properties.

State of Progress:

A. Five soil series were identified, four of which were studied in detail. They have been classified as:

Soil Series	Soil Family
Labucheri (La) sand	Psammentic Paleustalf; sandy, siliceous, isohyperthermic
Zogoti (Zo) sand	Psammentic Paleustalf; sandy, siliceous, isohyperthemic
Tondi (To) sand	Petroferric Haplustult; sandy, siliceous, isohyperthemic
Dayobu (Da) sand	Ustoxic Quartzipsamment; isohyperthermic, coated

B. Moisture retention capacities of all four investigated soils is very low.

- Within the effective rooting depth of the pearl millet crop, the 0.1-1.0 bar moisture contents range from 1.7 cm/cm to 2.6 cm/cm at the 0-15 cm depth and from 0.4 cm/cm to 2.5 cm/cm at the 15-30 cm depth.
- Volumetric saturation values (representing total porosity) within 0-30 cm range from 33.7% to 43.3% at 0-15 cm and from 37.4% to 41.2% at 15-30 cm; subsoil values are comparable to those given for 0-30 cm.

- Two days of profile drying following rainfall results in volumetric field moisture values ranging from 7.5% to 12.5% at 45 cm.
- Ten days of profile drying following rainfall results in volumetric field moisture values ranging from 6.3% to 10.8% at 45 cm.
- Fifty days following the final rain of the reason, volumetric field moisture values at 45 cm range from 2.8% to 3.7%.
- All soils exhibit pronounced selfmulching upon continued dessication.
- Laboratory estimations of field capacity (.1 bar moisture) are greater than in-situ estimation of soil profile volumetric moisture contents after 24 hours of drainage by a factor of 1.5 to 3.0 in the upper 30 cm.
- Soil Profile moisture contents to one meter at the commencement of the rainy season range from 19 cm to 40 cm.
- Over the nine-month dry season, soil profile volumetric moisture contents decrease in the upper 75 cm by as little as 52 cm to 89 cm.
- Assuming no runoff, 20 mm of rainfall should recharge 20 cm of depth to moisture contents corresponding to levels obtained after 24 hours of drainage.
- A direct relationship of total clay and organic carbon to 15 bar moisture and an inverse relationship of total sand to 15 bar moisture was demonstrated using regression analysis.
- The proximity of a lateritic contact and 0.1 bar bulk density values both showed inverse relationships to in-situ volumetric moisture content following drainage.
- Available water capacity is directly related to both organic carbon and 0.1 bar bulk density.

Constraints to Progress:

None. All objectives were fulfilled.

Applicability of Results to TropSoils Goal:

The results of this investigation and the methodology employed have relevant and practical applicability to agricultural research and production models on soils of similar textural class, not only in Niger but throughout the entire northern Sahel region of West Africa within the 300 600 mm isohyet, i.e. from Senegal in the west to Chad in the east.

The evidence helps to identify those research objectives and parameters appropriate to agricultural production on sandy-textured soils in the Sahel and contribute to the body of knowledge serving agricultural research, extension and production in the semi-arid tropics.

Training Component:

The research provides hands-on training of project-affiliated technical agents and graduate students in the methods and technology employed in agricultural research and, especially, laboratory and field soil moisture studies.

CHARACTERIZATION AND MODIFICATION OF THE SOIL TEMPERATURE REGIMES IN NIGER

Leadership Personnel:

Robert G. Chase, TAES
Charles W. Wendt, TAES

Date Research Initiated:

April, 1983

Rationale for Investigation:

It is well known that both soil chemical and biological reactions are affected by changes in soil temperature and soil moisture. Although there is often scientific work being done outside the Sahel to study its soils or to produce results which can be used in the Sahel (crop varieties, for instance), the differences in the physical environment are often not appreciated. The most obvious example of this is the failure of some millet varieties developed in India to germinate or emerge in the hot soils of the Sahel.

Although some modeling has been done to help predict soil temperatures, accurate descriptions of the soil's temperature and moisture profiles, and the factors affecting them, have not been made readily available in the literature. Information such as this could be useful for research in many subjects, including more precise computer modeling, plant breeding and studies of plant physiology and soil chemistry (plant nutrients, organic matter and toxic elements).

Objectives:

A. Determine the soil temperature regimes in millet production in Niger
B. Determine the influence of surface modification on the soil temperature regimes in Niger.

C. Determine the effects of surface modifications on the water balance and growth of millet.

D. Determine if soil moisture can be predicted from weather data.

Experimental Approach:

This research is conducted at the ISC, Niamey, Niger.

Copper/constantan thermocouples were placed at depths of 9 (surface), 2, 5, 10, 20, 50, 100, 150, 200 and 300 cm in 16 plots in a latin square pattern with four treatments: untreated control, white (sand) surface, black (burned rubber) surface and tie-ridge surface. The upper eight thermocouples from each plot were attached to the data-logger of the CR 7 "Measurement and Control" weather station as were the weather station probes. Beginning 10 July 1983, temperature and climatic data were taken at 2 hours intervals. Climatic data included maximum/minimum air temperature, maximum/minimum humidity, maximum/average wind speed, wind direction, solar radiation, net radiation and rainfall. Soil moisture (30-300 cm) was taken in each plot at least weekly using a neutron probe moisture meter, calibrated for the soils in this experiment. Surface moisture (0-15 and 15-30 cm) was determined gravimetrically. All data are available on computer discs. CIVT millet was grown on the plots with 100 Kg/ha SSP and 100 Kg/ha urea to simulate crop conditions.

State of Progress:

Significant soil temperature differences were observed to depths of 150 cm between the three color treatments. Initial analysis of soil moisture profiles indicate that there was no significant difference in soil moisture due to surface treatments during the growing season. Because 1983 was a relatively wet year, this may or may not be indicative of the importance of soil temperature on the water balance during drier years. An indication of its relative importance may be gleaned from the "drydown" of the soils after the 1983 rainy season as seen by the soil moisture profile data during the 1983-84 dry season. This is yet to be looked at.

The effect of soil temperature on crop growth and production was not pursued due to extremely high in-lot variability in crop growth.

Climatological data have been logged and printed for the period July 10 - December 4, 1983. Data beyond this time was not retrievable until recently due to a change in the data collection program and a lack of computer programming skills available in Niger.

Soil temperature data has yet to be analyzed pending sufficient time and availability of data due to the same communication problem.

There are sufficient data available to test a simple model under study. However, changes in soil moisture strongly effect the temperature, heat capacity and thermal conductivity of a soil. Therefore, a more comprehensive model will be required to take into account rainfall, particularly during the physically complex but agronomically important rains at the beginning of the rainy season. The use of a water balance model such as CONSERVB within the model being treated could provide this flexibility.

Constraints to Progress:

Computer failure, lack of local programming ability and a shortage of time for data analysis are the major limiting factors.

Applicability of Results to TropSoils Goal:

This information will be used to help understand what physical effects through soil management such as erosion control, water catchment, etc. may have on crop establishment and growth. It is hoped that such an analysis will aid in the understanding of the physical relationships within the soil environment, and will therefore aid in the prediction of successful crop establishment under given meteorological conditions. Through an understanding of these relationships, particular soil management schemes may be evaluated for their practicability before placing experiments in the field.

Training Component:

No formal training plans are contemplated at this time.

WATER AND ENERGY BALANCE OF A NIGERIEN SOIL

Leadership Personnel:

Robert G. Chase, TAES
Robert J. Lascano, TAES

Date Research Initiated:

May, 1984

Rationale for Investigation:

The characterization of the water balance of a soil is necessary to quantify the different processes involved for developing water management practices. Of particular importance is the amount of water lost due to evaporation and the amount stored in the soil for plant use. The realization of these measurements has to be done in the context that the processes involved are dynamic. Since the quantification of each component of the water balance equation is not practical, one solution is to use a physical model that describes the system. The model must be dynamic to account for the daily fluctuations of the weather and the resulting water balance and has to account for the physical characteristics of the soil under study.

A model that fits this description is CONSERVB, which is 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 the conclusion drawn that it is suitable for a field situation.

Objective:

To evaluate the application of the CONSERVB model in predicting a water balance in the bare dune soil over time.

Experimental Approach:

This research will be conducted at the ISC, Niamey, Niger and the TAREC, Lubbock, TX.

The field experiment at ISC consists of collecting weather and water and temperature profile data as a function of time. The purpose of this data collection is to evaluate the water balance of a typical Nigerien sandy soil. The water balance study will be supplemented with a model of the flow of heat and water that is designed to calculate water and temperature profiles. The measurements will be compared to the model calculations.

The work to be done by the soil physics personnel at TAREC will consist of two parts. First, laboratory determination of the soil moisture retention curve for the selected experimental site, and second, the modeling effort. The modeling effort includes several parts, such as: thermal characterization of the sandy soil, calculation of the unsaturated hydraulic conductivity, and the estimation, by modeling, of the variability of the soil properties. The most important aspect will be in the comparison and evaluation of measured and calculated profiles of water and temperature. The final evaluation will be in the determination of the water balance of the soil.

It is anticipated that three simulation runs, over the experimental period, will be made. Two of the simulations will give information regarding the limits for the calculations to be within 0.90 of the mean, and the third simulation will give the average values.

State of Progress:

Raw data have been collected and organized for future analysis. In addition, 1983 data from the Labucheri soil are being analyzed and may prove valuable due to the very different rainfall pattern during this season, thus, providing a test for the CONSERVB model at the opposite extremes of rainfall frequency and quantity.

Constraints to Progress:

Data analysis delays due to equipment limitations, i.e., computer and automated data loggers.

Applicability of Results to TropSoils Goal:

The advantages of using a soil water balance model are many. Among them, the CONSERVB 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 very difficult to measure. This in turn can be used to manage agronomic practices of importance for the sandy soils of the Sahel, 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 tested under the conditions in which the model is intended to be used. Furthermore, the model must also be able to describe the inherit variability associated with the soil properties of the area.

Training Component:

No formal plans at this time. Informal, hands-on training will be provided on an occasional basis for INRAN and ICRISAT personnel. We may also assign a graduate student to a portion of this study in the future.

SOIL PHYSICS LABORATORY

Leadership Personnel:

Robert J. Lascano, TAES
Charles W. Wendt, TAES

Date Research Initiated:

February, 1984

Rationale for Investigation:

A laboratory is needed to measure hydraulic and physical properties of selected soils. These properties are required as input data for the evaluation of two models. One model deals with the flow of water and energy, and the other is a mechanistic model that simulates root-water uptake.

The hydraulic properties of interest are: (1) the relation between pressure potential and volumetric water content and (2) the relation between unsaturated hydraulic conductivity and volumetric water content. This includes the value of the saturated hydraulic conductivity. Physical properties of interest are: (1) soil texture, (2) bulk density, (3) soil porosity and (4) thermal characteristics.

Objectives:

To organize, equip and operate a laboratory to measure soil physical properties.

Experimental Approach:

The research is conducted at the TAREC, Lubbock, Texas. Soil-hydraulic properties measured are:

A. Soil moisture retention curve. This curve relates soil-pressure potential to the volumetric water content. The equipment to measure this relationship is commercially available.

B. Unsaturated hydraulic conductivity. This function refers to the relation between unsaturated hydraulic conductivity and the volumetric water content. This function will be measured by the method proposed by Van Grinsven et al. and Bouten and Van Grinsven.

Other soil physical properties will be measured by the methods described in Methods of Soil Analysis. The thermal properties will be calculated as suggested by De Vries. These calculations are based upon the textural composition of the soil.

The hydraulic and physical characteristics of two soils will be measured:

1. A sandy soil from Niger, Africa. These data are needed as an input to a model of the flow of water and energy.
2. Soils from the TAREC. Modeling work will be conducted in two separate sites. One effort is in conjunction with a windbreak study and another in conjunction with the evaluation of root water extraction by cotton plants in a dry-land system.

State of Progress:

The necessary equipment has been purchased and is currently being installed and tested. Soil samples from Niger have been obtained and transported to TAREC. It is anticipated that by December, 1984 the hydraulic and physical characteristics of the soils will be completed.

Constraints to Progress:

The installation of the soil physics laboratory has been limited by the lack of appropriate facilities such as space and equipment. We anticipate that a more permanent than the one we are currently using will be required in the future. The problem with the equipment has been with its procurement from commercial suppliers. The process of purchasing parts is slow and time consuming.

Applicability of Results to TropSoils Goal:

The purpose of this project is to measure the physical properties of soils that are currently being used to evaluate mechanistic models used in TropSoils. The mechanistic models deal with the flow of water and energy in the soil system and water use by plants. The first model will provide a record of the water balance of a sandy soil, and the second model will aid in the interpretation of water use data as it relates to the climate of the region and its interaction with the water balance of the soil.

Training Component:

The soil physics laboratory can be used to train both undergraduate and graduate students, and technicians in laboratory methods to measure soil physical parameters. Also, both domestic and foreign students will use the equipment as our program develops.

GAMMA AND NEUTRON MOISTURE METER CALIBRATION

Leadership Personnel:

Robert J. Lascano, TAES
Charles W. Wendt, TAES

Date Research Initiated:

Pending

Rationale for Investigation:

The measurement of volumetric water content by gamma attenuation provides the means to measure water content near the soil surface, where the neutron method is inadequate. The gamma equipment, because of its geometry, also provides the means to measure water content at more finite depths. However, for water content determinations below 0.30-0.40 m, the neutron method is reliable and preferred over the gamma method because of its simplicity. Regardless of which instrument is used, they have to be calibrated in the field using the soil in which the instrument is to be used. The calibrations are tedious and laborious. Therefore, any time-saving techniques that simplify the calibration are desirable. Furthermore, if the calibration of the two instruments could be combined the necessary work would be simplified.

Objectives:

A. To develop a technique to calibrate gamma and neutron meters.
B. To establish a "standard" that can be used to verify and recalibrate old and new neutron and gamma equipment.

Experimental Approach:

This research will be conducted at the TAREC, Lubbock, TX.

- Calibration of the gamma equipment. This calibration requires the measurement of certain constants which make it necessary to compare our meter with a meter that has been calibrated. The other two constants can be determined independently. It is proposed that our meter also be compared to a similar meter operated by Dr. J. Nieber's group in College Station.

- Site calibration. This calibration will serve two purposes: (1) to calibrate the site and determine the bulk density profile with the gamma equipment and (2) to obtain neutron readings with the existing meters. In this way the existing calibration curve can be verified and modified as necessary. This procedure has to insure that the proper range of volumetric water content is sampled. To do so, it is anticipated different quantities of water will have to be applied to the site. The desired range can also be induced by water extraction of plants around the site.

State of Progress:

The initiation of this project is pending delivery of the gamma attenuation equipment.

Constraints to Progress:

The initiation of this project has been delayed by the procurement of the gamma equipment.

Applicability of Results to TropSoils Goal:

This project will develop practical techniques that can be used to calibrate gamma and neutron equipment used to measure volumetric water content. The measurement of water content is an integral part in the evaluation of the water balance of a soil and water. The quality of the data is influenced by the calibration curves used to convert the readings. These calibration curves are not easy to obtain, and the techniques to be developed will aid in their measurement.

Training Component:

The proper use of gamma and neutron equipment to measure water content in the field is a major drawback in the evaluation of soil and plant evaporation. With this equipment and with the procedures developed students and technicians could be instructed in their proper use.

MEASUREMENT AND SIMULATION OF WATER USE UNDER DRYLAND CONDITIONS

Leadership Personnel:

Robert J. Lascano, TAES
Charles W. Wendt, TAES

Date Research Initiated:

February, 1984

Rationale for Investigation:

The rate of water use by the crop cannot be described by a simple formula. It is necessary to have a water balance for the crop as a function of time, weather, plant growth and soil properties. This water balance can be obtained through the use of a mechanistic model that simulates the processes of the system.

The simulation part can be simplified considerably for conditions of high leaf area index. However, for a crop with an incomplete cover, planted in rows, the radiation-geometry of the crop is complicated 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 important for the calculation of soil evaporation and plant transpiration which are important in the calculation of water use efficiency.

Objectives:

A. To develop a simple theoretical model that can be used to calculate the water use by a cotton crop as a function of time.
B. To test the model with appropriate field experiments.

Experimental Approach:

This research is conducted at the TAREC, Lubbock, TX.

A model that is suitable for the purpose of the objective has not been developed. Thus, one must be developed before proceeding with the field experiments. The starting point of the theoretical development of the model will be the algorithm proposed by Van Bavel and Ahmed and later simplifed and tested with sorghum. The model, once it has been coded, will be tested with a field experiment to be conducted at the TAREC to collect the data to validate the model.

State of Progress:

The theoretical model is currently being developed.

Constraints to Progress:

The principal limitation in this project is the lack of an adequate theory to model and describe the process of root water extraction in a dryland system. Also, necessary field techniques to measure separately soil and plant evaporation are needed.

Applicability of Results to TropSoils Goal:

The advantage of using mechanistic over empirical models is that the mechanistic models can be applied, without major modifications, to any site because models of this type are based upon principles and not on empirical relations that are a function of the site. This allows the use of a model of water use developed at the TAREC to be applied to the semi-arid tropics. The only modification would be in the input data that characterizes the system, e.g. weather, soil properties and others. The proposed model will be tested and verified with cotton. It is expected that the resulting model will be applicable to millet production under dryland conditions in Africa.

Training Component:

This project is well suited as a thesis topic for a graduate student at the Ph.D. level. The project combines both theoretical and practical aspects of water use by plants in a field experiment. Currently no provisions have been made for a graduate student.

SOIL SURVEY OF THE ICRISAT SAHELIAN CENTER

Leadership Personnel:

Larry T. West, TAMU
Larry P. Wilding, TAMU
Jonathan K. Landeck, TAMU
Frank G. Calhoun, TAMU
Les Fussel, ICRISAT
Claude Charreau, IRAT

Date Research Initiated:

July, 1982

Rationale for Investigation:

Agricultural research results and technology generated at the ISC must play a major role during the coming years in reversing crop yield declines throughout the Sahel. The potential success of the ISC rests, to a great degree, on the transferability of this technology to regions of the Sahel far from southern Niger.

A well designed, intensive soil survey is a major forward in neutralizing some of the site specific constraints to technology transfer. This survey provides information on the range of chemical, physical and mineralogical properties of the soils of the ISC thereby facilitating predictions of crop response under the 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.

Objectives:

To characterize and classify soils at the ICRISAT Sahelian Center according to U.S. Soil Taxonomy and the Soil Fertility Capability Classification Systems.

Experimental Approach:

The approach to this survey was similar to that used for soil surveys in the U.S.

State of Progress:

The major accomplishment of this project was providing a soil survey of the area where much of the future TropSoils research in the SAT will be conducted. The survey includes a complete discussion of the soil morphology and properties found in the area, property variability and the classification of the soils. This information provides a benchmark that other soils in other parts of the Sahel can be compared. The survey provides information that can possibly be used to explain the success of various practices. This information and similar information from other areas can then be used to predict the applicability of various research and practices to other areas.

Five different soil series were recognized in the survey area that differ in terms of soil thickness depth to a restrictive iron pan (petroferric or laterite layers), pedogenic development and soil texture. These properties govern soil management practices, water retention and soil physical-chemical responses. Specifically the following conclusions are in order:

A. Soils of the ISC are uniquely different than Ustalfs in semi-arid regions of the U.S.

B. Soils of this region have developed under climatic shifts over geologic time and the area was considerably more humid in the past than today.

C. The parent sands of these soils are of eolian origin that have undergone periods of stability and instability over geologic periods. This is inferred from the dunal surface topography, uniform grading of sands of variable thickness over a laterite scarp and identification of a buried paleosol.

D. Soils of the area are low-charged, kaolinite/iron oxide (systems) that are only slightly buffered chemically. They are acid with high percentages of exchangeable Al in the upper sola.

E. Coarse surface textures of these soils make them highly susceptible to wind erosion and to water erosion on sloping surfaces, or where they are shallow to laterite.

Constraints to Progress:

None

Applicability to TropSoils Goal:

This project provides detailed soils information in an area where little such information was available. This type of information benefits Nigerian researchers by providing them with a reference point that they can use for comparison. The survey also provides an example of the U.S. approach to inventorying soil resources. The survey benefits ICRISAT by providing soil property and distribution information that can be used to explain research results and to aid in plot selection and design. Benefits to TropSoils are similar to those for the other agencies. The scientific community benefits from the presentation of data for soils in an area where little is known concerning soil conditions.

Training Component:

In addition to the two Nigerian students who participated in the field portion of the project, training activities include the following:

A. A nine-hour short course on the various aspects of the survey. The course included six hours of classroom lecture and discussion concerning geology and geomorphology of the area, how the survey was made, properties of the soils, soil property variability and interpretations of the soils. An additional three hours were spent at the ISC observing and discussing the soils in their natural setting. This course was attended by about 40 people including personnel from ICRISAT, INRAN, FAO, USAID and Peace Corps.

B. A three-hour lecture was presented to soil science students at the University of Niamey. About 40 students attended the lecture which discussed the U.S. System of soil classification and its application to the soils of the Sahel.

SOIL-GEOMORPHOLOGICAL RELATIONSHIPS OF DALLOL BOSSO, NIGER AFRICA

Leadership Personnel:

Larry P. Wilding, TAMU
Frank G. Calhoun, TAMU
Naraine Persaud, TAES
Elisabeth Bui, TAMU
Jonathan K. Landeck, TAMU
Raymond Daniels, NCSU
Ouattara Mamadou, INRAN

Date Research Initiated:

August, 1983

Rationale for Investigation:

The purpose of this work is to establish baseline soils data so the hydrological linkage can be established between the uplands as a water-recharge area and the dallol as a water-receiving reservoir area. This is critical to evaluating the beneficial aspects of soil/water conservation practices in plateau and valley wall segments of the uplands.

Secondly, this work will determine the respresentativity of soils at the ISC to surrounding millet-cowpea production areas in the southern Niger.

Objective:

To investigate the soil/geomorphology/hydrological relationships between the Dallol Bosso, adjacent uplands and the ISC.

Experimental Approach:

This research project was instituted as a 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, and the geomorphology, stratigraphy, hydrology, wind and water erosion attributes were compared to the ICRISAT Sahelian Center.

It was concluded on the basis of the soil/geomorphology study that priority for future work should be given to the dallols because of their potential for intensive agricultural use for crop production and shallow groundwater supplies. It is on the basis that the following approach to this project was designed:

A. A detailed soil/geomorphology field study will be conducted from August to December, 1984, along E-W transects perpendicular to the N-S trending Dallol Bosso. Each transect will extend 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 will be established that reflects major geomorphic landforms, stratigraphic units and corresponding soils. A 2-4 km-wide strip will be mapped along each transect.

C. Major soils, geomorphic landforms and stratigraphic units will be sampled to serve as a baseline data for soil classification, hydrology, soil management and erosion interpretations. This work will be referenced to the soil survey of the ISC so applicability of research transfer can be evaluated.

State of Progress:

A. In the uplands the stratigraphy is a sequence of sandy cover materials over ironstone caps over Miocene-age deposits (continental terminal). The dallols are sandy fluviatile deposits of undetermined depth filling fossil drainageways that have been wind reworked into low dunal landforms.

B. Four geomorphic units were identified including gently sloping plateaus, sloping sand valley systems, broad sand plains and dallols.

C. Laterite forms and impermeable contact on all geomorphic surfaces and strongly controls vertical and lateral water movement, erosion and aquifer recharge.

D. Soils on all geomorphic surfaces are highly subject to wind erosion;

water erosion is an important problem on sloping plateaus and valley sand systems.

E. From a pedomorphological perspective, soils on the ISC are representative of extensive millet/cowpea production centers in the vicinity of Niamey. However, hydrologically they differ significantly from dallol and valley sand systems. Water erosion would be much greater on the valley sand soils than at the ISC. Wind erosion across the area would be similar.

F. Major soils of the area have clay enriched subsoils and would be classified as Psammentic Paleustalf, Psammentic Haplustalfs and Petroferric subgroups of Haplustults, Haplustalfs and Dystropepts. Ustoxic Quartzipssamments occur extensively on the dallols.

G. Paleoclimatic influences on pedogenesis and landform evolution in southern Niger are evident from modern soils, paleosols, multiple level laterite-capped plateaus and sand-plugged valley (dallols).

Constraints to Progress:

Transportation and field logistics are a problem in Niger for studies that lie at the periphery of those being conducted by the two permanent Senior Soil Scientists. When studies such as this one are conducted during the months from April to October, it puts a considerable strain on the two field vehicles and the one sedan available to TropsSoils.

One of the more humorous but at the same time frustrating experiences that occurred during the field survey in the summer of 1983 was getting stuck in wet sand with a Toyota 4-wheel drive Landrover one evening near dusk. Without the benefit of light, food or strong backs we managed to bring in enough dry sand, brush and anything else we could carry or find (laterite blocks) to put under the jacked-up wheels. Four hours later, exhausted but relieved, we drove out. You learn a lot about aquic soils, "wet-lands", soil trafficability (or lack thereof), hydrophytes and "good" soil scientists when experiencing such an event in the parched landscape of the region.

Applicability of Results to TropSoils Goal:

This research will provide the benchmark data that should precede other soil and crop management research efforts if the latter are to be fully understood and their significance evaluated on a country-wide or regional basis. The results will be available to other donor agencies and institutions with agricultural research programs within the Niger or the Sahel (such as CARE, IFDC, ICRISAT, FAO, IRAT and ORSTROM).

This work will provide the collaborating country with the first detailed soil/geomorphological study to serve as a model for other soil surveys in the country. It will provide solid baseline data for hydrological/conservation/soil management research and interpretations. It will foster better understanding of past climatic and cultural shifts that impact on current agricultural and soil management practices.

Training Component:

During the 1983 reconnaissance soil/geomorphology survey, Mr. Quattara and Mr. Annou and other personnel of INRAN joined us in the field for one day of training. They brought with them two cartography specialists for field training also. The research will be used in developing the doctoral thesis for Ms. Bui.

ROLE OF AMORPHOUS AND CRYSTALLINE IRON IN THE FORMATION OF SURFACE CRUSTS AND IRONSTONES OF SOIL IN WEST AFRICA AND TEXAS

Leadership Personnel:

Joe B. Dixon, TAMU
Harbi Shadfan, TAMU
Frank G. Calhoun, TAMU

Date Research Initiated:

January, 1982

Rationale for Investigation:

Evidence shows that the crusting of soils is especially a problem in arid and semi-arid regions. There are mainly three types of soil crusting (1) calcareous and saline crusts caused by the accumulation of soluble salts, (2) compaction of soil particles due to impact of raindrops and drying and (3) ferruginous crusts and hardening of soils (e.g. laterite). The latter two are the focus of this study.

Iron oxides contribute to the formation of ironstones in the soils of West Africa, Texas and many other parts of the world. There are other soils which contain large percentages of iron oxides that are friable and permeable to water. A hypothesis being tested is that the hardening of iron cemented material was related to crystal growth of the iron oxides. A strong relationship ($r^2 = 0.97$) was found between strength and the average crystal dimension. This relationship suggests that as the hardening process develops, iron oxide crystals acquire more iron and grow until they are close enough to interact and control most of the hardness of the material. Thus, it becomes more like rock than soil. This relationship was found for iron-rich nodules and the surrounding soil matrix and from laterites of tropical climates. Similarly hardened laterites occur in West Africa.

Iron oxides in agricultural soils are usually very fine particles and, in contrast to the above example of hardening, they contribute to the softness and friability of soils. Also, they improve soil structure and moisture intake. It is in this finely divided state that they can be utilized best in soils.

Objectives:

A. Make a field study of the crusting problem and obtain samples of typical soil properties for strength determinations.
B. Examine fracture surfaces and determine elemental distribution.
C. Model the crust formation process with selected soil particles sizes and amendments to emulate natural conditions and possible field trials.

Experimental Approach:

Sample ferruginous crusts of varying hardness and soil that crusts after wetting and drying in West Africa and in Texas. Determine the strength required to rupture the crust under controlled humidity and temperature. Determine selected elemental, mineralogical, particle size, and morphology properties that may influence the strength of the crust. In selected cases determine the composition of particle surfaces by electron microscopic methods to elucidate the mechanisms of crust formation and hardening. Make synthetic crusts of selected particle size fractions to test the influence of iron compounds and other substances that appear to be related to crust or aggregate formation.

State of Progress:

As the size of synthesized particles became smaller the particles were more inclined to stick together and physical dispersion was difficult to obtain.

Soils from the ISC contain iron oxides that could not be identified by routine methods. They may be amorphous or poorly crystalline. Thus, research on poorly crystalline synthetic iron oxides holds promise for modeling those systems in crust prevention experiments.

Preliminary results indicate that amendments of iron colloides reduce the strength of crusts produced by simulated rainfall on a synthetic mixture of soil fractions. The understanding of laterite and iron oxide nodule hardening has been advanced by the discovery that there is a close relationship between strength and crystal size of the iron oxide.

Constraints to Progress:

There is a need for adequate samples to represent the conditions of interest in West Africa and an instrument to measure the strength of laterite and crusts.

Applicability of Results to TropSoils Goal:

Understanding the factors that relate to the hardening of laterite will be of value in explaining the role of mineralogical and chemical processes during development of plateaus protected by these materials in certain landscapes of West Africa and possibly other places in the world. The same crystal growth process relates to the hardening of nodules in soils of the southeastern United States. The iron cycle in nature will be better understood by recognizing what factors are related to the hardening process.

Training Component:

The progress of the research will be reviewed in research group meetings, in graduate seminars, and at national scientific meetings.

PROPERTIES AND GENESIS OF VERTISOLS AND ASSOCIATED SOILS IN THE MAROUA REGION OF NORTHERN CAMEROON

Leadership Personnel:

Bernard Yerima, TAMU
Frank G. Calhoun, TAMU
Larry P. Wilding, TAMU

Date Research Initiated:

June, 1984

Rationale for Investigation:

Of major importance among the soils of the semi-arid tropics are the Vertisols. They are dark-colored, dominantly montmorillonitic, clayey soils which occupy about 260 million hectares in the world. These soils contract, crack and harden when dry and are very plastic and expand when wet. The distribution of Vertisols worldwide and their unique management problems pose a major challenge for development of soil management technology for small farmers in the semi-arid tropics. It is anticipated that an improved understanding of the morphology, genesis and classification of Vertisols in Northern Cameroon will enhance the interpretation and transfer of soil management research on this soil order throughout the Sahel and Sudano-Sahel.

Objectives:

A. To determine morphological, physio-chemical and mineralogical properties of the soils.
B. To determine phosphorus levels and correlate P-fixation capacity with clay mineralogy.
C. Relate soil microfabric to physical properties and classification of soils.

D. Determine parent material uniformity and mineral reserves by quantification of nonlabile elements and calcium and potassium for the sand and silt fractions.

E. Classify the soils according to the French, FAO and U.S. systems of soil classification.

F. Assess pedogenesis and potential for forest regeneration and agriculture.

Experimental Approach:

The project involves an integrated field and laboratory study using current pedological and mineralogical methodologies. Cooperation with both the Cameroon ministries of Agriculture and Higher Education and Scientific and Technical Research provide logistical field support in assistance in locating sites and sample collection. Sites selected were representative of Vertisols on the major geomorphic surfaces of north Cameroon and relate to specific forest regeneration problems experienced by ONAREF in the regions.

- Objectives A. Sample collection and profile descriptions were made following standard U.S. Soil Survey procedures. Laboratory determinations will include (1) particle size distribution and fractionation, (2) bulk density and coefficient of linear extensibility, (3) soil reaction, (4) organic carbon, (5) calcium carbonate equivalent, (6) cation exchange capacity and exchangeable bases and (7) sand, silt and clay mineralogy by XRD, DTA and IR.
- Objective B. Relationships of P fixation as a function of amorphous material, clay type and amount will be determined.
- Objective C. Thin sections of these soils will be made from oriented samples from each genetic horizon. these will be analyzed under a polarizing microscope to determine the types of microfabrics. This analysis will enhance interpretations of Vertisol utilization for agricultural and engineering purposes.
- Objective D. Elemental analyses and particle size ratios will be determined in order to gain information on parent material uniformity and nutrient reserve status. Stratification influences soil

water movement and soil genesis interpretations and subsequently soil management. Calcium and potassium concentrations give an indication of mineral reserves. Titanium, zirconium and iron distributions and rations will indicate lithologic breaks. Elemental analysis will be done by X-ray spectroscopy.

- Objectives E and F. All morphological, chemical, physical, mineralogical and micromorphological data will be collated and analyzed for each soil. Application of diagnostic criteria for each of the French, FAO and U.S. systems of soil classification will allow placement of each soil in its proper taxonomic category. Having accomplished this the soils will be evaluated both individually and and as a group in terms of agricultural production and forest regeneration potential.

State of Progress:

Mr. Yerima is finishing the field phase of this project. Two Vertisol sites have been sampled and described which are representative of the "lowland" Vertisols of north Cameroon. Both soils will classify as Pellusterts and are typical of the region based on reconnaissance of the same geomorphic/stratigraphic unit.

Two other sites were selected to represent "upland" Vertisols. These sites are located on ONAREF forest regeneration plantations. These Vertisols have developed in situ from maficrich volcanic rock. Both soils have the requisite morphological features of Usterts.

A fifth site was chosen at Mora where an ONAREF regeneration plantation is doing poorly. The soil there is an Ustalf with hard granite occurring at depths of 0.75 to 1.5 meters below the surface. Possible contributing factors to poor tree establishment include (1) shallow, droughty soils; (2) overgrazing and/or (3) an aridic microclimate due to a local oragraphic effect.

Constraints to Progress:

None to date. Field objectives were realized and the soil samples have since arrived at TAMU.

Applicability of Results to SM-CRSP Goal:

A major contribution of this study to TropSoils goals is increased knowledge of cracking soils of the SAT of which only minor areas occur in Niger.

The results will apply most specifically to the SAT of southern Chad, south central Sudan and significant areas of Kenya. Vertisols are also extensive in India, northern Australia, the Pacific Coast of Central America and central Texas. Interpretations derived from this study should have a positive impact on ONAREF reforestation strategies for north Cameroon Vertiosols.

Increased knowledge of the reforestation and agricultural potential of north Cameroon Vertisols will have a positive effect on rural development strategies by ONAREF and other agricultural institutions of the region. This knowledge and insight will also reside in a Cameroon national, Mr. Yerima, who will be able to follow through on these strategies upon his return as a part of the agricultural infrastructure.

Training Component:

The principal training objective for this project is to enable Mr. Bernard Yerima, a Cameroon national, to meet the partial requirements of a Ph.D. degree at Texas A&M University. He will complete this training having (1) gained the field and laboratory skills of a pedologist and (2) completed a dissertation research program of immediate impact on his home country. The opportunity for him to do research in Cameroon has allowed him to re-establish contacts with the agricultural research, extension and education communities. This will facilitate his professional reabsorption into the agricultural infrastructure of Cameroon after he graduates in late 1985.

SOIL CLASSIFICATION AND SOIL LOSS FROM STEEPLANDS IN HAITI

Leadership Personnel:

C. Tom Hallmark, TAMU
Will Blackburn, TAMU
Pierre Louis, Haiti
Fritz Marcelina, Haiti
Frank G. Calhoun, TAMU

The project is supported, in part, by funds from three sources: USAID-HAITI/TAMU, AID Strengthening Grant, and SM-CRSP

Date Research Initiated:

June, 1984

Rationale for Investigation:

Virtually all observers note the negative impact that accelerated soil erosion has had on agricultural production in Haiti. Deforestation and subsequent cropping of the steeplands have greatly degenerated the soil resource. In the steeplands, efforts should focus on soils which have greatest production potential and yet lowest erosion hazard. Soils with lowest production potential and highest erosion hazard should be removed from annual cropping systems and placed into permanent vegetation.

Oxisols are relatively resistant to erosion due to high Fe-Al oxide content, favorable structure and good water transmission properties. Therefore, relatively productive cropping systems could be developed for the Oxisols but an understanding of the soil properties, to include physical, chemical and mineralogical properties, as well as the erodability of the soils as a function of management systems, is necessary to evaluate long-range effects and minimize soil deterioration.

Objectives:

A. To classify the major soils, relate properties to genesis and interpret the effects of soil properties on management.
B. To characterize the physical, chemical and mineralogical properties of soils occurring on the major geomorphic positions.

C. To evaluate soil erosion via soil loss models and present the simulated impact of different conservation practices and cropping management systems.

Experimental Approach:

A study area on Cap Rouge, approximately 20 km North of Jacmel, Haiti was selected. The soils are representative of the Oxisols observed elsewhere in the region. It is the site of the USAID/HAITI ADS-2 project. field observations were made noting common soils representative of landscape position. From these observations, a slope sequence, representative of the study area was selected. Detailed soil descriptions were obtained and soil samples returned to TAMU for analyses. Soils will be classified at the family level in Soil Taxonomy and the influence of soil properties on cropping management schemes will be evaluated.

Additionally, for each landscape position-soil studied and each major management practice, three transects were made to determine canopy cover, bare soil, rock and litter percentages. A meeting with about 40 farmers was held to discuss cropping systems, rotation, soil erosion and rationale for specific management techniques used in the study area.

State of Progress:

A. Within the Cap Rouge area, agricultural production is primarily agronomic and horticultural. Almost all farmland is fallowed during one of the two major growing seasons except for those fields in footslope positions. During fallow periods livestock are tethered to harvest the volunteer forbs. Significant degrees of compaction occur during this tethering period.

B. In general, all soils of the study area are formed from limestone residuum or materials derived from the limestone. Soils of each landscape position will be discussed.

C. Summit. Soils of the summits are generally well-drained Oxisols (Tropeptic Eutrorthox; clayey, oxidic, isohyperthermic). They consist of shallow (<50 cm) to very deep (>2m) soils developed from limestone. Generally they are level to gently sloping. They are generally very low in coarse fragments, and texture throughout the solum is clay loam to clay. Soil reaction in the plow layer ranges from strongly acid to neutral, depending upon past management while subsoils are medium to slightly acid. Permeability is moderately rapid and runoff is very slow to slow. The water retention capacity is low to very high depending upon soil depth. The erosion hazard is slight and erosion from these soils is slight to moderate.

D. Shoulder. Soils of the shoulder are generally too shallow for oxisols and tentatively are classified as Lithic Eutropepts; clayey-skeletal, mixed, isohyperthermic. They are very shallow and are developed from limestone residium and are sloping to moderately steep. Fine earth textures are clay loam or clay. Soil reaction throughout the solum is mildly to moderately alkaline. Permeability is moderate and runoff is moderate to rapid. The water retention difference is very low. Erosion hazard is moderate to high; past erosion is believed to be moderate to severe.

E. Backslope. Soils of the backslope are very similar to those on the shoulders. They are generally Lithic Eutropepts; clayel-skeletal, mixed, isohyperthermic. These very shallow to shallow soils are developed from hard limestone residuum and are on steep (20-45%) to very steep (45%) slopes. The fine earth texture is generally clay loam to clay. Soil reaction throughout the solum is mildly to moderately alkaline. Permeability is moderate but runoff is rapid to very rapid. Due to the shallow depth to bedrock and high content of coarse fragments, water retention difference is very low. Erosion hazard is high or very high. Past erosion is believed to be severe to very severe.

Footslope. Soils of the footslopes are well drained Oxisols. (typic Eutrorthox; clayey, oxidic, isohyperthermic). They consist of deep to very deep soils developed in colluvium and alluvium from upslope positions, principally the shoulder and backslope. Generally they are strongly sloping (8-12%) to gently sloping (1-3%). The texture range from clay loam to clay. Soil reaction ranges from medium acid to neutral. Presumably, these soils are base-charged as they receive significant sediments from upslope.

Permeability is moderately rapid and runoff is slow. The water retention capacity is very high. Erosion hazard is none to slight as these soils represent areas of deposition rather than erosion.

To date, soil samples are being prepared for analyses in the TAMU Soil Classification Laboratory. Further, transect and infiltration data are being analyzed for input into USLE erosion analysis by position and soil type.

Constraints to Progress:

None to date. All field objectives were met.

Applicability of Results to TropSoils Goal:

The final approval documentation from AID/Washington requested that each of the three funded programs (humid tropics, semi-arid tropics and the savannas) address soil management problems of the steeplands within the respective agroecological zone. This project addresses the issue of soil erosion on steeplands in Haiti for the semi-arid tropics zone. This research was not conducted in Niger because of a lack of suitable sites and necessity. The results of this project will be applicable to those steepland areas of the tropics with Oxisols and Inceptisols that have udic, but marginal to ustic, soil moisture regimes.

Training Component:

The data and interpretations of this study will be utilized for M.S. theses by Mr. Louis and Mr. Marcelin, Haitian nationals. These two students are under USAID/Haiti sponsorhip at TAMU.

TropSoils/TAMU anticipates continued collaborative opportunities in steepland research with these two individuals upon their return to Haiti.

SPATIAL VARIABILITY IN NIGER SOILS

Leadership Personnel:

Robert G. Chase, TAES
Mamadou Ouattara, INRAN
Leslie Fussell, ICRISAT
Phil Serafina, ICRISAT

Date Research Initiated:

May, 1983

Rationale for Investigation:

It has been observed that hills of millet in Niger vary in such characteristics as height, leaf area, root depth and perhaps soil water extraction and other plant properties. These differences result in variable yields over relatively short distances. From an experimental point of view, this situation causes several problems, e.g. the design of experiments to quantify response-type treatments is difficult. The coefficient of variation within an experimental unit is so variable that statistical analysis of the data often results in uncertain conclusions.

The expected variability in millet growth is a function of such factors as: (1) soil physical properties, (2) soil chemical properties and (3) plant properties, such as seed vigor. The interaction among these factors is complex so they can only be dealt with one property at a time. Because of the nature of the variability of the soil properties in space, traditional soil survey techniques will not solve the problem. An alternative approach is the use of geostatistics techniques to quantify how the properties are distributed in space.

The main drawback to geostatistical techniques is that a large number of soil samples are initially required to effectively characterize the soil property of interest. Therefore, the first question that must be answered for any given soil property is the frequency of sampling so as to obtain the most significant data with the minimum number of samples. Frequently, the sampling distance will be different for each soil property.

Objectives:

A. To obtain baseline data and farmers' explanations as to why pronounced short-distance spatial variability exists in their fields.

B. To determine optimal sampling distance to be used to evaluate certain soil chemical and physical properties.

C. To delineate the spatial variability of various soil and plant parameters in one "precision plot" at the ISRC.

Experimental Approach:

The research will be conducted at the ISRC, Niamey, Niger and in farmers' fields in the country.

Four areas near Niamey were selected for sampling and discussions with farmers. Transects were run and samples taken for analysis in three directions from the center of poor-yielding areas into good-yielding areas.

Soil profiles were sampled at four sites, two in productive and two in nonproductive soils. Plant height at harvest in 1983 and at two weeks after planting in 1984 were also taken for correlation studies. Maps of plant height at harvest were taken to correlate plant growth with soil properties. Plant height is a good indicator of plant growth or crop yield in millet. Similar data are being collected from another location where TropSoils has a year of climatical and soil temperature data.

State of Progress:

Farmers had excellent, though sometimes simplistic and religious, insights as to why some soils produced better crops than others and the effects of yearly storm events on differential crop damage. Organic matter appears to be the most important factor discussed by all farmers; however, O.M. analyses were not done in several interesting cases due to small sample sizes. Differences between high-producing and low-producing soils appear to be as follows.

Soil	General Location	Possible Soil Type	Production Capability	
1	Lowland Near River	Sandy Loam Texture Type	Very High	Rich in organic matter from river flooding.Called "Black Soil" by farmers
2	Upland Flatlands	Alfisols	High	Manuring required every 3 years. Effects may last up to 10 years
3	Upland Flatlands	Alfisols	Moderate to Poor	Poor production due to absence of manure treatment in previous 3 years.
4	Blown Dunes or Depressions	Entisols	Poor	Requires 2X manure for the same yield as an Alfisol
5	Micro-Gullies	Uncertain	None at Present	Sealed surfaces keep this otherwise usable soil out of production

Farmers identify God, manure, rainfall and wind, roughly in that order, as the overriding factors in millet production. Manure is expensive and hard for the farmers to find. Inorganic fertilizers are more expensive, and most farmers are not yet sure of their value.

Constraints to Progress:

Ability of the INRAN Soils Laboratory to handle increased soil sample analysis load.

Applicability of Results to SM-CRSP Goal:

This project addresses the variables of soil type, soil environment interactions including infiltration, wind and water erosion, evaporation temperature and the interaction between the soil and ammendments applied. Methodologies derived from this study will be applicable to experiment stations and farmer fields throughout the SAT. Principles for ascertaining the effects and amelioration of microvariability will be developed, resulting in further refinement of soil management strategies for the SAT.

Training Component:

No formal plans at this time. Informal, hands-on training will be provided on a regular basis for INRAN, ICRISAT and University of Niamey personnel. A TAMU graduate student or a University of Niamey senior student may be assigned a portion of this study in the future.

SPATIAL VARIABILITY OF SOIL PROPERTIES

Leadership Personnel:

Robert Lascano, TAES
Charles W. Wendt, TAES

Date Research Initiated:

June, 1983

Rationale for Investigation:

Since soils are variable, treatments within an experimental site are replicated to find the average and the deviations from the mean. In turn, the variability is quantified by using statistical methods that have originated as a result of observed deviations. This approach is referred to as "classical statistical methods" and is based on the assumptions that the samples are random, independent of one another and the population normally distributed. If any one of these assumptions fails, the selected statistical test used to analyze the data is in error. If the samples are not independent, classical statistics does not offer an alternative.

The concept of spatial versus statistical variation has caused some confusion. Statistical variation is 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 of the variable 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".

Among the agronomic properties that can be studed by the use of geostatistics are air and soil surface temperature, yield, texture, fertility, salinity, chemical and physical properties, etc.

Objectives:

A. To develop algorithms to analyze data for geostatistics.

B. To develop a method to scale the hydraulic parameters of a soil that are used as input to simulation models.

Experimental Approach:

This research is conducted at the TAREC, Lubbock, TX. The computer algorithms to calculate the following parameters will be implemented: auto-correlation, semi-variance and kriging. The majority of these programs are available and implementation consists of adapting these computer codes to operate with the computer system available. The procedure to scale the hydraulic properties is numerical. The necessary data have been collected and only computer analysis is required.

State of Progress:

The computer algorithms to calculate autocorrelation, and semivariance have been coded and are running. The computer programs to reduce the field data to pore-size distribution and values of pressure potential have been coded and part of the data has been analyzed.

Constraints to Progress:

The modification of computer codes from one installation to another is a slow process. The analysis of results, due to the large number of data points has taken considerable time.

Applicability of Results to TropSoils Goal:

The techniques developed will be applicable to other areas of research, such as: characterization of the physical properties of soils in Niger, and the analysis of data for any experimental plot. This technique could be applied, to the study of deep placement of phosphorus and residual and applied nitrogen.

Training Component:

The programs that have been implemented can be used to train both domestic and foreign students in the procedures to scale hydraulic properties of soils.

SPATIAL VARIABILITY IN SOIL CHEMICAL AND PHYSICAL PROPERTIES IN RELATION TO BARREN AND ADJACENT FORESTED SOILS

Leadership Personnel:

Robert G. Chase, TAES
John Heermans, USAID (FLUP)

Date Research Initiated:

June, 1983

Rationale for Investigation:

Aerial distribution of the present Guesselbodi forest, which is typical of extensive areas of degraded Sahelian forests, has the appearance of stripes or spots when viewed from above or on aerial photographs. It is a mosaic of clumps or strands of vegetation interrupted by barren, crusted soil. Hence the names "tiger" and "leopard" bush. This study was designed to test the hypothesis that pre-existing soil conditions contributed to this morphological appearance following man's intervention through over-exploitation of this system.

Objectives:

To determine what chemical and/or physical soil parameters cause or are caused by the spatial distribution of forested and barren soils.

Experimental Approach:

This research will be conducted at the Guesselbodi Classified Forest, near Niamey, Niger.

Due to the wide variety of reasons given for the clumped distribution of trees and shrubs, several factors are included for study. These are: (1) land elevation/depression, (2) soil thickness above the laterite and (3) cracks or differences in the laterite substratum.

For (1) and (2), a trench was cut through a forested area beginning and ending in the adjacent barren areas. Soil thickness, distribution of tree roots and frequency of termite holes were mapped. Samples of the laterite gravel subsoil were collected and analyzed for particle size distribution and percentage of infested topsoil.

Soil samples were taken across a transect at three depths.

State of Progress:

The case for surface or subsurface micro-depressions as prerequisites for forested clumps is not substantiated by the data. Differences in soil depth likewise do not appear to cause differences in plant establishment. Other visual or derived information could be effects of, as easily as causes for, plant distribution.

The most likely synthesis of the existing data is that the shape of the remaining clumps of vegetation is due to subtle and numerous independent or interdependent reasons, resulting in a favorable microclimate within the vegetation and supported by the vegetation itself. The implication is that it would be easier to sustain an existing forest than to rebuild one after the chemical and physical properties of the soil have deteriorated due to the loss of vegetative cover by overgrazing and/or poor wood harvesting practices.

Constraints to Progress:

A major constraint has been the inability of the INRAN soils laboratory to absorb the additional load of soil samples.

Applicability of Results to TropSoils Goal:

The results will be applicable to areas of the Sahel where forest degradation has reached the "tiger"/"leopard" bush stage. It will facilitate better design and interpretation of soil management/agroforestry research conducted in such areas.

Training Component:

Informal, hands-on training will be provided for INRAN, ICRISAT and University of Niamey personnel.

SOIL PREPARATION TECHNIQUES AND THE INTERACTION OF SOIL PREPARATION AND NITROGEN AND PHOSPHORUS FERTILITY ON SORGHUM YIELD

Leadership Personnel:

Mamadou Simpara, IER
Mamadou Keita, IER
Arthur B. Onken, TAES
Charles W. Wendt, TAES

Date Research Initiated:

March, 1984

Rationale for Investigation:

The conclusion has been reached that in the southern Sahel of West Africa, deficiencies of nitrogen and phosphorus are a more serious problem than low rainfall. The transition from growth determined by nutrients to that determined by water occurs at about 300 mm annual rainfall

Objectives:

A. To compare the effects of several techniques of soil preparation on soil water status and crop yield.
B. To determine the effects of nitrogen and phosphorus fertilizers applied alone and in combination with water conserving practices on crop yield.

Experimental Approach:

The test area will be located at the Cinzana Experiment Station in Mali. Cultural treatments planned include control, ridging, subsoiling, subsoiling + ridging, tied ridges and subsoiling + tied ridges. Nitrogen and phosphorus fertilizer treatments as determined by soil tests and crop yield potential will be superimposed upon water conserving soil management practices. Treatments will include current practices and improved practices that research has shown to be effective in other semi-arid areas. Appropriate weather, water, soil and plant measurements will be made and subjected to statistical analyses and interpreted.

State of Progress:

The work plan and budget have been approved, but research has not been initiated.

Constraints to Progress:

Considerable time has been required to complete the agreement necessary to conduct the on-site collaborative program in Mali. The limited number of potential collaborators in the country has been a further factor that caused delay. Problems associated with communication and logistics are a continuing deterrent.

Applicability of Results to TropSoils Goal:

The results will apply to a large part of the semi-arid region of West Africa. They should contribute to an increase in food production and preservation of soil resources in the collaborating countries and their institutions will experience an increase in informed and trained scientists. Increased knowledge of semi-arid tropical soils will accrue to scientists of lead institutions and the scientific community in general.

Training Component:

Mamadou Simpara will receive short-term training in the U.S. on techniques of establishing soil management and run-off plots, including installation of recorders and data handling.

RELATIONSHIP BETWEEN SOIL WATER UTILIZATION AND SOIL PLANT NUTRIENT STATUS

Leadership Personnel:

Arthur B. Onken, TAES
Charles W. Wendt, TAES
Mamadou Simpara, IER

Date Research Initiated:

March, 1984

Rationale for Investigation:

Stroosnijder observed that nutrient deficiencies resulted in usable water being left in the soil by native vegetation in the Malian Sahel. He concluded that application of nutrients could increase crop production five fold in the southern Sahel under natural rainfall conditions. Preliminary analyses of soil samples from Mali indicate severe nitrogen and phosphorus deficiencies. Wendt and McMichael have shown that in Texas High Plains soil root growth and water extraction are much less in zones low in phosphorus than in zones of adequate nutrient supply even when the surface of the soil has an adequate supply of phosphorus. Significant amounts of water that could be used by plants remain in the soil. Newman has shown that water use efficiency of cotton was increased 8% under dryland conditions and from 5 to 15% under irrigated conditions by proper fertilizer applications. Onken and Peterson have identified sorghum breeding lines that are significantly different in phosphorus and nitrogen use efficiencies. The above combination of circumstances support two areas of investigation. One is to determine the effects of fertilizer placement on soil water extraction and use. The other is to determine if a plant that produces relatively more dry matter under low nutrient conditions will extract and make more efficient use of soil water than one that produces relatively less dry matter under low nutrient conditions.

Objectives:

A. To determine the effects of soil plant nutrient status in a given portion of a soil profile on plant utilization of water from that profile.

B. To define the relationship of values obtained from current soil test methods and water utilization from various zones in the soil profile.

C. To determine the rate and placement at which nutrients need to be applied for most efficient utilization of soil water by plants.

D. To evaluate the water use efficiency, in nutrient deficient soils, of sorghums differing in nitrogen and phosphorus use efficiencies.

E. To compare phosphorus reactions in tropical and temperature zone Alfisols.

Experimental Approach:

The research will be conducted at the TAREC, Lubbock, TX.

The field research for Objectives A, B and C will be conducted in two stages: (1) to establish whether fertilizer applied to a nutrient deficient zone in a soil profile will enhance water utilization from that zone and (2) to determine the appropriate rates and placement of nutrients to obtain maximum soil water use efficiency.

Field study No. 1 will be to accomplish Objectives A, B and C and field studies 2 and 3 will be to accomplish Objective D.

Study No. 1. This study will be conducted at the TAREC. Two rates of phosphorus will be applied into a subsurface phosphorus deficient soil layer. If the surface soil is deficient in phosphorus, it will be corrected by fertilizer application. 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. 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.

Based upon the first year's results, additional rates and placements in the phosphorus deficient zone will be incorporated in the second and third years to establish the best rates and configuration of placement to maximize efficient use of soil water.

Study No. 2. Four sorghum breeding lines that have been shown to differ in nitrogen use and in early growth water use efficiency will be planted on a nitrogen deficient soil. Water extraction from the root zone will be determined.

Study No. 3. Four sorghum breeding lines differing in phosphorus use and water use efficiency will be planted on a phosphorus deficient soil. Water extraction from the root zone will be determined.

Data for Objective 5 will be obtained from a laboratory study. Surface soil from a tropical Alfisol will be collected from the Cinzana Experiment Station in Mali and transported to Lubbock. An Alfisol of similar texture and low in phosphorus will be collected from the Texas South Plains. The soils will be treated similarly and phosphorus reactions studied.

State of Progress:

Research has been initiated for Objectives A through D and data are being obtained during the 1984 crop season. Soil has been obtained from the Cinzana Experiment Station for Objective E, but the experiment has not been initiated.

Constraints to Progress:

Considerable time was required to determine the specific objectives for this research due to the necessity of establishing collaborating relationships and insuring relevance to both West Africa and West Texas conditions.

Applicability of Results to TropSoils Goal:

Results from these studies will provide necessary information for designing subsequent research in Sahelian Africa to maximize fertilizer and water use efficiencies. These efficiencies will contribute to the goal of increasing food production through more efficient use of plant nutrients and available soil water.

Training Component:

Mr. Simpara and associates at the Cinzana Research Station have participated in the identification of research objectives and will be consulted and advised on the results and interpretations for local considerations.

EVALUATION OF THE EFFECTS OF A NEEM SHELTERBELT/WINDBREAK PLANTATION ON WIND VELOCITY, SOIL MOISTURE CONTENT AND YIELD OF MILLET

Leadership Personnel:

Naraine Persaud, TAES
Steve Dennison, CARE
Steve Long, CARE
N. Zachary, CARE

Date Research Initiated:

Rainy season, 1984

Rationale for Investigation:

The CARE Maggia Valley shelterbelt/windbreak plantings provide a site in Niger for studying the role of shelterbelts and windbreaks in improving crop growth and yield. The value of these plantings is being recognized by the local population. There appears to be a growing 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 the shielding from high winds and dust rather than a perception of the possible effect of the trees in moisture conservation, crop growth and yields.

Careful studies are needed to understand the effects of the present windbreak 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.

Objectives:

A. To measure simultaneously wind-velocity profiles outside and inside the shelterbelt.

B. To mathematically analyze these profiles to quantify the physical parameters controlling the effect of the windbreak on wind velocity.

C. To quantify the effect of the windbreak on soil moisture storage during the rainy season and on the yield of millet.

Experimental Approach:

This research is conducted in the Maggia Valley, near the town of Bouza, Niger.

Anemometers together with a direction sensor mounted on movable masts will be used to study wind velocity profiles. Automated microelectronic data loggers will be used to collect the data on wind velocity. These data will be used to satisfy objectives A and B. Two transects will be laid out beginning outside and traversing the shelterbelt between two parallel adjacent windbreak rows. One transect will be situated midway between the rows and the other halfway between this transect and one of the rows. A third transect will be marked out perpendicular to the rows and cutting across at least 10 rows. Small plots will be demarcated equidistantly along these transects. Observations will be taken of soil moisture in each plot. Yield of millet and dry matter yield at flower initiation will also be taken. Techniques of analyzing interrupted space series will be used to obtain quantitative measures of changes in trends, levels and variance as the series of observations progresses from outside to inside the shelterbelt area.

State of Progress:

This project is conducted in cooperation with CARE International who established the shelterbelt and at present is evaluating the socio-economic aspects of the plantation. A pedological examination has been completed to determine the uniformity of the soils. This information is needed to choose an appropriate spacing for the plots along the transects. The remainder of the study has not been initiated.

Constraints to Progress:

Initiation of the project has been delayed because the anemometers and dataloggers have not arrived in Niger.

Applicability of Results to TropSoils Goal:

There is considerable interest by the Nigerian Forest Service in making similar plantings at other locations. This is an expensive endeavor, and thus, it is necessary to demonstrate quantitatively and conclusively that there is a beneficial effect of the shelterbelt rows on the yield of millet planted as an intercrop between the rows. Demonstration of the applicability of space series analysis techniques to agronomic problems would be a contribution to methodology used in this subject of study.

Training Component:

Mr. Steve Long, CARE technician, will monitor data collection for this project on a daily basis. A portion of this study, under the supervision of Dr. Persaud, who is a member of the TAMU graduate faculty, will be used for a master of science thesis at TAMU for Mr. Long.

INFLUENCE OF WINDBREAKS ON WATER EVAPORATION FROM A BARE SOIL

Leadership Personnel:

Charles W. Wendt, TAES
Robert J. Lascano, TAES

Date Research Initiated:

May, 1984

Rationale for Investigation:

It has been suggested that in arid and semiarid regions the main benefit from windbreaks is in the reduction of water use under conditions of sensible heat advection. A review of the literature on the effect of shelters has led to the conclusions that they alter microclimate, reduce potential evapotranspiration, reduce actual evapotranspiration, improve internal water relations, provide improved opportunity for photosynthesis and generally increase yield.

In studying the effect windbreaks have in the water and energy balance of the sheltered area, it is of interest to separate soil evaporation from plant transpiration. Therefore, it is proposed to evaluate, as a first approximation, the effect windbreaks have on evaporation from a bare soil.

Objective:

To evaluate the effect windbreaks have on evaporation from a bare soil.

Experimental Approach:

This research is conducted at the TAREC, Lubbock, TX.

The experimental method combines measurements of soil evaporation with simulated results. The simulated results will be obtained with a model of the flow of water and energy in the system. To validate the model and evaluate the effect of wind on soil evaporation will involve measurement of the soil water, soil temperature, weather variables and surface evaporation.

State of Progress:

The study was begun in May 1984 with site preparation and installation of field equipment. The collection of data was started on July 2 and will continue through the end of September. Data being collected consists of: soil temperature, soil water content, soil evaporation, and weather information.

Constraints to Progress:

The main limitation of the experiment has been the breakdown of equipment and the time it has taken to replace the parts. We have had technical problems with the power supply of a CR-7 data collector, and with a fan of a wet-dry bulb psychrometer.

Applicability of Results to TropSoils Goal:

In arid and semiarid regions the problems of water conservation dictate that any means of modifying the environment to conserve water would be beneficial. Windbreaks represent a physical barrier that have been shown to reduce water use by plants and evaporation from the soil surface. The results obtained from our experiment could be used to evaluate the effect windbreaks might have in Africa in terms of water conservation, and increase in yield.

Training Component:

For this experiment no provisions were made for the training of personnel. However, the possibility of a graduate student working in this area, as a research project, would strengthen this experiment. More work in this area is anticipated in the future.

EFFECT OF LOW-INPUT SOIL CONSERVATION PRACTICES ON EROSION LOSSES, RUNOFF AND SOIL MOISTURE STATUS

Leadership Personnel:

Naraine Persaud, TAES
Mahmadou Gandah, INRAN
Daouda Idrissa, Tapis Vert Project
Nikola Thiessen, Tapis Vert Project

Date Research Initiated:

Scheduled for 1984

Rationale for Investigation:

Erosion control and soil moisture conservation are complementary practices for increasing yields. There has been very little research effort to quantify soil losses and runoff under different management practices in the Niger and other Sahelian countries. From a soil and water conservation viewpoint the important physical and chemical properties of lateritic soils that influence their erodibility and moisture relations need to be understood. The measurements and observations planned for this study are designed to further this understanding. In addition, they will contribute in developing needed empirical relationships for use in estimating runoff and erosion losses.

Objectives:

To evaluate the effect of low-input conservation practices--specifically cropping systems, structural barriers and soil-tillage practices on sediment yield, runoff and moisture conservation.

Experimental Approach:

The research will be conducted at Chikal, Niger.

Large field plots will be utilized. They will be isolated from surrounding runoff using cut corrugated galvanized sheets. Each plot will be equipped with a 2-inch Parshall flume to determine runoff hydrographs and concrete collection tanks to determine total runoff and sediment yield for each rainfall event. An automatic recording rain gauge will be installed at the site to monitor rainfall mass curves. Gravimetric measurements of soil moisture status and observations of plant growth and yield will be made at suitable times. Soil hydrological parameters and characterisics at the site will be measured.

State of Progress:

Four plots have been installed on a farmer's field at Chikal. The treatments are (1) bare plot, (2) cropped with millet in the traditional manner, (3) cropped traditionally but with prior deep cultivation and (4) cropped traditionally but with sunken laterite barriers. No results are available at present. The monsoons were delayed at Chikal.

Constraints to Progress:

Full instrumentation of this experiment has been delayed since the two inch Parshall flumes and automatic recording rain gauge have not arrived in Niger.

Applicability of Results to TropSoils Goal:

The results of this project will be applicable to sloping, sandy soils with argillic horizons which are very common to the Sahel. The treatments will allow an evaluation of low-input soil and water conservation practices on sloping lands under the SAT environment.

Training Component:

Discussions are currently underway between the principle investigator and Dr. Persaud on the possible assignment of a TAMU graduate student to this project in 1985.

EVALUATION OF THE EFFECTIVENESS OF A SANDFIGHTER

Leadership Personnel:

Robert G. Chase, TAES
Charles W. Wendt, TAES

Date Research Initiated:

April, 1983

Rationale for Investigation:

The sandfighter is a tool used in west Texas to stabilize sand dunes and to reduce the effect of wind damage to young plants. In the Sahel region, sand blasting and burial of young millet plants is a common phenomena, and the use of a "sandfighter" could help in the establishment of a crop. Preliminary work with the tool in the Sahel region during 1983 indicated that indeed it can have a beneficial effect. This work was qualitative and consisted primarily in evaluations based on visual observations. One of these observations was that a treated area, during a rainfall, had no redistribution of water whereas plots that had not been sand-fought did.

Another potential beneficial effect of the sandfighter may be in reducing wind speed near the soil surface due to an increase in soil-air friction. The effect needs study including a description of wind velocity profiles as influenced by use of the sandfighter. This needs to be done at two windspeeds due to daily decrease in wind friction and resultant increase in wind speed which generally occurs between 0700 and 0900 in this area.

Objectives:

A. To determine if variability in crop establishment or growth is affected by the sandfighter's influence on sand blasting, seedling burial, surface redistribution of rainwater and soil physical properties.

B. To determine if effective sandfighting can be accomplished at lower speeds than required in Texas, thus, permitting use of animal traction.

C. To determine if sandfighting can reduce or eliminate surface redistribution of rainwater.

D. To quantify changes in the zero plane of displacement due to the roughened surface created by a sandfighter.

Experimental Approach:

The research is conducted at the ISC, and elsewhere in Niger.

Objective A: A modified sandfighter will be used in the planted fields, between crop rows, after each rain until the crop is well established. The difference in percent crop establishment, and variability in plant growth and yield between treated and non-treated fields will be determined.

Objective B: After the first rainfall, portable recording anemometers mounted at 0.4, 2.0 and 6 m above the soil surface will be placed at several locations across a barren field, in line with the wind, both before and after sandfighting. The differences in Zo and μ (zero plane and boundary layer resistance) will be calculated for each point.

Objective C: Sand traps will be placed at the two ends of six 30 x 30 m fields, half of them treated with the sandfighter. Sand will be collected over varying periods of time, depending on wind speed, and weighed to determine the quantity that enters and the quantity that leaves.

Objective D: A rainfall simulator will be used to create simulated storms of differing intensity. Infiltration rates will be calculated to determine the effectiveness of the sandfighter in minimizing short and long distance runoff in sandy soils.

State of Progress:

A tractor-drawn sandfighter was used on numerous occasions to stabilize the bare soil surface at the ISC and was found to be extremely useful.

Sandfighters must be drawn slowly across the soils at the ISC and even more slowly at the Kolo Station, presumably because of the low clay content of these soils. Animal traction appears to be sufficient to pull the sandfighter at these slow speeds, which are considerably below the minimum speeds required to operate the sandfighter in the higher-clay soils of West Texas.

The sandfighter increases the surface's water holding capacity by nearly 7 mm and the surface area by 18% and breaks up surface crusts. We have documented that this combination of factors assures infiltration of rainwater, even after heavy, intense rains.

Results of the study of the effect of sandfighting two or more days after a rain resulted in mixed, difficult-to-quantify observations. One general trend did appear however: as the soil dries, the sandfighter must be drawn at lower speeds to form stable holes and clods. At some point, from one to five days after a rain depending on the quantity of rain, existing soil moisture, soil texture and potential evaporation following each rainfall, stable clods will not form and after further drying, stable holes will not form. This may be a problem in early-season planting due to the fact that extremely dry subsurface soils cause the surface soils to dry out rapidly. Acceptable early-season sandfighting was difficult to achieve presumably due to this factor and the unavailability of a tractor immediately after the early-season rains.

The 1984 season has been extremely dry compared with 1983. No runoff has yet been observed in cultivated fields; surface redistribution of rainfall is not a consistent phenomenon but may still be an important factor in rainy years. Plant variability is still pronounced and is therefore either an indirect result of runoff or of unrelated factors.

Research on objective "D" has not been initiated.

Constraints to Progress:

Progress on objective "B" has been slowed due to late arrival of portable recording anemometers. Results for objective "C" may be compromised due to difficulties in design of proper sand traps. Success for objective "D" will depend on timely delivery of a rainfall simulator.

Applicability of Results to TropSoils Goal:

This project addresses problems in wind and water erosion and crop establishment which are of major importance to those semi-arid regions of the tropics and the U.S. which have sandy-surfaced Ustalfs, Ustults and Entisols.

Training Component:

No formal plans have been developed at this time. Informal, hands-on training will be provided on an ad-hoc basis for INRAN, ICRISAT and University of Niamey personnel. We may also assign a graduate student to a portion of this study in the future.

REJUVENATION OF CRUSTED, BARREN FOREST SOILS IN NIGER

Leadership Personnel:

Robert G. Chase, TAES
John Heermans, USAID (FLUP)

Date Research Initiated:

April, 1983

Rationale for Investigation:

Firewood is an extremely important commodity in Niger, particularly near population centers. In 1973, in Niamey, for example, the 70,000 inhabitants consumed an estimated twenty million kg of wood. However, firewood is becoming more difficult to find. It is brought from greater and greater distances and the price is rapidly increasing.

The use of forests near Niamey has been restricted to the harvesting of dead wood only. This inefficient utilization of the biotic potential of the forest has been in reaction to the rapid decline in forest stands 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. Between the diminishing stripes and spots of forested area are expanding areas of shallow, crusted, totally barren soil. Infiltration rates are extremely low, resulting in dry soils and a loss of most rainwater to runoff. These areas represent a serious waste of needed woodland, a loss of precious groundwater and an increasing erosion danger downslope.

Objective:

To develop simple, low-cost methods to reverse an accelerating, long-term loss of productive forest land.

Experimental Approach:

This research is be conducted at the Guesselbodi Classified Forest near Niamey, Niger.

A cooperative research project was begun in April, 1983, between the Forest Land Use Project (FLUP), INRAN Soils Laboratory and TropSoils to study the causes and methods of reversing this deforestation trend. Twenty crusted, barren sites were located in the Tiger Bush area of the Guesselbodi Forest: 10 protected from grazing and 10 not protected. In May the following treatments were applied: (1) control, (2) hand tillage to approximately 10 cm, (3) mulching with small branches and (4) a combination of tillage and mulching. The 5 x 5 m plots were randomized on each of 20 sites.

Three new plots were established in 1984 in both the protected and nonprotected areas. This will permit direct comparison of results between newly treated soils and soils which have already gone through a one-year cycle. This is especially important in this area, where yearly climatical parameters change dramatically.

State o` Progress:

The results are striking. By July, only eight weeks into the rainy season, grasses were established on all treated plots. Soil moisture in treated plots were 2-4 fold higher than in control plots, the latter of which remained barren throughout the first season of the experiment. In the first year, tillage-only produced about twice the vegetation as did the mulch-only treatment and half as much as the combination treatment. Although no seeding was done, tree species were found in 60% of the treated plots. By December most of the tilled plots appeared to have redeveloped smooth hard surfaces, many with crust-like appearances. The mulched surface on the other hand showed considerable termite activity and residual surface deposits of sand trapped by the mulch.

The 1983 data establish the fact that considerable short-term changes in the productivity of otherwise barren forest soils can be made with both high- and low-input treatments. The combination of the two treatments was best, sometimes exceeding the existing natural system in forage production.

The 1984 data show that tillage-only plots are reforming their surface crusts, have decreased infiltration and consequently have plant establishment less than the mulch-only treatment. In addition, most of the native tree species that established themselves in the tillage-only treatment did not survive the dry season, as determined in mid-June. It now appears that mulching is the more effective treatment in the long term, probably due to sand and leaf entrapment as well as decreased temperatures and evaporation rates underneath the mulch. Termite activity may also be an important factor in the success of this treatment.

Constraints to Progress:

Results and interpretations for this study have been timely as long as extensive laboratory or computer analyses have not been necesary.

Applicability of Results to TropSoils Goal:

This is an applied research project which has considerable potential significance in terms of forest regeneration, improved soil and water conservation, chanced biomass productivity, better rural incomes and improved quality of life in the Sahel. It has major implications for reversal of desertification in the Sahel. Early results indicate that minimal input treatments (waste vegetation from woodcutting) can have maximum impact on forest (firewood) regeneration. The technology should be easily transferable to all "tiger"/"leopard" bush regions of the Sahel.

Training Component:

No formal plans at this time. Informal, hands-on training will be provided on a regular basis for INRAN, ICRISAT and University of Niamey personnel. A TAMU graduate student or a University of Niamey student may be assigned a portion of this study in the future.

ACID SAVANNAS

ACID SAVANNAS PROGRAM

ORGANIZATION

Lead Institution

Cornell University

Support Institution

North Carolina State University

Collaborating Institution

Empresa Brasileira de Pesquisa Agropecuaria

Linkage Institutions

Centro de Energia Nuclear via Agricultura
Centro International de Agricultura Tropical
Empresa de Pesquisa Assistencia Tecnica e Extensao Rural de Mato Grosso do Sul

Research Site

Centro de Pesquisa Agropecuaria dos Cerrados, Brasilia, Brazil

Principal Investigators

Lead Institution

Douglas J. Lathwell

Support Institution

John J. Nicholaides, III

Representatives on Board of Directors

Lead Institution

Edwin B. Oyer

Collaborating Institution

Elmar Wagner, through August, 1984
Wenceslau J. Goedert, after August, 1984

ACID SAVANNAS PROGRAM **** BRAZIL

TECHNICAL PERSONNEL

Name, Degree	TropSoils Responsibility	Affiliation
Douglas J. Lathwell, Ph.D.	Soil Fertility[1/]	CU
Jorge Adamoli, M.S.	Land Capability Mapping	EMBRAPA
David R. Bouldin, Ph.D.	Soil Fertility	CU
Walter T. Bowen, M.S.*	Soil Fertility	CU
Ray B. Bryant, Ph.D.	Pedology	CU
Walter Couto, Ph.D.	Soil Fertility	EMBRAPA
Fred R. Cox, Ph.D.	Soil Fertility	NCSU
Enéas Zaborowsky Galeão, M.S.	Micronutrients	EMBRAPA
Elias de Freitas, Ph.D.	Soil Physics	EMBRAPA
Euclides Kornelius, Ph.D.	Farming Systems	EMBRAPA
Ibere Lins, M.S.*	Soil Fertility	EMBRAPA
Jamil Macedo, B.S.*	Pedology	CU
Christopher McVoy, M.S.*	Soil Physics	CU
Peter Montavelli, M.S.*	Soil Fertility	CU
José Madeira Neto, M.S.	Resource Evaluation	EMBRAPA
John J. Nicholaides, Ph.D.	Soil Fertility	NCSU
José Roberto Rodrigues Peres, M.S.	Soil Microbiology	EMBRAPA
João Pereira, M.S.	Soil Fertility	EMBRAPA
Jorge Quintana, M.S.*	Soil Fertility	CU
W. Shaw Reid, Ph.D.	Soil Fertility	CU
Antonio Eduardo dos Reis, Ph.D.	Soil Physics	EMBRAPA
Euzébio da Silva, M.S.	Irrigation	EMBRAPA
Djalma G. de Souza, M.S.	Soil Chemistry	EMBRAPA
Plínio de Souza, Ph.D.	Soil Fertility	EMBRAPA
Eric R. Stoner, Ph.D.	Soil Resource Inventory	CU
Allert Rose Suhet, M.S.	Soil Nitrogen	EMBRAPA

R. J. Wagenet, Ph.D.	Soil Physics	CU
Armand Van Wambeke, Ph.D.	Pedology	CU

[1/] Also Principal Investigator

*Enrolled in a graduate program leading to next highest academic degree.

ACID SAVANNAS PROGRAM
AN OVERVIEW[1/]

The acid savanna regions of the tropics are dominated by the soil orders Ultisols and Oxisols. These regions are the largest land areas in the world that are either not farmed or only partially utilized. At least 500 million hectares of acid savannas are found worldwide with major portions in South America. There are nearly 200 million hectares in Brazil alone. In addition, large areas occur in Africa and Southeast Asia. These areas are characterized by a wet-dry cycle with sufficient precipitation for at least one crop per year. Many of the acid savannas are rapidly being developed without a sound soil management base, resulting in low productivity and widespread erosion.

Crop Production Potential:

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

1/ Prepared by Douglas J. Lathwell, Principal Investigator

Previous research carried out by Cornell University in collaboration with the Brazilian Ministry of Agriculture and North Carolina State University on the Oxisols of the acid savanna regions has identified a number of important management considerations. Some are new ideas; others are verification and extension of existing knowledge. Our previous results have verified that the highly weathered, well-drained Oxisols, indeed, have a very high production potential. Maize yields on properly managed soils in Brazil have averaged over 6 ton of grain/ha over a ten year period, as an example. Without adequate lime and phosphorus on many of these soils grain yields are essentially zero.

The Phosphorus Problem:

The problem of supplying sufficient phosphorus to meet crop needs at reasonable cost requires special consideration for most of the Ultisols and Oxisols. Phosphorus is extremely deficient on soils that have not been under cultivation and they require substantial applications of phosphate fertilizer in the first years of cultivation for good crop production. A combination of a large broadcast application of soluble phosphate as a capital investment followed by smaller annual applications of banded phosphate seems to provide adequate phosphorus for sustained crop production. Lack of response to fertilizer phosphorus on similar soils that have had a long history of phosphate fertilization shows conclusively that there is a high residual effect of phosphate on these soils.

The Soil Acidity Problem:

Aluminum toxicity, the major factor associated with soil acidity, poses a problem on extensive areas of Ultisols and Oxisols. Addition of limestone readily ameliorates the condition in the surface horizon, thereby creating a more favorable environment for plant growth. Aluminum toxicity in the subsoil restricts the root system of many food crops and thus affects the capacity of plants to absorb nutrients and water. Incorporation of modest amounts of limestone to depths of 30 to 60 cm improves the situation but may not be feasible because of cost. Over time, surface applications of lime and gypsum may correct subsoil acidity but more information is needed. In the absence of toxic levels of aluminum, liming may be necessary to provide sufficient calcium and magnesium for adequate plant nutrition in soils where the quantities of exchangeable calcium and magnesium are extremely low. The amounts of lime needed for such purposes are usually small by conventional standards. A simple but reliable test for lime requirement of the Ultisols and Oxisols of the tropics related to specific crop requirements is needed.

The Nitrogen Situation:

The native capacity of many of these soils to supply nitrogen is greater than is generally appreciated and good crop production can be obtained with moderate applications of properly applied fertilizer nitrogen. Fertilizer nitrogen must be supplied and managed in relation to growth of the crop. Timing is critical and it is greatly affected by rainfall patterns. Split applications improve the efficiency of fertilizer nitrogen use for many crops.

The Water Factor:

Water is likely to be a limiting factor in many of these regions even during the rainy season, particularly where subsoil acidity restricts root growth. One or two weeks without rain can nullify the beneficial effects of the other necessary inputs. For extensive areas of the Central Plateau of Brazil it is estimated that average yields of maize during the rainy season may be only about half of what is possible if supplementary irrigation were provided or if lime were incorporated to a depth of 30 cm or more. Timing of planting and minimizing runoff by good conservation practices where supplementary irrigation is not possible should help insure good crop production.

Previous Experience:

Cornell, along with North Carolina State University, conducted research at the Centro de Pesquisa Agropecuaria dos Cerrados (CPAC) from 1971 to 1978. There were relatively few scientists involved in the program. During that period work was begun which has been continued by the Brazilian staff and has led to the understanding of management of lime, fertilizer phosphorus, and fertilizer nitrogen that is being applied today. In addition, work on ion movement and water relations was begun. By the time the present collaborative agreement was made, the CPAC had developed into a National Research Center for the Cerrados (acid savannas) and its scientific staff had grown to over one hundred. The research base had broadened to cover a wide range of activities related to agricultural development of the Cerrado region of Brazil.

Developing A TropSoils Program:

Based on what already had been learned from previous research at CPAC and the ongoing program at the Center, and given the limited 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.

Nitrogen Management Research:

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 increased cost of fertilizer nitrogen, the thrust is to improve the utilization of biologically fixed nitrogen. There is a need 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. Projects to investigate these problems are either under way or are at the active planning stage.

Quantification Of Water And Chemical Budgets:

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.

Soil Constraints To Management:

The third research topic on soil constraints to management of acid savanna soils has as its goals, the identification of chemical and physical factors of significance to use and management, to understand the genesis of these properties, and to inventory these properties for use in management of the acid savanna soils. One active project is under way to determine the relationships between soil color patterns and natural drainage characteristics to develop means of identifying those Oxisols with restricted drainage. A project to investigate the effect of soil compaction and erosion on limitations to crop production is in the advanced planning stage.

Current Situation:

All of these research topics and associated research projects have been developed in collaboration with Brazilian collaborating 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.

Cornell has had a senior faculty person stationed at the CPAC since July 1983. Also, a graduate research assistant has been working on his thesis research at CPAC since July 1983. He expects to return to Cornell mid 1985 to complete his program. A second graduate research assistant will be posted at the CPAC in January 1985 to work on his thesis research. Two additional graduate research assistants began their programs in September 1984 to prepare for their research at CPAC in 1985 or 1986. One Brazilian student supported by EMBRAPA from CPAC is at Cornell working on the genesis of the Oxisols with restricted drainage. A Brazilian student studying at North Carolina State University will be going to CPAC in October 1984 to work on his thesis project.

This total program has taken considerable time to implement - first to get the necessary agreements approved to work in the acid savanna soils and secondly to develop a truly collaborative program with the Brazilians. Establishing the necessary working relations with personnel at CPAC has taken further time. However, all of these have now been accomplished and the program is fully developed and operational.

NITROGEN AVAILABILITY FROM LEGUME CROP RESIDUES AND GREEN MANURES TO THE SUCCEEDING NON-LEGUME CROP

Leadership Personnel:

Walter T. Bowen, CU
Eric R. Stoner, CU
Albert Rosa Suhet, CU
W. S. Reid, CU

Date Research Initiated:

July, 1983

Rationale for Investigation:

Fertilizer nitrogen is an expensive input for crop production in developing countries and because of this high cost, nitrogen frequently is a serious constraint to achieving desired yields. Crop residues and green manure crops are valuable sources of nitrogen for succeeding non-legume crops. However, there are many factors which can influence crop yields, and management schemes which effectively use organic sources of nitrogen must take these into consideration. Their relative influence is uncertain, and thus, a procedure is needed for screening the many variables so that a few of the most promising management parameters can be selected.

Objective:

To develop and evaluate procedures for estimating the ability of legume crop residues and green manures to supply nitrogen for succeeding non-legume crops.

Experimental Approach:

The field research will be conducted at the CPAC, Brasilia, Brazil.

The N mineralized during a cropping season is approximated by the equation

$$N_I = KN_O + N_S \qquad (1)$$

where N_I = the mineral N accumulated during the cropping season, N_O = total N in residue/green manure, K = fraction of N_O mineralized during the cropping season and N_S = mineral N furnished by the soil.

The nitrogen taken up by the succeeding non-legume crop is approximately equal to

$$N_p = K_1 N_I \qquad (2)$$

where N_p = amount of N in the above ground dry matter, and K_1 = constant of proportionality.

A necessary condition for (2) to be useful is that the yield potential of the crop exceed the amount of N available; that is, if more inorganic N were available the increase in N accumulation would be proportional to the increase in inorganic N available.

If the crop accumulates nitrogen at approximately the rate it is mineralized (and hence losses are small), then K_1 will be about 0.7 to 0.8. If K_1 is less than 0.6 then probably appreciable losses are occurring.

The hypothesis being tested is that estimates of N_1 for equation (2) can be made from measurements of mineral N made on a paired fallow plot, subject to the condition that leaching is not serious in either of the paired plots. In the fallow plot, leaching will be controlled in the dry season by limited irrigation and in the wet season by using a plastic cover. The leaching in the cropped plot will be controlled by maintaining a crop which will take up the inorganic N approximately as rapidly as it accumulates.

State of Progress:

A field experiment was begun in October 1983 on the Red-Yellow Latosol at the CPAC in which two legume crops were planted--(1) soybeans in which the grain would be harvested and the residue left on the soil for the succeeding crop and (2) the green legume, mucuna, where the entire plant was incorporated into the soil. These crops were grown through to April 1984.

The average soybean grain yield was 2500 kg/ha and 5500 kg/hg of residue was returned to the soil. The average yield of mucuna forage was 9000 kg/ha. The residues and forage were incorporated into the soil and maize was planted in June 1984 on one series of plots. A second series of plots was kept fallow so that soil samples could be taken and the rate of inorganic nitrogen accumulation without crop uptake could be measured. The maize crop will be taking up nitrogen about as rapidly as it is being mineralized. From this information the availability of the nitrogen in the residues and green manures to the maize crop will be calculated.

Constraints to Progress:

The primary constraint has been the time required to move from a conceptual framework to a collaborative program. A large number of people are involved, thus, creating additional time demands.

Applicability of Results to TropSoils Goal:

This research is directed toward minimizing nitrogen as a constraint to crop production. The procedure investigated has been useful in New York and has shown that the first year following the incorporation of alfalfa residues into the soil, the quantity of nitrogen mineralized along with the soil supply is sufficient to meet the demands of the maize crop. The relevance of this work to acid savanna conditions is being evaluated. It appears now that a significant portion of the total nitrogen requirement of the maize grown on the Red-Yellow Latosol may be met by mineralization of the residues.

Training Component:

Mr. Bowen is a candidate for the Ph.D. degree at Cornell University and has a strong interest in international agricultural development. This research will be used in part for the doctoral thesis.

LABORATORY MINERALIZATION STUDIES AS A SOIL TEST FOR NITROGEN AND THEIR CORRELATION WITH FIELD RESULTS

Leadership Personnel:

Jorge Quintana, CU
David R. Bouldin, CU
Eric R. Stoner, CU
Albert R. Suhet, CPAC

Date Research Initiated:

September, 1983

Rationale for Investigation:

Effective nitrogen management in cropping systems requires reliable indices of nitrogen availability from soil organic matter and other organic sources of nitrogen. How rapidly these sources mineralize can affect greatly the amount of supplemental nitrogen that may be required to grow a crop. We have evaluated manure, crop residues, and previous legume crops by assigning a specific value to the amount of inorganic nitrogen each is expected to supply to a succeeding non-legume crop. The values assigned are based on a fairly extensive set of field experiments performed over several years. Recently we have begun to search for ways to evaluate in more detail the residual effects of past treatments through tests on soil samples. Sufficient progress has been made that we are prepared to calibrate an incubation procedure in Brazil as a method for comparing treatments in an experiment. The ultimate aim is to develop a general soil test for mineralizable nitrogen.

Objectives:

To investigate the utility of laboratory incubation studies to predict the effect of differential organic nitrogen management on nitrogen supply to crops.

Experimental Approach:

The research will be conducted at CPAC, Brasilia, Brazil and at Cornell University.

For the last several years a major program in New York, Pennsylvania and USDA, Beltsville, has been to develop a "soil test" for nitrogen which reflects the residual effects of past manure applications and legume crops on non-legume crop yields (principally corn). Several approaches have been tried including extractions and laboratory incubations. Presently, the most promising approach appears to be incubation in the laboratory. The application to be made in Brazil is two-fold: (1) To use the incubation test as a screening procedure for various green manure and organic nitrogen treatments being investigated. If these procedures can be used for screening them, the number of field trials needed to evaluate the amount of nitrogen supplied by the test treatments can be reduced. (2) If these procedures are as useful in Brazil as in New York, then we will have a "soil test" for nitrogen which can be extrapolated to other areas in the tropics. Mr. Quintana is currently learning the techniques necessary to carry out the incubations through actual hands-on experience and obtaining the necessary training in chemistry, physics, statistics and soil fertility to effectively carry out the research in Brazil.

State of Progress:

To date the only results available are those obtained in New York. During the period 1978-1982 various manure applications were made in the field, and corn yields with no fertilizer N and 3 rates of fertilizer N were superimposed on the manure treatments. Thus, the effective nitrogen supplying ability of the manure could be deduced from the corn yields. The correlation between nitrogen mineralized in the laboratory and nitrogen uptake by the corn without fertilizer N depended upon how the soil sample was treated after it was taken: the correlation was poor if the sample was not dried after taking from the field, but if the sample was over dried shortly after taking the correlation between inorganic nitrogen mineralized and N uptake by corn was 0.71. Modifications of the incubation procedure are being investigated.

Mr. Quintana will move to Brazil in January, 1985 to develop the laboratory necessary for the incubation studies there. He will obtain soil samples from ongoing research in field plots to investigate the effects of treatment of the soil samples subsequent to removal from the field. Subsequently, he will participate in field investigations to further calibrate the incubation period.

Constraints to Progress:

The primary constraint has been the time required to develop a collaborative program on a sharply focused project which could maximize the use of existing resources.

Applicability of Results to TropSoils Goal:

Presently the incubation procedure appears to be useful for comparing different residual nitrogen effects in a specific experiment for screening different green manures and organic residue managements with respect to their effects on nitrogen supply to non-legumes. Once it is properly calibrated, it should be an extremely useful screening procedure. Whether or not it will prove to be useful as a soil test for nitrogen has not yet been demonstrated. Only future research will answer this question. The potential benefit to a soil test for nitrogen amply justifies this research.

Training Component:

Mr. Quintana is a Nicaraguan national enrolled in a graduate degree program at Cornell University. This research will be used in fulfilling the thesis requirements. He will gain experience in both laboratory and field-oriented research in soil management under closely supervised conditions and where self-reliance will be required.

FERTILIZER NITROGEN MOVEMENT IN CERRADO SOILS

Leadership Personnel:

Elias de Freitas, EMBRAPA
R. J. Wagenet, CU
Antonio Gueira, CENA

Date Research Initiated:

February, 1984

Rationale for Investigation:

There is a need for nitrogen management strategies based upon a comprehensive understanding of the physical, chemical and biological processes that affect its fate in Cerrado soils. Many field experiments have addressed this issue, and a substantial data base have been assembled. It remains to generalize these results into a broadly based set of nitrogen management guidelines. One method 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. Although a number of such models have been developed, they are principally research, not management, tools and have been tested primarily on nitrogen fertilizer studies conducted in soils of the temperate climates. The basic formulation of these models provides a starting point for description of nitrogen in Cerrado soils.

Objectives:

A. Test and adapt a dynamic simulation model of nitrogen movement and transformation in cropped soils of the Cerrado using field data collected at CPAC.

B. Use the model as a guide 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.

Experimental Approach:

Field experiments are currently in progress at CPAC, Brasilia, Brazil. The leaching and transformation of nitrogen 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. The results will guide the design of further experiments. As increased understanding is gained of fertilizer nitrogen fate in such systems, the present complicated research model will be simplified to a form useful in management. This will require a minimum of three field seasons of data, although preliminary work will be initiated early in the research program and will continue as a parallel activity with the field experiments. Initial contact has been made with personnel at CENA. They have expressed interest in collaborative efforts.

State of Progress:

The planning phase has been completed and investigations will commence shortly.

Constraints to Progress:

The primary constraint has been the time required to develop a collaborative program on a sharply focused project.

Applicability of Results to TropSoils Goal:

The need for nitrogen management strategies based upon complete understanding of nitrogen transport and transformation is established. This project should develop information relative to basic processes under field conditions, integrate those processes in the form of a model which will provide management guidance.

Training Component:

Dr. de Freitas is planning to visit Cornell during the period June-August 1985 to initiate the modeling activity.

INFLUENCE OF SOIL TEXTURE AND LIMING ON PHOSPHORUS AND ZINC SOIL TEST LEVELS AND FERTILIZER MANAGEMENT OF CERRADO OXISOLS.

Leadership Personnel:

Ibere Lins, EMBRAPA
John J. Nicholaides, NCSU
Fred. R. Cox, NCSU

Date Research Initiated:

November, 1984

Rationale for Investigation:

The tropics contain approximately 240 million hectares of potentially arable acid savanna soils, most of which are classed as Oxisols. Of these, 109 million hectares (45%) are located in the Cerrado of Brazil. The most widely cultivated crop on these soils is soybean.

Besides Al toxicity and low Ca levels, low P and Zn soil levels and high P retention capacity are major factors limiting soybean production on these Oxisols.

The clay content of these soils ranges from about 18 to 84%. Previous work has shown that increasing clay content increases P retention capacity in Oxisols. Also, increasing soil pH generally increases P availability and can lead to Zn deficiency.

Thus, it is important to have soil tests which indicate not only whether P or Zn fertilizer are needed, but also the necessary rate of each for an Oxisol at a given clay content and a given pH to obtain maximum economical soybean production.

Objectives:

A. To determine the yield response of soybeans to P and Zn rates when grown on Oxisols of different texture and varying pH.

B. To determine the effect of rate of fertilizer P and Zn applied to Oxisols that vary in pH and texture on extractable P and Zn concentrations with time.

C. To determine P retention by Oxisols as influenced by pH and clay content.

D. 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 economic returns for soybeans.

E. To validate the developed model with field data.

Experimental Approach:

The research will be conducted primarily at CPAC and at NCSU.

To meet objective one, the following steps are proposed:

- Six different textured Oxisols will be used in a greenhouse experiment with five levels of applied P; four P extraction methods will be investigated;
- 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;
- 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;
- 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 CPAC. Each experiment will consist of a factorial arrangement with three rates each of lime P and Zn.

State of Progress:

Although this program is just beginning, a publication "A Phosphorus Soil Test Interpretation for Acid Soils Varying in Crystalline Clay content" by Cox and Lins is forthcoming in Communications in Soil Science and Plant Analysis. Also, a second paper, "A Phosphorus Soil Test Interpretation for Three Acid Soils of the State of Mato Grosso do Sul, Brazil Varying in Clay Content" is in progress.

Constraints to Progress:

None

Applicability of Results to TropSoils Goal:

This research will allow the development of proper P and Zn fertilization management strategies for some of the various textured Oxisols of the Cerrado of Brazil and other developing countries with similar soil - crop - climatic regimes. As P is the primary limiting element to crop production on Oxisols and no research with this objective, except for some initial work by Lins, has been done, the potential benefits are substantial.

Training Components:

The results of the research will be used, in part, to fulfill the requirements for a PhD for Mr. Lins at NCSU.

MORPHOLOGICAL EVIDENCES OF A SEASONALLY HIGH WATER TABLE IN A RED-YELLOW LATOSOL AND ITS IDENTIFICATION ON LANDSAT IMAGES

Leadership Personnel:

Jamil Macedo, CPAC
Ray Bryant, CU
Eric R. Stoner, CU

Date Research Initiated:

January, 1984

Rationale for Investigation:

The Red-Yellow Latosols show none of the morphological characteristics associated with wetness that are presently used as diagnostic criteria in Soil Taxonomy for classifying soils with restricted drainage. However, a seasonally high water table (<2 meters) has been observed in some of the Red-Yellow Latosols of the Cerrado Region, Brazil.

The presence of a seasonally high water table in these Red-Yellow Latosols has several possible implications for management. Susceptibility to compaction by tillage may be greater in these soils than in freely drained Red-Yellow Latosols or associated Dark Red Latosols. Subsequent to compaction, these soils may become highly susceptible to erosion. Water and nutrient movement in Red-Yellow Latosols with restricted drainage is expected to differ. Consequently, these soils may have more favorable water relations for crop growth during short periods of environment stress and nutrients may not be lost by leaching as rapidly as in associated well-drained soils.

Although other investigators have reported seasonally high water tables in soils without wetness characteristics, the genesis of these soils is not understood, morphological characteristics that might be used to identify these soils in the field have not been recognized, and the extent and significance of such soils in the tropical regions of the world has not been assessed.

Objectives:

A. To describe the genesis of the Red-Yellow Latosols having restricted drainage.

B. To identify morphological characteristics associated with wetness in Red-Yellow Latosols.

C. To assess remote sensing techniques for mapping Red-Yellow Latosols with restricted drainage.

Experimental Approach:

Jamil Macedo and Ray Bryant traveled to the CPAC, Brasilia, Brazil in June, 1984 to undertake the field portion of the study.

A transect across a Red-Yellow Latosol with restricted drainage was constructed. Five sites used in a related study by Walter Couto, in which fluctuations in the water table were monitored, were located. Four additional sites were located to extend the transect across the Red-Yellow Latosol into the adjacent associated soils of the Morundos area and the Dark-Red Latosols. Pits were excavated, and the soils were described and sampled. Piezometers were installed at each site and depths to the water table are being measured at weekly intervals.

Soil samples were brought to the Soil Characterization Laboratory at Cornell University for standard characterization. Iron mineralogy of the root coatings and the surrounding soil matrix will be characterized by X-ray diffraction, Mossbauer, UV-Visible spectroscopy and wet chemistry methods.

Copies of all available imagery of the Federal District and surrounding areas are being collected for analysis. Preliminary analysis is being conducted at CPAC in cooperation with the research staff. More extensive analysis will be conducted at Cornell.

Photographs and satellite imagery analysis will use the techniques of image enhancement and standard interpretative procedures to attempt to identify these soils and assess their extent and distribution in the Cerado region near Brasilia. If this is successful then this approach may be extended to other areas to evaluate soil and land resources.

A tour was made of the Cerrado region to observe landscapes, soils and vegetation to provide ground truth for interpretation of remotely sensed data.

State of Progress:

Field studies show a pattern of morphology in the Red-Yellow Latosols that suggests a relationship between the iron mineralogy of these soils, as reflected by the soil color and drainage conditions. The upper horizons of the Red-Yellow Latosols have 10YR hues and the lower horizons have 5YR hues. Although gray mottles, which are indicative of reducing conditions and a high water table, are absent there does appear to be a good correlation between depth to the 5YR hues and depth to the water table in these soils. Soils that are shallower to 5YR hues have higher water tables for longer periods of time during the growing season. This morphological feature may be useful in assessing their drainage characteristics. The relationship might also be a useful criteria in their classification.

A genetic relationship between soil color and drainage is suggested by the presence of iron coatings on the surfaces of roots in the 10YR horizons. Many and common roots were observed in the 10YR horizons but a few roots extended into the 5YR horizons. These observations suggest that reducing conditions may exist in a micro-environment around the root at some time during the rainy season. Reduced iron may move to the root by mass flow and be reoxidized to the yellowish geothite mineral during the prolonged dry season. Upon death and decay of the root, subsequent biological activity would disrupt the coatings and incorporate them into the soil matrix. This process when continued over long periods of time could result in the transformation of hematite to geothite and 5YR hues to 10YR hues.

Constraints to Progress:

Lack of some remote sensing information in the study area and other data base information has slowed efforts to confirm the extent of these soils in the region.

Applicability of Results to TropSoils Goal:

This project is aimed at collecting basic soils information for understanding soil properties and for continuing soil survey and development of soil classification to extrapolate the experimental results at CPAC to similar soils in other Acid Savanna regions.

Training Component:

Mr. Jamil Macedo is an employee of CPAC and is presently at Cornell University studying for the M.S. degree. Parts of this work will be used for his M.S. thesis. Parts of this work will contribute also to the Soil Management Support Services Soil Taxonomy training programs.

ABBREVIATIONS

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AGRHYMET	Agriculture and Hydrology Meterological Organization
CENA	Centro de Energia Nuclear via Agricultura
CEPLAC	Commissao Executiva do Plano da Lavoura Cacaueira
CES	Cinzana Experiment Station
CIAT	Centro Internacional de Agricultura Tropical
CIP	Centro Internacional de La Papa
CORDELOR	Corporación de Desarrollo de Loreto
CPAC	Centro de Pesquisa Agropecuaria dos Cerrados
CR	Costa Rica
CSR	Center for Soils Research
CU	Cornell University
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuaria
EMPAER	Empresa de Pesquisa Assistencia Technica e Extensao Rural de Mato Grosso do Sul
EPC	Equity Policy Center
ESAT	Escuela Superior de Agricultura Tropical
FCC	Fertility Capability Classification System
FLUP	Forest Land Use Project
FONAIAP	Fondo Nacional de Investigaciones Agropecuarias
FSR	Farming System Research
IBSTRAM	International Board of Soil Research and Management
IBTA	Instituto Boliviano de Technologia Agropecuaria
ICA	Instituto Colombiano Agropecuario
ICRAF	International Council for Research in Forestry
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IER	Institut D'Economie Rurale
IFDC	International Fertilizer Development Center
IIAP	Instituto de Investigaciones de la Amazonia Peruana
IICA	Instituto Interamericano de Cooperacion para la Agricultura

IITA	International Institute for Tropical Agriculture
INIAP	Instituto Nacional de Investigaciones Agropecuarias
INIPA	Instituto Nacional de Investigacion Y Promocion Agropecuara
INRAN	Institut Nationale de Recherches Agricoles der Niger
INTSORMIL	Sorghum/Millet Collaborative Research Support Program
IPBNP	Institute Pertananian Bogor Nutrition Department
IRAT	Institut de Recherches Agronomiques Tropicales
IRRI	International Rice Research Institute
ISC	ICRISAT Sahelian Center
IVITA	Instituto Veterinario de Investigaciones Tropicales y Altura
NCSU	North Carolina State University
ONAREF	Office of National de Regeneration des Forests
PNIPA	Programa de Investigacion y Promocion Agraria en Selva
PPI	Potash and Phosphate Institute
PTTSM	Parce las de Transerencia de Technologia y Semilla Mejorado
REDINAA	Red de Investigación Agroecológica para la Amazonía
RF	Rockefellow Foundation
SAT	Semi-Arid Tropics
SM-CRSP	Soil Management Collaborative Research Support Program
TAES	Texas Agricultural Experiment Station
TAMU	Texas A & M University
TAREC	Texas Agricultural Research and Extension Center
UEPAE/MANAUS	Unidade de Execucao de Pesquisa de Ambito Estadual de Manaus
UF	University of Florida
UH	University of Hawaii
UI	University of Illinois
UNA	Universidad Nacional Agraria
UNAS	Universidad Nacional Agraria de la Selva
UNP	Universidad Nacional de Pucallpa
USLE	Universal Soil Loss Equation
YAES	Yurimaguas Agricultural Experiment Station