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Executive Summary Report

The Soil Management Collaborative Research Support Program

25 September 1992
through
24 September 1993

COLLABORATING ORGANIZATIONS

U. S. Government

United States Agency for International Development
Bureau of Research and Development

Board of International Food and Agriculture Development
Joint Committee on Agricultural Development

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Parker F. Pratt	Special Consultant
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I. SUMMARY

A. Introduction

1992-93 was Year 12 for the Soil Management CRSP. It was the first year NifTAL was administratively merged into the CRSP through a grant modification implemented by the University of Hawaii subgrant to save overhead charges and to minimize the number of subgrants to be administered. This completed the administrative merger that was needed to facilitate the programmatic merger requested by USAID. The goal of that merger was to integrate the Global bureau strengths in soil and water management into one program.

CRSP activities strengthened the working relationships with USAID field-mission programs and with International Agriculture Research Centers. The CRSP earmarked $150,000 that will be administered by USDA/OICD to provide field support to USAID missions on a request basis. Cables were sent to all missions to inform them that this service was available.

The CRSP relationship with IRRI was strengthened during visits to IRRI upland programs in Southeast Asia. Dr. Russell Yost was selected to serve on the consortium steering committee. CIAT has invited the CRSP to participate at both the steering committee and working-group levels on their Central and South American consortium focusing on acid soils, forest margins and steeplands. Scientist-to-scientist collaboration was developed with IITA, ICRAF, and CIMMYT through targeted research and thesis projects for research assistants. NifTAL has a senior soil microbiologist stationed at IRRI in the Philippines and at IITA in Nigeria.

A number of other duties were prematurely forced onto the CRSP during this program year; these required the expenditure of a great deal of energy and completely unraveled the planning process that had been developed by the technical committee and approved by the institutional Board of Directors.

The Annual Summary Report includes the research, training and outreach progress gained during 1992-93 (FY93) and the list of publications and contributions to sustainable and equitable soil management for economic growth and environmental protection.

B. The Global Planning Workshop

After months of planning and numerous last-minute agenda changes and schedule juggling, the very successful Global Planning Workshop was held from January 25-28, 1993, in the McKimmon Center on the North Carolina State University campus. The event was organized by the Office of the Management Entity and implemented with administrative support from Office of Continuing Education and management of the McKimmon Center. It was the first workshop of this scope and quality organized and executed during the 12 years of the Soil Management CRSP.

There were more than 15 developing countries, three International Centers, and four PVOs, but no other CRSP accepted the free invitation to be included among the more than 115 participants. This Planning Workshop was structured into plenary sessions during which developing-country and IARC scientists identified pressing soil management issues. The issues were then discussed in ten breakout discussion groups of four-hours each. Priority programmatic needs were recorded. Each breakout group was lead by a USDA/SCS trained discussion facilitator. A 121-page workshop record details the needs and priorities. More than 300 copies have been requested. The participants rated this as a new high watermark for this CRSP.

C. The Stopping and Starting of the Global Planning Process

During the above-mentioned successful workshop, USAID/R&D had called an emergency meeting of the Board of Directors for two expressed purposes: (1) to bring all planning operations and momentum to a complete stop, and (2) to nominate a new Board of Directors and propose a new operating structure for this CRSP. This was to be completed before planning could regain lost momentum, all without knowledge of program content and possible level of funding.

The new Board members were introduced during a March 1993 meeting when it was decided to continue through this grant as a transitional period with a combined Board of the institutional representatives and the new members. A planning committee was formed and Dr. Charles B. McCants was contracted to chair this planning group. A planning process was formulated, proposed, and accepted by USAID and the combined board, after which the integrated process of developing the global plan was again put back into motion near the end of FY93.

D. Assistant Director Position

The second attempt to fill the position of Assistant Director to the Office of the Management Entity ended when the USAID stopped all planning momentum and proposed there would ample funding to support at least two full-time program leaders. This Assistant Director position was specially earmarked and funded within the present grant to carry the increased administrative load resulting from the mergers of SMSS, TSMM, and NifTAL programs.

E. CRSP Participation in Successful Technical Workshops

The scientists active in the Soil Management CRSP are increasingly being requested to contribute to international workshops that provide inputs to guide global policies on the management of our soil/water and associated natural resources.

The International Workshop on Stressed Ecosystems was hosted by ICRISAT in Hyderabad, India, and sponsored by ICAR, ICRISAT, SMSS and others, to identify major resource-management issues in the semi-arid regions. CRSP scientists participated on the program as keynote, plenary, and discussion-group leaders. The proceedings are being published from this workshop and donors are requesting continuing efforts with such joint sponsored workshops to help guide and target their efforts.

The third in a series of International Workshops to develop the Framework for the Evaluation of Sustainable Land Management (FESLM) was held in Lethbridge, Canada. This workshop included plenary sessions, poster sessions, computer software demonstrations and one full day of breakout discussion groups targeted to develop the pillars and parameters for the FESLM. The abstract for all presentations (plenary and posters) and proceedings have been printed and distributed

The International Center CIAT has been in dialog with the Soil Management CRSP over the past two years to collaborate in their acid savanna, forest margins and steepland program in Central and South America. CIAT sponsored one CRSP scientist and two CRSP institutions sponsored scientists to participate in a week long workshop in Cali, Columbia, to review researchable problems, organize the steering committee, identify working groups, frame a functioning consortium, and formulate a program for which to seek international donors. The results from this workshop were presented and very favorably received during the CGIAR centers week.

The long-awaited ICRISAT sponsored workshop for a "Working Group on Acid Soil Tolerance in Grain Legumes" (WGASTGL) was held in Brisbane, Australia.

The Soil Management CRSP responded to the invitation to participate as a full partner by sending one scientist to the initial planning session of this working group. This presented an excellent opportunity to demonstrate the ADSS and GROUNDWORKS 1 to a potential collaborating group. The Australian's have since expressed the interest to validate and extend the ADSS data base in an acid soils program they plan to initiate in Asia.

The Workshop on Long-Term Soil Management Experiments in the Tropics was sponsored by the Rockefeller Foundation, World Bank, CGIAR, USAID, etc. It was hosted by Ohio State University. The long-term continuous cropping study conducted collaboratively in Yurimaguas, Peru, by INIAA and North Carolina State University was presented. The papers presented during this workshop will be published as a special edition in the *Advances in Soil Science.*

F. New Relationships Developed

MOROCCO: The USDA/ERS institutional component to this CRSP responded to the USAID Morocco mission invitation to develop a collaborative soil management program with the L'Institut National De La Recherche Agronomique (INRA-Morocco) and Institut Agronomique Et Veterinaire Hassan II (IVA-Morocco). The invitation was based on the use CRSP seed monies to implement the collaborative program upon which the mission would buy into and provide long-term support. The ME Office has successfully completed the signing of a general Memorandum of Understanding (MOU) that includes INRA and IVA and will permit all CRSP institutions to participate on a programmatic basis. The USDA/ERS has designed the initial program that will be implemented for purposes of long-term collaboration and mission buy-in support.

CIRAD: Parallel to implementing the MOU to structure collaboration in Morocco, CIRAD asked the CRSP to sign a general MOU that would facilitate collaboration with soil management supported institutions and a mechanism to support socioeconomic research in Morocco and other Francophone countries. This MOU was drafted, agreed upon and signed through correspondence.

IICA: The Inter-American Institute for Cooperation for Agriculture (IICA) requested that the Soil Management CRSP complete a general MOU as a mechanism for this CRSP and IICA to enhance collaboration in central and south America.

BURKINA FASO: The Directeur General of CNRST expressed interest in establishing collaborative soil management research activities with this CRSP. This was supported by the USAID mission, and a general MOU was agreed upon and signed to provide the mechanism for developing joint research activities. There is interest on the part of CNRST to conduct joint research and graduate training as very productive means to work in collaboration with this CRSP. A Burkinanabe graduate from the CRSP program would be available to coordinate the research and training efforts. The USAID mission views the CRSP as a cost-effective way to maintain continuity in efforts to overcome problems of dessertification and land degradation resulting from poor soil management.

G. The CRSP Program

The three global thrusts of the Soil Management CRSP are: 1) Natural Resource Management; 2) Sustainable Agriculture; and, 3) Outreach. CRSP activities are focused on five constraints of global importance within each of these thrusts. There are eleven activities in natural resource management, fourteen activities in sustainable agriculture, and ten activities in outreach. Research programs such as soil degradation and rejuvenation, green manures and legume management, phosphorus management and amelioration of soil acidity have more than one institution conducting research with a central theme. Each activity report includes the goals and objectives and progress over the past year. The publications and products developed are reported separately in this executive summary of FY93 CRSP activities.

H. CRSP Publications and other Product Activities

Section III, Appendixes is the record of many of the published referred papers, publications, training and other product development activities of the CRSP. Some major accomplishments include:

- 37 referred papers published or in press.
- 33 Special and miscellaneous publications
- 68 Book chapters, symposia papers, posters, etc. presented at professional meetings
- 8 Graduate earned at CRSP institutions
- 42 Research assistance in graduate degree track programs

- 16 Demonstrations and/or training activities in the use of the Acid Decision Support System

- 6 Special training workshops

- 12 Other training activities participated in or conducted

The complete documentation of these activities can be found in Section III of this report. All trip reports are published and disseminated as separate and informative activities.

I. Informing our peers, followers and benefactors

The Soil Management CRSP, a natural resource management program works with more that thirty commodities used for food, fiber, fuel, fodder and construction materials, some in combinations of systems. There are also more than ten soil orders and over 10,000,000 series and phases in the tropics alone. Thus this CRSP must be selective. Transfer of this technology is based on diagnostics and the U.S. Soil Taxonomy system. Therefore, the impact often passes through many intermediaries, some of which we never meet to target the ultimate users, societies' custodians of our soil resources (farmers) and the ultimate beneficiaries, society as a whole (all the people of the world).

In FY92 the communications coordinator initiated the Soil Management CRSP "NEWSWIRE" to inform interested parties about activities, publications, and impacts from the CRSP programs. From a modest mailing list start of about 400 known addresses of interested users of CRSP technologies this mailing list has increased, by request, to over 1,000 followers. Tracking requests over the past two years for CRSP publications reveal these come from over 76 countries. This points out that what this CRSP has developed in the process of serving societies' custodians of the world soil resources is a strong professional following. Much of the CRSP technical information is utilized as undergraduate and graduate teaching materials in Institutions and Universities in the U.S., Europe, and many developing countries. CRSP publications also serve as resource materials for IARC scientists, PVOs and NGOs and mission-funded bilateral programs.

J. Soil Management CRSP Disbursements

The Soil Management CRSP total disbursements by institutional components are presented in Table 1. During the early years of the CRSP, the Communications activities, Board of Directors, Technical Coordinator, External Evaluation Panel (EEP), planning and special reserve fund distributions were all lumped under the Office of the Management Entity. Starting in FY90 these funds were separated out

so that the Board of Directors, EEP and USAID would have a true picture of what the true cost of the ME office is and what other CRSP functions must be funded to meet terms of the grant.

Table 1. Soil Management CRSP Disbursements 1981-1993.

	Year of CRSP									
	1-4 81-85	5 85-86	6 86-87	7 87-88	8 88-89	9 89-90	10 90-91	11 91-92	12 92-93	Total
	($1,000)									
Cornell	561	395	443	352	319	308	375	299	314	3,366
Hawaii	1,376	675	454	353	303	322	420	382	319	4,604
N.C. State	3,559	1,090	651	522	514	481	571	541	477	8,406
Texas A&M	1,881	752	543	431	476	481	589	499	534	6,186
USDA/SCS	-	-	-	-	-	-	92	600	600	1,292
USDA/ERS	-	-	-	-	-	-	68	450	450	968
USDA/ARS	-	-	-	-	-	-	42	270	270	582
USDA/RSED/OICD	-	-	-	-	-	-	-	-	150	150
NifTAL	-	-	-	-	-	-	-	269	1,140	1,409
ME	904	480	387	306	292	222	202	299	226	3,318
Communications	-	-	55	94	150	150	132	119	100	800
Cont/Sp.Requests/Reserve	-	-	46	43	31	147	-	25	(167)	125
BOD	-	-	-	-	-	9	9	14	-	32
TC	-	-	-	-	-	10	10	24	5	49
EEP	-	-	-	-	-	10	10	11	30	61
Planning	-	-	-	-	-	-	-	14	245	259
	8,281	3,392	2,579	2,101	2,085	2,140	2,520	3,816	4,693	31,607

II. PROGRAM SUMMARIES

A. NATURAL RESOURCE MANAGEMENT

1. COMPARATIVE AGRONOMIC, ECOLOGICAL AND SOCIO-ECONOMIC ANALYSIS OF HUMID TROPICAL PRODUCTION SYSTEMS

Project Number:

NCSU-01

Constraints Addressed:

Land-clearing pressure
Inadequate resource information
Production-demand pressure

Project Leader:

A.G. Wollum, North Carolina State University

Research Collaborators:

J.C. Alegre, ICRAF
C.B. Davey, NCSU
G.A. Carlson, NCSU
J.C. Day, USDA/ERS
G. Romero, PDAR/Conchabamba
R. Delgadillo, IBTA/Chapare
B. Pashanasi, INIAA
P.O. Ruiz, NCSU
A. Salazar, NCSU
T.J. Smyth, NCSU
L.T. Szott, CATIE

GOALS AND OBJECTIVES:

The goal is to systematically compare processes and characteristics of promising management systems to understand how and why theses options differ. The objective is to be able to recommend, based on this understanding, the use of specific systems in specific physical, biological and socio-economic environments.

PROGRESS REPORT

The seventh year of production data were collected for the replicated field experiment in Yurimaguas, Peru, which compares five management systems:

1) mechanized continuous cropping, 2) low input cropping, 3) peach palm plantation, 4) multistrata system, and 5) shifting cultivation. Economic data on all field operations, inputs and outputs for each treatment and crop were compiled into a database for subsequent economic analysis. Preliminary analysis for Yurimaguas conditions show a net deficit for mechanized continuous cropping, and a net profit ranging from US$ 733 to 28,766 among the other treatments. The graduate student assigned to this project was sent to Bolivia in September. Prior to leaving a working outline was developed by the student and supplies were acquired for use by the project. After arriving in Bolivia, a cropping experiment was established adjacent to the La Jota Experiment Station. Approximately 1 ha of secondary forest was cleared without burning. Plots were laid out and *Inga edulis* seedlings or *Cassia reticulata* seeds were planted. Rice was established as the initial grain crop for a rice-cowpea rotation cropping sequence which will be conducted over a two year period. Grain yields from this first harvest will be used to determine the inherent variability of the experimental site. Preliminary observations indicate successful establishment of both the trees and the rice crop. Soil samples have been collected for the time zero phase and will be analyzed for acidity and soil nutrients. Rooting barriers have been installed on some plots to study the effect of tree root competition on grain production. Preliminary analyses have been made to test the efficacy of different soil P determinations to follow changes in P pools which might occur as a result of foliage pruning and mulch management. Cropping will continue for two years, during which, crop yields, soil properties and nutrient contents of the prunings and grain yields will be measured as a function of the distance from the tree rows.

ADDITIONAL FUNDING AND SUPPORT

Support through cost sharing:IBTA - Chapare (Bolivia) has provided a vehicle for transportation of project personnel and supplies from their residence (Cochabamba) to their place of work (La Jota). Labor has been provided for land clearing and plot establishment and will continue for plot maintenance and harvesting activities. Some supplies in the form of seeds (rice and cowpea) and limited quantities of reagents for laboratory tests have been provided for the project.

Support to project in kind: on-site supervision, coordination and routine maintenance of the field experiment in Yurimaguas by ICRAF and INIAA personnel.

2. PROCESSES OF SOIL DEGRADATION AND REJUVENATION UNDER DIFFERENT LAND USE SYSTEMS

Project Number:

NCSU-06

Constraints Addressed:

Inefficient use of water resources
High erosion rates

Project Leader:

Keith Cassel, NCSU

Research Collaborators:

Dennis Garrity, formerly of IRRI, but now at ICRAF, co-leader on hedgerows to reduce soil erosion and increase water use
Ken Cassman, IRRI, providing assistance in obtaining the proper field site to conduct further research on soil erosion, water use, and land rejuvenation
Fahmuddin Agus, employee for Center for Crops and Soils Research, Bogor, Indonesia, who is working on his Ph.D. dissertation
Bir Thapa, student from Nepal who is working on his Ph.D. studying soil erosion and land degradation and rejuvenation on steeplands
April Horowitz, M.S. student working on biological methods to control soil erosion and rejuvenate degraded steeplands

GOALS AND OBJECTIVES:

The goal is to create knowledge of soil degradation and rejuvenation processes on which technologies for maintenance and improvement in soil physical conditions can be developed. Specific objectives are to (1) evaluate several plant species on hedge row terrace formation on acid, infertile sloping lands, (2) evaluate temporal and spacial changes in hydrology (infiltration, redistribution, runoff and soil loss) of the soil under the various hedge row systems, (3) evaluate temporal and spatial changes in leaching under hedge row terrace systems, and (4) quantify temporal and spatial changes in soil physical properties as hedge row terraces develop.

PROGRESS REPORT

The field and laboratory research being conducted by Fahmuddin Agus for the Ph.D. dissertation on the abatement of accelerated soil erosion on steep, acid infertile soils at two sites (Compact and Cabacungan) near Claveria, Mindanao, Philippines, was completed in December. Various contour hedgerow systems were evaluated with respect to their effect on soil properties, water runoff and soil loss; yield of corn and rice food crops grown in the alleys between the hedgerows; and the fertilizer effect of the leguminous hedgerow crops on soil fertility of the alleys. Main plot treatments include hedgerows consisting of double rows of *Gliricidia sepium* (G), *G. sepium* plus *Paspalum notatum* (GP), *G. sepium* plus napiergrass (GN), double rows of napiergrass (N), and a control without hedgerows (C).

A 20% reduction in food crop yields on the hedgerow treatments occurred the first 2 years, but yields during the next two years were higher for the G and GP treatments when no nitrogen was applied, a result related to the increase in N from the hedgerow clippings applied to the area planted to food crops. Soil loss was reduced 72% in treatment GP compared to the 42 ton/ha/yr loss for the control. Food crop production was greatest in the lowest portion of the alley because of the development of more favorable soil physical and chemical properties and higher water availability. Exchangeable Ca, K, Bray-2 P soil pH, and organic C increased as elevation in the alley decreased. Food crop production was suppressed in the rows adjacent to the hedgerows. Overall, it appears that Gliricidia has great promise as a biological agent to reduce soil erosion and delay or even reverse the land degradation process.

Bir Thapa began a field experiment in Claveria, Philippines evaluating the influence of various tillage practices in conjunction with various contour hedgerow systems. This research entered the second year with on-site work being carried out through ICRAF under the guidance of Dennis Garrity. April Horowitz began work on her M.S. program and is developing a detailed work plan dealing with soil erosion, biological control of soil erosion, and rejuvenation of land degraded by soil erosion.

ADDITIONAL FUNDING AND SUPPORT

Cost sharing from IRRI consisted of the provision of local transportation of project personnel and significant amounts of field supplies, equipment and laborers. Also, IRRI and ICRAF collaborators provided on-site supervision, coordination and routine maintenance of the field experiments.

3. EFFECTS OF SOIL CHEMICAL PROPERTIES ON STRUCTURAL STABILITY OF SOIL AGGREGATES IN THE TROPICS

Project Number:

CU-04a

Constraints Addressed:

Factors determining physical stability of aggregates in soil of the tropics

Project Leader:

Murray McBride, Cornell University

Research Collaborators:

Eugenio Marcano-Martinez, CU
Elemer Bornemisza, University of Costa Rica

GOALS AND OBJECTIVES:

The goal is to determine the factors that control structural stability and soil aggregates and thus to develop treatments that contribute to improvement in soil quality. The objectives are to (1) identify the mineral components of oxidic soils which are most highly dispersible, (2) characterize the surface charge properties of the soils as well as their mineral components, (3) observe the effects of amendments on charge properties and dispersibility of these soils, (4) develop a physical-chemical model of aggregate stability and (5) establish recommendations for maintaining soil structural stability.

PROGRESS REPORT

To surface horizons from three different Oxisols, calcium (as $CaCl_2$), sulfate as (SO_4), and $CaSO_4$ were added to soil suspensions at different pH's and changes on clay dispersion and electrophoretic mobilities and points of zero charge were measured. The presence of calcium reduced the dispersion of clays and made the surface charge more positive, thus raising the points of zero charge of the soils. Sulfate had an effect opposite to calcium, promoting the dispersion of clays and decreasing the points of zero charge. Gipsum ($CaSO_4$) application had an effect similar to sulfate but to a lesser extent. Above pH 6 there was a significant increase in the degree of clay dispersion in the three soils in all treatments and this was also reflected in a sharp increase in electrophoretic mobility of the colloidal phase.

The rest of the experiments will be carried out in the Soil Chemistry Lab at Cornell University by the principal investigators.

Similar studies to those made with the Brazilian Oxisols will be carried out with the soils collected from Costa Rica. Different chemical treatments will be applied to the soils in the laboratory to continue studying in more detail the effects of these on the surface charges of the colloidal fraction. Soil aggregates separated from the soils will also be subjected to immersion in different solutions to test some of the results from the previous experiments.

4. DEVELOPMENT OF MANAGEMENT PRACTICES REDUCING THE IMPACT OF SURFACE CRUSTS ON WATER STORAGE IN ALFISOLS OF SOUTHERN TOGO

Project Number:

CU-04b

Constraints Addressed:

Inadequate resource information
Landscape restrictions
Soil physical limitations
Water stress

Project Leader:

Philippe Baveye, Cornell University

Research Collaborators:

C. Bielders, CU
S. Warov, Institut National de Sols Lomé, Togo
A. Casenare, ORSTOM, Niamey, Niger
C. Valentin, ORSTOM, Niamey, Niger

GOALS AND OBJECTIVES:

Soil crusting is a primary concern in agricultural systems because of its adverse effects on water infiltration, runoff and erosion. Land degradation in the form of soil crusting is commonly observed on the coarse-textured alfisols of the terres de Barre region in southern Togo (pleuvert, 1988). Low soil organic matter contents resulting from cultivation are thought to be responsible for this phenomenon. The crusts that form at the soil surface reduce the infiltration capacity sufficiently to induce ponding and runoff during the often high-intensity rainfall events typical of tropical climates. Apart from increasing the erosion potential, water runoff can also result in decreased water availability for crop production as less water infiltrates into the soil. This is of particular concern in southern Togo because the large intra-annual variability in rainfall frequently causes periods of water deficit during which crops rely on available water in the soil profile.

A priori it would seem logical to solve the problem of soil crusting by using any practice that would limit crust development. Ultimately one should aim at maintaining soil structural stability by means of organic or inorganic compounds. However, for mostly economic and climatic reasons, such approaches are not viable in the short term in southern Togo (Poss and Saragoni, 1993). Farmers already faced with low yields and space shortage cannot afford the cost of

chemicals, of leaving crop residues behind or of leaving land fallow for the extended periods of time required to restore soil structural stability. Soil tillage may be used to break up surface crusts. However such practices have been shown to improve infiltration for only a very short period of time as the crust is fully restored within 1 or 2 rainfalls.

A last possible approach to the control of surface runoff at the field scale would be to take advantage of crust formation and surface microrelief. Several previous studies have considered surface crust development on the alfisols of the terres of Barre (Pleuvert, 1988; Poss *et. at.*, 1989-90). These studies confirmed a general model of spatial and temporal crust differentiation proposed by Valentin (1981) for coarse-textured soils. Well-defined crust morphologies with significantly different hydraulic properties can be associated with specific positions on the microrelief. If the permeabilities of the various crust types were known, it should be possible to devise a tillage practice that would modify the surface microrelief so as to maximize the extension of the most permeable crust and avoid runoff by ensuring temporary surface storage. In this way water infiltration should be optimal. In order to propose such a practice, our understanding of the spatial distribution and hydraulic properties of surface crusts needs to be refined through field and laboratory experiments.

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5. INTEGRATED MANAGEMENT OF SMALL AGRICULTURE WATERSHEDS AND AGROFORESTRY SYSTEMS

Project Number:

TAMU-05

Constraints Addressed:

Landscape restrictions
Inadequate resource information
Climatic variability
Production-demand pressure

Project Leaders:

A. Manu, Texas A&M University, Niamey, Niger
T. Thurow, Texas A&M University, College Station, TX
A.S.R. Juo, Texas A&M University, College Station, TX

Research Collaborators:

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F. Beidari, INRAN, Niamey, Niger
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E. Torquebiau, ICRAF, Nairobi, Kenya
B. Kang, IITA, Ibadan, Nigeria
G. Tian, IITA, Ibadan, Nigeria
J. Heilman, Texas A&M University, College Station, TX
R. Fischer, Texas A&M University, College Station, TX
L.P. Wilding, Texas A&M University, College Station, TX
L.R. Hossner, Texas A&M University, College Station, TX
C. Wendt, Texas A&M University, Lubbock, TX
R. Schwartz, Texas A&M University, College Station, TX
M. Thompson, Texas A&M University, College Station, TX
D. Leonard, LUPE Project, USAID/Honduras
F. Gomez, MNR, Escuela Agricola Panamericana, Honduras
D. H. Meckenstock, INTSORMIL, Honduras Program, Honduras

GOALS AND OBJECTIVES:

The overall goal of this project is to develop and adapt sustainable agricultural watershed management and agroforestry technologies by the evaluation of appropriate strategies which integrate socioeconomic constraints and improved technology components of soil fertility management, soil moisture management, soil conservation and crop/fodder/tree crop production. The specific objectives of the project during this reporting period were:

(1) To provide logistic and technical support to the USAID/INRAN/TAMU collaborative project entitled "Integrated Management of Agricultural Watersheds" (IMAW) in Niger. The principal objective of this project is to carry out research and demonstration trials in appropriate technologies for sustained crop/fodder production, soil/water conservation and natural vegetation management,

(2) To provide soil management expertise in support of research for the InterCRSP Honduran Watershed Management initiative and to allow the development, adaption and assessment of management options for sustainable agricultural production in the hilly regions of southern Honduras, and

(3) To evaluate above and below ground competition in alley cropping systems.

PROGRESS REPORT

Integrated management of agricultural watersheds (Niger)

The principal activities carried out over the past year under this project are data collection and analysis. More specific details of this year's activities are contained in the quarterly technical reports.

Vegetation reestablishment on microcatchments.

Monitoring of growth and establishment of the two plant species, *Prosopis africans* and *A cacia holo*, was the main activity carried out on the degraded plateau during this reporting period. Data collected in the four replicated blocks each of degraded thicket ring zones and bare corridors were plant height and survival rates.

Based upon the data obtained to date, the type of bare area has not been a factor in the survival rates of both plant species. However, growth rate and biomass revegetation are relatively higher in the degraded thicket ring zones than in the bare corridors.

Vegetation reestablishment on contour dikes.

As a purely demonstration exercise, the use of a contour dike as a water harvesting technique made a very positive impression on farmers. This technique was found to be very favorable to crops such as sorghum, pigeon pea and cassava which can tolerate short periods inundation in the rooting zone. Millet and maize, however, were unable to survive under these conditions and died. All tree species planted in the contour dike (*Ziziphus* sp., *Prosopis africans* and *A cacia holo*) as well as the grass *Andropogon guyanus*, performed very well during the first year.

Watershed hydrology and erosion studies.

Precipitation in the watershed was measured using a network of 8 non-recording rain gages. Mean precipitation for the watershed during 1992 was 704 mm which is significantly greater than the long-term mean annual rainfall of 405 mm. Starting in late May, rainfall continued steadily throughout the growing season until the end of September. Runoff and sediment production associated with these rains were evaluated on the three USLE plots installed in the backslope position of the watershed. Data collected in this study included:

> Amount and duration of each rainfall event and 5-minute intensities as recorded using a tipping bucket rain gage and data logger.
>
> A fraction (1/20) of the runoff emanating from the USLE plots.
>
> The weight of sediment after evaporation of known volumes of runoff.

The modular drop-forming rainfall simulator is being used for the determination of infiltration rates and sediment loss on selected micro-plots on crusted areas, cropped fields, fallow fields and fields that have been cultivated for one year after a three-year fallow. This sub-study is intended to compliment the information gained from the USLE plots. Selected plots are pre-wet the evening before data collection to reduce any variability in antecedent soil moisture. Plots are covered with plastic sheets overnight and allowed to equilibrate. Sediment load of one l liter subsamples are utilized to quantify sediment loss. Dry season data collection will be terminated in mid-April. Similar data will be taken on the same sites a few weeks after the onset of the 1993 rains.

On-farm agronomic trials.

With the exception of the farmyard manure treatment, yields of similar treatments were significantly higher in the RMT than in the FMT. This could be a reflection of differences in management (timely application of amendments, weeding and/or application of insecticides) under the two management systems.

The use of organic and inorganic amendments significantly increased crop yields. Highest yields (both grain and biomass) were obtained with the use of 5 tons/ha of

farm yard manure in the FMT. In contrast, inorganic fertilizers produced maximum yields of both millet and cowpea in the RMT's.

Soil type was not a major factor in determining crop yields in these trials during this year. Another important management factor was plant density. Closer spacing of plants (1.75 m x 0.7 m) under farmer management almost tripled yields. Further analyses will be carried out to study factors responsible for the yield differentials both among treatment and among RMT and FMT.

Yield variations exhibited by crops may be due to several factors including soil physical and chemical properties, climatic factors, specific treatments applied and management. Appropriate physical and chemical analyses were carried our on soils collected during the course of the season from both researcher- and farmer-managed trials. Soil properties determined include: texture, pH, exchangeable aluminum, available P, exchangeable bases and total carbon.

Improved fallow management.

Half of the two 30-m x 30-m enclosures installed in 1989 were cleared for cultivation of millet and cowpeas, three years after being in protective fallow. Soils were also sampled and analyzed.

Three years of fallow did not significantly alter the nutrient status of the soil compared to adjacent fields which have been under continuous cultivation for at least five years. This raises the question of the resiliency of these systems relative to plant nutrients in the short term, even under protected conditions. Biomass yields, on the other hand, were generally higher under fallow which could be attributed to factors other than the soil chemical conditions evaluated.

Honduran watershed management

In response to the request of host country collaborators, a research project addressing steepland soil and water conservation is being initiated in collaboration with the Honduran Ministry of Natural Resources, INTSORMIL, USAID/LUPE and the Pan American School of Agriculture. Joint planning of this project has been underway since the signing of the MOA with the Ministry of Natural Resources in January, 1992. In October of 1992, T. Thurow traveled to Honduras to discuss local funding support and to select additional watershed sites for long-term hydrological and sedimentation studies.

An agreement was reached with the Honduran Ministry of Natural Resources (MNR) and the USAID sponsored Land Use Production Enhancement Project (LUPE) to work collaboratively to:

(1) determine the extent of soil and nutrient loss and runoff associated with existing farming practices on steepland sites in southern Honduras,

(2) determine the effectiveness of soil and water conservation technologies that LUPE is working to establish in the region (*e.g.*, grass strips, rock walls, and agroforestry practices),

(3) develop guidelines which will optimize the filed implementation of these techniques.

Beyond meeting the needs of the natural resource field managers, the data obtained from this study will also provide the basis for planners, economists and administrators to have a more complete understanding of the value of such a program in terms of maintenance of on-site production and reduction of downstream problems associated with siltation and flooding.

An area near Choluteca, Honduras was chosen as the study site in April, 1993. Three fields, approximately 0.5 hectares, with 60% slopes were instrumented with flumes and stage recorders. These fields were being farmed with a maize/sorghum crop in a pattern typical for southern Honduras.

Data collected from the traditional farming system during the 1993 cropping season is being used to calibrate the watersheds and to characterize the extent of runoff, soil erosion and nutrient loss associated with the traditional farming practices. In 1994 and 1995 field work will assess the impact of conservation technologies that will be installed on the contours of two of the fields (*i.e.*, vetiver grass barriers and alley cropping with leucaena). The remaining field will serve as a control, continuing to represent traditional farming practices. Data characterizing the physical characteristics of each of the watersheds, rainfall parameters, and sediment yields will be used to improve the capabilities of models to predict runoff, soil and nutrient losses.

Above and below ground competition in alley cropping systems

During this reporting period, a proposal was developed to measure competition in alley cropping systems. This proposal has been subsequently accepted by IITA and ICRAF to do research at the respective research stations in Ibadan, Nigeria and Machachos, Kenya. Both IITA and ICRAF have agreed to provide local support including equipment and supplies. Currently preparations are being made to initiate the research in Nigeria during March of 1994.

ADDITIONAL FUNDING AND SUPPORT:

The Integrated Management of Agricultural Watersheds Project (IMAW) is a collaborative project of the Texas A&M University (TAMU), TropSoils CRSP and the Niger National Institute for Agronomic Research (INRAN) that is funded in part by USAID/Niamey through a cooperative agreement (No. 624-0250-A-00-1301-00). Project implementation began in July, 1991 with a two year funding level (under the cooperative agreement) of approximately $500,000. An eight

month extension with additional funding ($56,000) was approved in September, 1993.

Local support provided by the LUPE project consists of lodging for a graduate student while in Honduras, local labor expenses, supply expenses and part time assignment of two LUPE technicians to the project. The total dollar amount contributed this year is estimated at $7,000.

6. PROCESSES OF SOIL DEGRADATION AND REJUVENATION UNDER DIFFERENT LAND USE SYSTEMS

Project Number:

TAMU-01

Constraints Addressed:

Landscape restrictions
Inadequate resource information

Project Leaders:

L. P. Wilding, Texas A&M University, College Station, TX
A.S.R. Juo, Texas A&M University, College Station, TX

Project Collaborators:

J. Heil, Texas A&M University, College Station, TX
C. Coulombe, Texas A&M University, College Station, TX
H. Lambert, Texas A&M University, College Station, TX
W. Greenburg, Texas A&M University, College Station, TX
M. Bell, CIMMYT, Deleg, Cuauhtemoc, Mexico
G. Wilson, JADF/JARP, Kingston, Jamaica
S. McDaniel, ALCAN, Jamaica
L. McLaren, JADF/JARP, Kingston, Jamaica
K. McInnes, Texas A&M University, College Station, TX
R. Knight, Texas A&M University, College Station, TX
M. Hussey, Texas A&M University, College Station, TX
L. Hossner, Texas A&M University, College Station, TX
A. Mangaroo, Prairie View A&M University, Prairie View, TX
L.R. Drees, Texas A&M University, College Station, TX
K. N. Potter, Texas A&M University, Temple, TX
F. W. Chichester, Texas A&M University, Temple, TX
Z. Kouyate, IER, Mali
M. Ouattara, INRAN, Niger
A. Manu, Texas A&M University, Niamey, Niger

GOALS AND OBJECTIVES:

The principal goals of this project are (1) to characterize land degradation processes which alter physico-chemical soil properties in tropical agroecosystems and (2) to develop appropriate and environmentally sound technologies for the rejuvenation of degraded landscapes. The specific objectives relating to the studies during this reporting period were to:

(1) Characterize degradation and rejuvenation processes of Vertisols to allow the development of management strategies for rejuvenation and utilization.

(2) Characterize processes of surface crust formation and hydraulic sealing to allow the determination of controlling factors and the soil susceptibility to crusting under different land use systems.

(3) Support collaboration and research activities with the Jamaican Agricultural Research Programme (JARP) under the auspices of the Jamaican Agricultural Development Foundation (JADF). The short term objective of this collaboration is to initiate research involving the rejuvenation of bauxite spoils.

PROGRESS REPORT

Degradation and rejuvenation process of Vertisols

Research addressing the structural properties and hydraulic behavior of Vertisols in response to land use was initiated in 1990. The research consists of three sub-studies.

The first sub-study consists of the comparison of the effects of a native site and one, six and ten years of no-till management and controlled traffic on the macroporosity and fabric of surface horizons of Vertisols in Texas. Kubiena samples for micromorphology were collected at 0-5, 5-15 and 15-30 cm depths. The samples were water replaced with acetone, impregnated with an acetone-polyester resin solution containing a UV dye and irradiated with cobalt for polymerization. Vertical and horizontal sections were obtained from each sample, polished and photographed under UV illumination for image analysis of porosity. Parameters measured from each pore with image analysis were: area, perimeter, angle of orientation, maximum diameter, minimum diameter, and mean diameter. Subsequently, thin sections of 30 μm in thickness were made from the same sample and described using the terminology of Brewer (1976). Data are being analyzed and a manuscript is in preparation.

The second sub-study consists of the evaluation of the impact of different land use systems on surface properties of Vertisols. The objective of this sub-study is to compare the properties of the surface horizons of Vertisols in five land use systems (native, restored fallow for 20 years, pasture, cereals and row crop under

controlled traffic). Each treatment site was sampled at six equally spaced intervals of 8 m along a transect of 40 m. Bulk samples, bulk density clods and micromorphology samples were collected at 0-5, 5-15 and 15-30 cm depth. Bulk samples were analyzed for total organic carbon, carbonate content, total nitrogen, total phosphorus, pH, cation exchange capacity, and extractable bases. Bulk density, available moisture and coefficient of linear extensibility (COLE) were determined. Micromorphology samples (Kubiena) were water replaced with acetone, impregnated with an acetone-polyester resin solution containing a UV dye and irradiated with cobalt for polymerization. Vertical and horizontal sections were obtained from each sample. Saturated hydraulic conductivity measurements were taken along the same transect.

The objectives of the third sub-study are to evaluate the changes in morphological, chemical and physical properties of three Vertisols that exhibit different stages of degradation; *e.g.*, degraded, mildly degraded and least degraded. A reconnaissance soil survey of the CIMMYT research station in Tlaltizapan, Mexico was completed at a density of one observation per hectare in order to select three representative sites. The selected sites exhibit different stages of degradation and iron chlorosis under similar cultivation practices. Each treatment was collected at three equally spaced intervals of 255 m along a transect of 50 m. Bulk samples, bulk density clods and micromorphology were sampled at 0-20, 20-35, and 35-50 cm. Additional bulk samples were taken at 50-75, 75-100, 100-125 and 125-150 cm for physico-chemical characterization. Bulk samples are being analyzed for total carbon, calcium carbonate equivalent, gypsum equivalent, pH, cation exchange capacity, extractable bases and particle size distribution. Bulk density, available moisture and COLE measurements have also been taken. Mechanical impedance measurements were also taken six times for each treatment along the sampling sites.

Surface crust formation.

Field work for a study addressing the characterization of surface sealing processes in Sahelian soils was completed in Niger (Hamdallaye) and Mali (Cinzana Research Station) during 1991. Six soils at Hamdallaye, Niger and two soils at the Cinzana Research Station are being studied. During this reporting period, additional thin sections were prepared from intact blocks and described with a petrographic microscope. Image analysis was utilized to investigate pore space. Thin sections were also observed under a scanning electron microscope using backscattered imaging and energy dispersive X-ray spectroscopy. A rotating disk rainfall simulator was used to create seals under controlled conditions. The bulk Hamdallaye soil was used for this experiment.

Seals in fallow fields at the Cinzana Research Station were actually deeply compacted soils due to structural losses from cultivation or heavy animal traffic. For the Hamdallaye soils, infiltration measurements with a disk infiltrometer were 130 $\mu m\ s^{-1}$ in the unsealed sites and 3 - 103 $\mu m\ s^{-1}$ in the sealed sites. Thin section analysis showed a dense 0.1 to 1 mm thick continuous plasmic layer just below a

1 mm thick layer of loose bare sand. All of the 12 sites studied with clay contents greater than five percent were sealed while all of those below five percent were not. All of the seals were associated with erosion where the sandy topsoil was eroded to expose an argillic horizon. A low pH in sealed sites caused the soils to flocculate, so that disaggregated clay remains flocculated in silt-size particles and clogs pores. Seals created under the artificial rainfall on the Hamdallaye soils consisted of either two- or four-layer seals, depending on clay content. The seals formed quickly and were fully developed after 30 minutes of rainfall. Dispersion of the clays with Na saturation before rainfall prevented seal formation in soils with less than 10% clay due to complete eluviation of the clay.

Results from this study suggest that surface seals most commonly occur where topsoil has been removed by wind and water erosion, thereby exposing argillic horizons. This is also supported by the close correlation between the occurrence and degree of seal development and the clay content of the soil at the surface.

Land quality and restoration of mined out lands in Jamaica

In January 1993, Wendy Greenberg (graduate student) conducted an initial evaluation and sampling survey of some restored bauxite mine land soils in Mandeville, Jamaica in collaboration with ALCAN. Twenty-nine depth transects were completed in six mine pits of different age. Soils were described and samples were taken from five backhoe pits and 18 auger holes. Field observations revealed several soil types ranging from topsoil over deep mine fill materials to topsoil over shallow limestone bedrock. Laboratory analysis of soils indicted the following:

> Soil texture was dominantly clay or clay loam.
>
> Base saturation was 100 percent.
>
> CEC ranged from 14 to 27 cmol kg^{-1} in the soil surface (generally varying with percent organic carbon) and decreased with depth.
>
> Organic carbon was 2 to 5 percent in the surface of the restored mine soils (which had been fertilized with chicken manure) and just under 2 percent in the surface of the unrestored and premined soil.
>
> The reclaimed and restored bauxite materials did not seem to pose serious chemical constraints but physical constraints such as soil dept and compaction may be more important.

Wendy Greenberg also discussed methods of reclamation and restoration with ALCAN employees and identified potential research plot areas for future work. Her report on this initial study was distributed to TropSoils, ALCAN, and JADF/JARP personnel.

A second study being conducted by Hugh Lambert (graduate student), Dr. Mark Hussey and Dr. Larry Wilding was initiated in May, 1993 also in collaboration with JADF/JARP and ALCAN. Crop plots were established in three sites and one premined site in an attempt to find an indicator plant for soil spatial variability. In October, 1993, Hugh Lambert returned to Mandeville, Jamaica to evaluate and document crop variability. Wendy Greenberg will return in January, 1994 to evaluate soil variability in relation to crop variability and to outline future research strategies in soil and water conservation of the soil resource base.

In May of 1993, Drs. Larry Wilding and Mark Hussey followed up on initial efforts at site characterization. They consulted with ALCAN mining personnel regarding several critical aspects of soil and water conservation, soil erosion, physical rooting constraints and strategies to overcome these limitations. They also identified appropriate strategies and a time line to conduct plots that are sensitive to potential soil-based growth constraints.

ADDITIONAL FUNDING AND SUPPORT

A portion of a total grant of $23,439.95 was received from JADF/JARP to support the graduate research assistantship, tuition and fees of Mr. Hugh Lambert. JADF/JARP also has provided funds (approximately $4,000.00) which covered per diem and air fare costs for travel of investigators to Jamaica. In addition, ALCAN has contributed substantial support to the Jamaican Projects in the form of transportation, back-hoe services and local labor. CIMMYT provided lodging facilities for Mr. Coulombe during his stay at the Tlaltizapan Station in Mexico.

7. SOIL CHARACTERIZATION AND INTERPRETATION OF NATURAL RESOURCES MANAGEMENT IN THE TROPICS

Project Number:

NCSU-02

Constraints Addressed:

Inadequate soil resource information
Landscape restrictions

Project Leader:

S.W. Buol, North Carolina State University

Project Collaborators:

H. Eswaran, USDA-SCS
R. Mejia, IBTA/Chapare
S.E. Monteith, NCSU
J. Schmidt, NCSU
M. Beck, NCSU

GOALS AND OBJECTIVES:

The goal is to enhance the soil data base with measurements of soil properties in seldom sampled parts of the world and extremely humid environments with a further objective of determining absolute soil mineral fertility potential for major soil-ecosystems of the world.

PROGRESS REPORT

Extreme contrast in soil fertility and reaction was identified within the Chapare region of Bolivia. While most soils in the area are acid and infertile, low lying stream terraces within watersheds originating from basic rock areas in the Andes have much higher pH values and contain more exchangeable basis. However, slightly higher terraces, often only one or two meters higher, have acid and infertile soils comparable to soils on all terraces along other streams.

Utilizing surface and subsoil samples of Ultisols with a 17-year history of fertilization and yield measurements the fractionation of P pools has been completed. It was found that only available and somewhat available forms of P are either increasing with excess fertilization or decreasing with excessive crop harvest. Representative samples from major soils around the world are now being fractionated to evaluate their potential P supplies. The samples selected represent major soil mineralogy suites identified by soil taxonomy.

ADDITIONAL FUNDING AND SUPPORT:

Support through cost sharing:

IFDC - support to present two lectures at workshop in Alabama.
SMSS - support to present paper to sustainable agriculture conference in India.
Asian Institution of Technology - support to present keynote address at International Workshop in Bangkok.
INTSORMIL - Plant Breeders workshop in Lincoln, Nebraska

Support to project in kind:

Sampling of soil in Madagascar - Duke/NCSU project.

8. LAND RESOURCES CHARACTERIZATION AND EVALUATION IN THE SEMIARID TROPICS

Project Number:

TAMU-04

Constraints Addressed:

Landscape restrictions
Inadequate resource information

Project Leader:

L. P. Wilding, Texas A&M University, College Station, TX

Project Collaborators:

M. Ouattara, INRAN, Niamey, Niger
P. Sankara, University of Ouagadougou, Burkina Faso
N. Zombre, University of Ouagadougou, Burkina Faso
A. Schubert, Texas A&M University, College Station, TX
A. Manu, Texas A&M University, Niamey, Niger
L.R. Drees, Texas A&M University, College Station, TX
O. Smith, Texas A&M University, College Station, TX
H. Eswaran, TSMM, USDA, Washington, D.C.
A. Van Wambeke, Cornell University, Ithaca, NY

GOALS AND OBJECTIVES:

The principal goal of this project is to characterize, quantify and evaluate land resources as baseline data for resource management research and technology transfer. The specific objectives relating to the studying during this reporting period were to:

(1) TropSoils/Peanut Inter-CRSP characterization of target research sites in Burkina Faso and Niger. Major soils will be analyzed for physical, chemical and mineralogical properties for samples collected during this funding period.

(2) Characterization of restored bauxite mine land soils in Mandeville, Jamaica.

The progress report for objective (2) is covered in it's entirety under TAMU-01.

PROGRESS REPORT

Tropsoils/Peanut Inter-CRSP soil characterization

The objective of this collaborative research is to determine the response of local and acid tolerant genotypes to soil amendments with regard to production potential. The Peanut and TropSoils CRSPs combined their expertise to evaluate the quality of soil resources in breeding selection field trials plots at five sites in Burkina Faso (Sari, Niangoloko, Bobo Dioulasso, Tenkodogo and Gampela). During 1991 to 1992, physical, chemical, mineralogical and microfabrics analyses were completed on 30 samples collected in 1989. During this reporting period 25 samples have been analyzed for characterization.

Mature peanut seed yields were increased for two of three genotypes by application of ash in southwest Burkina Faso. No significant yield responses were obtained from the application of phosphorus or gypsum. Plant analysis indicated that ash significantly increased the potassium concentration and decreased the manganese concentration of the peanut plant. As would also be expected from an increase in pH.

ADDITIONAL FUNDING AND SUPPORT

This is a joint project between TropSoils and Peanut CRSP. Collaborators of host country institutions and Peanut CRSP funded all in-country activities associated with this project.

9. SOIL MANAGEMENT SUPPORT SERVICES (SMSS)

Project Number:

SMSS

Constraints Addressed:

Lack of quality and availability of resource information
Lack of consistency of soil databases
Under-utilization of soil resource information
Diverse background of potential users

Project Leader:

Hari Eswaran, USDA-SCS

Collaborating Institutions:

International:

Indian Council for Agricultural Research, New Delhi, India
Indian Agricultural Research Institute, New Delhi, India
Department of Agriculture, Kerala, India
Konkan Agricultural University, Dapoli, India
International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India
University of Pretoria, South Africa
Drainage and Irrigation Department, Johannesburg, South Africa
International Board for Soil Research and Management (IBSRAM), Thailand
National Research Center, Egypt
ICRAF, Kenya
Agriculture Canada
University of Ghana, Accra
IFDC, Togo
PCARRD, Philippines
Bureau of Soil and Water Management, Philippines
Resource Management Division, DOA, Malaysia
University Pertanian, Malaysia
University Kebangsaan, Malaysia
Department of Land Development, Thailand
Kasetsart University, Thailand
Forestry and Fuelwood Project, Thailand
Royal Forestry Department, Thailand
Department of Irrigation, Sri Lanka
Center for Sustainable Agriculture, Madras, India
Anna University, Madras, India
DOA, Tamil Nadu, India

Domestic:

USDA, Economic Research Service
Department of Agronomy, Iowa State University
Defense Mapping Agency
U.S. Army Corps of Engineers
State Department
EROS Data Center
Foreign Agriculture Service, USDA
World Food Outlook Board
Economic Research Service, USDA
Center for Disease Control, Atlanta, Georgia
USDA Agricultural Marketing Service

GOALS AND OBJECTIVES:

The goal is to assist LDCs implement policies and commitment to sustainable land management for food and fiber production and conservation of natural resources. The objectives are (1) to assist in the strengthening of LDC institutions and human resources to address the challenges os sustainable agricultural development, (2) to collaborate with NCSS and NSSC in the development of priority areas to address global and regional constraints to agricultural development and discriminatory use of soils, (3) to use the resources of SCS, USDA and NCSS to provide the scientific expertise to other government agencies and international donors to carry out their respective mandates and (4) to assist in the development of networks of scientists and institutions to foster the development and application of innovative technologies in soil research and management.

PROGRESS REPORT

FY93 is the penultimate year of the proactive, impact driven global project of the U.S. Agency called the Soil Management Support Services (SMSS). The project was initiated in October 1979 but became fully operational in April of 1980. In 1991, it was merged with the TropSoils Collaborative Research Support Program (TropSoils-CRSP) with its Management Entity in Raleigh, North Carolina. The marriage was also accompanied by a drastic reduction in funds. The merger was also not accompanied by the normal meticulous attention by AID to focus, relevance, purpose, and impact and consequently, SMSS proceeded with its own approach which is elaborated later.

FY93 was extremely productive compared to FY92 which was largely used to plan activities, establish contacts, and develop a demand-driven program. This program has few relationships to the TropSoils-CRSP, although with time, we made a concerted effort to streamline our work to fit some of the objectives of the CRSP.

The major change in our work has been the introduction of computerized databases and the application of the Geographic Information System (GIS). Now we have a DOS based ARC-INFO and a UNIX based GRASS system fully functional and early drafts of our maps are available (some have been submitted to AID as examples of our output). We have also moved into the area of Global Climate Change and environment, the latter mainly in the realm of land degradation. We are using this three-year interim period before the new Soil Management CRSP is operational in FY95 to develop the groundwork for the new thrust. In this context, we organized or helped to initiate four major international meetings to address:

(1) Sustainable Land Management -- Thailand, 1991
(2) Soil degradation and soil resilience -- Hungary, 1992
(3) Stressed ecosystems -- India, 1993
(4) Framework for sustainable land management -- Canada, 1993

Our training activities on Soil Taxonomy and Sustainable Land Management, were also re-initiated with the following:

(1) India -- December, 1992
(2) Thailand -- June, 1993
(3) Philippines -- July, 1993

As part of the training or in response to a request from USAID Mission, a country, or an International Agricultural Research Center, we characterized soils in the following countries:

(1) Kenya -- 6 sites (ICRAF, IBSRAM)
(2) Malawi -- 6 sites (ICRAF, IFDC)
(3) Mongolia -- 6 sites (USAID)
(4) Philippines -- 15 sites (SANREM)
(5) Venezuela -- (SCS)
(6) Russia, Siberia -- (OICD)

All the above activities were cost-shared.

ADDITIONAL FUNDING AND SUPPORT:

Activity	*Organization*	*Person*	*Amount $*
1. Training at ICRISAT India	OICD	H. Eswaran	3,200
2. Sampling in Egypt/Kenya	ACE	D.Yost	
		T. Calhoun	14,000
3. Visit S. Africa	OICD	H.Eswaran	2,000
	S. Africa		1,000
4. IBSRAM meeting, Nairobi	TropSoils	H.Eswaran	5,500
5. Stress Workshop	ICAR		15,000
	ICRISAT		45,000
6. Indian Training	Kerala		15,000
7. Thailand Training	DLD		25,000
8. Philippines Training	PCARRD		20,000
9. Mongolia	OICD	H. Eswaran	1,500
TOTAL			147,200

10. TECHNOLOGY FOR SOIL MOISTURE MANAGEMENT/ECONOMIC RESEARCH SERVICE

Project Number:

TSMM/ERS

Constraints Addressed:

Landscape restrictions
Climatic variability
Production demand pressures
Inadequate resource information

Project Leaders:

J. Day, U. S. Department of Agriculture
W. Butcher, WSU, Department of Agriculture Economics
D. Taylor, VPI, Department of Agriculture Economics
F. Boadu, TAMU, Department of Agriculture Economics

Research Collaborators:

U.S. Universities:

D. Deybe, WSU, Department of Agricultural Economics
C. Stockle, WSU, Department of Biosystems Engineering
I. Silva-Barbeau, VPI, Department of Rural Sociology
G. Carlson, NCSU, Department of Agricultural Economics
J. Smyth, NCSU, Department of Soil Science,
P. Baveye, Cornell, Department of Soil, Crop and Atmospheric Sciences
S. Riha, Cornell, Department of Soil, Crop and Atmospheric Sciences
A. Van Wambeke, Cornell, Department of Soil, Crop and Atmospheric Sciences

Oversees Entities
Institut National de la Recherche Agricole
Centre d'Aridoculture, Settat, Morocco
M. El Mourrid, Director of Center, Soil Scientist
M. Bendaoud, Agricultural Economist, PI
M. Boughlala, Soil Scientist
M. Laamari, Agricultural Economist
M. Moussaoui, Agricultural Economist
Institut Agronomique et Veterinaire Hassan II, Rabat, Morocco
R. Doukkali, Head, Agricultural Economics, PI
Y. Bathaoui, Agricultural Economist
M. Taya, Soil Scientist

Institut d'Etudes et de Recherche Agricole, Burkina Faso
S. Ouedraogo, Director, RSP, Agricultural Economist, PI
F. Lompo, Director, ESFIMA, Soil Scientist
Institut d'Economie Rurale, Mali
A. Maiga, Agricultural Economist, PI
ICRISAT/Sahelian Center
S. Deborah, Agricultural Economist, Mali Station
R. Shetty, Head, Farm Resources Unit, Niamey
Parc Forestier HANN, Senegal
A. Niang, Director, Senegal Reforestation Project
Centre de Cooperation Internationale en Recherche Agronomique Pour le Development, France
F. Girard, URPA, Agricultural Economist

GOALS AND OBJECTIVES:

The overall goal of the SM-CRSP/TSMM Economics Program is to identify farm technologies and resource management practices that will improve income, food production and consumption, and preserve the long-term productive capacity of natural resources. The objectives were (1) to develop multi-disciplinary analytical methodologies effectively integrating soils, agronomic, agroclimatic, and economic data for accurate assessment of soil and water management practices and related land use strategies, (2) to assemble baseline and response data suitable for use in the methods and procedures of objective 1 and (3) to identify sustainable agricultural production systems through socioeconomic analyses of soil, water, vegetation, and livestock management options.

PROGRESS REPORT

The major accomplishments during this period were development of methodology and plans for integrated bio-physical and socio-economic analysis of agriculture and related land resource management in Burkina Faso and Morocco. Collaborative work with researchers in Burkina Faso has resulted in two professional papers and establishment of a cooperative research program with INERA that is getting underway at a site in western Burkina. In Morocco, two sites have been selected and a similar cooperative research program, with INRA and IAV Hassan II, is beginning. An analysis of productivity and sustainability of bush-fallow rotations is nearing completion. We are making good progress in analysis of the interconnections between crop production, livestock production, and the use of common lands. Applications are being developed for Burkina Faso and Mongolia.

The economic potential of increased wood production in western Senegal was evaluated in a study completed by VPI. A feasible study of providing technical, financial, and marketing assistance to farmers in Bolivia, through a private entity, was also completed.

Ph.D. qualifying exams (oral and written) were completed by Deborah Wagner (VPI). Final preparations were also completed for her to begin field data collection this fall in Senegal leading to a dissertation. This analysis will focus on the role of women in agricultural production and related resource management decisions. The project is being carried our in collaboration with the USAID Senegal Reforestation Project (SRP). The Mission will provide logistical support for the field work.

At TAMU, analysis has begun of data collected in June from farmers in ICRISAT study villages in Mali. This analysis will evaluate farmer's willingness to pay for soil and water conservation measures. Discussions continue regarding a joint study of resource issues in Mali involving TAMU, VPI, ICRISAT, and IER (Mali). The interest is strong for such a study, but Malian counterparts are overburdened with external demands on their time, *eg.*, the World Bank, FAO, GTZ, and it is difficult to capture the time necessary to come to closure.

Ex-post analysis of the NCSU Yurimagus data has begun under the supervision of Dr. Jerry Carlson. Completion is expected in January 1994.

ADDITIONAL FUNDING AND SUPPORT:

Support through cost sharing and leverage was $197,000.

11. LAND EVALUATION AS A TOOL FOR SUSTAINED RURAL DEVELOPMENT

Project Number:

CU-05

Constraints Addressed:

Fragmented agricultural development research
Lack of communication between disciplines
Communication gap between agronomists and decision makers

Project Leaders:

Dr. A. Van Wambeke, CU
Dr. G. Gillman, IITA, Yaounde, Cameroon
Dr. Hauser, IITA, Yaounde, Cameroon
Dr. Stephen Weise, IITA, Cameroon

Research Collaborators:

Mr. S. Numbem Tchatchoua, Graduate Research Assistant, Department of SCAS, CU
Dr. Ayuk Takem, Minister of Scientific Research Yaounde, Cameroon
Dr. S. S. Jagtap, Agroclimatologist, IITA, Ibadan, Nigeria

GOAL AND OBJECTIVES:

The project intends to give decision makers a tool capable of building expert systems that integrate all data important for optimum, sustainable land use. This would reduce the present abuse of soil resources. The land utilization types to be included are food crops, rotations, tree crops under different levels of management.

The goal is to provide services to farmers using extension agents as well as rural, city or regional planning agencies.

PROGRESS REPORT

Progress and accomplishments for 1992-93 (Sept. 25, 1992-Sept. 24, 1993).

Cameroon

Field research preparation continued and included the following activities:

Digitized maps of the Central Province of Cameroon

The maps show the location of the villages that the Dvorak socio-economic survey carried out by IITA has studied.

Physiographic description of the Central Provence

Preliminary data on the natural resources of the Central Province of Cameroon have been collected. They include climate, vegetation and geology.

Definition of a quantitative sustainability index

Several options have been reviewed from the literature. The following criteria will be considered: Sustainability is *always applied to a system* that has at least *two* components: land and people. Sustainability evaluation is a *stepwise procedure.* It is firstly applied to the changes in *properties* of a soil that is subjected to management practices. It is subsequently extended to include cropping systems that produce yields that translate into economic returns. Sustainability is then viewed in a social environment by comparing the returns to the financial expectations and quality of life standards of people. The

sustainability index has to be placed in a time frame. in most economic evaluations a 30-year life span is considered to be adequate.

Sustainability evaluation requires an *end-point:* At what time, or at which *threshold value* of an attribute will a system cease to be sustainable and permanently unable to function satisfactorily? A number of criteria have been used to answer this question: land qualities, land use requirements, threshold values, resilience, stability indices of outputs, trends, etc.

In terms of economic evaluations the following methods are being examined: Lynam and Herdt (1989) who define a sustainable system as "one with a non-negative *trend* in measured output"; Ehui and Spencer (1990) who developed a *total factor productivity index* (TFP) that takes into account changes in soil or land characteristics or qualities that determine the trend that a system is taking over time. A non-negative trend is the overall indicator of sustainability. Soil losses, changes in nutrient stocks are accounted for by attaching opportunity costs for their replacement in the calculation of the TFP index.

The sustainability index will have to be attached to a *geographical area.* When production or profitability is the most limiting factor in the appraisal of the sustainability of farms, their sizes become important. Quantitative assessment of the economic sustainability of farms will therefore have to take *economics of scale* into account. Sustainability may have to be expressed by unit area.

GIS integration of soil information and Dvorak database

The GIS software Idrisi is being used for georeferencing; the land evaluation system ALES is interfaced with Idrisi. A small scale soil map of the Central province has been entered in the GIS system. The Dvorak database is used to determine the areas where the major food corps are grown in Cameroon (rice, corn, sorghum, cassava, etc.)

Other countries

No further direct contacts have been made with other African countries as had been planned. The intended countries were Burkina Faso, Niger, and Morocco. Indirect contacts were maintained through the TSMM program of the Economic Research Service of USDA (Dr. J. Day). It was agreed that ERS would initiate the negotiations with the national institutions and that we would step in once there was a clear USAID and national interest. The information received indicates that Burkina Faso and Morocco have expressed interest in the integration of economic surveys with land resource data.

B. SUSTAINABLE AGRICULTURE PRODUCTION

1. SUSTAINABLE SOIL MANAGEMENT ALTERNATIVES TO SLASH AND BURN

Project Number:

NCSU-03

Constraints Addressed:

Soil acidity
Nutrient deficiencies and losses
Soil physical limitations
Erosion
Water stress and weeds

Project Leader:

M.G. Wagger, North Carolina State University

Research Collaborators:

D.K. Cassel, NCSU
P. Luna, NCSU
J. Salinas, PDAR
T.J. Smyth, NCSU

GOALS AND OBJECTIVES:

The overall goal is to develop soil management technologies that can substitute for slash and burn land management systems. The objectives are to determine the factors responsible for sustainable production in principal crop and pasture-based soil management options for the humid tropics and to determine the lower threshold values below which the aforementioned management options are environmentally or economically impractical.

PROGRESS REPORT

Mr. Pedro Luna completed his field research in the Chaparre region of Bolivia this past February. Upon his return to NCSU in March, laboratory analyses were begun on the final set of plant and soil samples. This phase of the research has also been completed and he is currently writing his dissertation. The expected completion date for the dissertation is July 1994.

2. BASE CATION DYNAMICS IN LOW-BASE STATUS TROPICAL SOILS

Project Number:

UH-07

Constraints Addressed:

Nutrient losses and deficiencies

Project Leader:

Thomas Dierolf, University of Hawaii
Russell Yost, University of Hawaii
I P. G. Widjaja-Adhi, Center for Soil and AGroclimate Research, Bogor, Indonesia
James Fownes, University of Hawaii

Research Collaborators:

Agus Sofyan, Center for Soil and Agroclimate Research, Bogor, Indonesia

GOALS AND OBJECTIVES:

The overall goal was to develop management recommendations that increase the use efficiency and sustainability of base cations in a low base-status soil. Specific objectives set to achieve the goal were (1) to quantify cation losses from the soil profile that occur through leaching and vegetation removal, (2) to understand how water moves through the soil and how the water movement affects cation leaching, and (3) to understand K dynamics in a rainfed agricultural system as affect by crop straw/stover management (returning versus removal) and K fertilization practices.

PROGRESS REPORT

Minimizing soil nutrient losses is a way of increasing the use efficiency of soil amendments and can reduce both production costs and environmental costs. By understanding the fate of nutrients contained in soil amendments, management practices that minimize nutrient losses can be developed. Thus, cation losses, through leaching and vegetation removal, from a clayey Indonesian Typic Kanhapludult, were quantified.

Water flow was characterized by the internal drainage method. An initial rapid phase of drainage (67% of a 7.25 cm water application passed below the 112.5

cm depth within the 100 minute irrigation period) was followed by a slow phase. Sharp breaks in the drainage curves separated the phases and provided estimates of the macropore (rapid phase) and micropore volumes (slow phase). Two hypotheses, developed from the characterizations of water flow, were that surface applied cations were susceptible to rapid leaching loss and that subsoil accumulation of cations would be difficult.

In one field experiment, essentially all of the K (100 kg K ha^{-1} was applied as KCl fertilizer) was recovered after irrigating with 9.1 cm of water. However, mass balance calculations for another experiment (six crops grown during 2 years) indicated that up to 285 kg K ha^{-1} (600 kg K ha^{-1} was applied) was not recovered and presumed to have leached below the 90 cm depth. Thus, cation leaching is more likely to occur because of the cumulative effect of rainfall (688 cm during the 2-year experiment) rather than for "individual, large storm events."

For one treatment in the 2-year experiment, only 5 kg K and 130 kg Ca ha^{-1} accumulated between 30-90 cm, while 285 kg K and 263 kg Ca ha^{-1} were calculated to have leached below the 90 cm depth. These results indicated that the majority of cations in draining water did not accumulate in the subsoil.

Returning the straw/stover resulted in optimal grain yields for all six crops when 70 kg K ha^{-1} was applied initially. Removing the straw/stover, for the same amount of applied K resulted in yield decreases by the fourth crop. Only moderate amounts of K are required for cowpea, rice, and soybean production as long as the straw/stover is returned evenly over the harvest area.

3. AGROFORESTRY SYSTEMS FOR ACID SOILS OF THE HUMID TROPICS

Project Number:

NCSU-04

Constraints Addressed:

Soil acidity
Nutrient depletion and losses
Topographic limitation
Water stress
Weeds
Loss of mycorrhizal and rhizobial inoculum

Project Leader:

C. B. Davey, North Carolina State University

Project Collaborators:

L. T. Szott, IDRC, CATIE
C. A. Palm, ICRAF
P. O. Rufz, NCSU
A. A. Salazar, NCSU
D. Desmond, NCSU
E. C. M. Fernandes, NCSU
A. Ricse, INIAA
J. M. Perez, INIAA
M. Arcos, INIAA
D. Lara, INIAA

GOALS AND OBJECTIVES:

The overall goal is to reduce fertilizer and herbicide input requirements for maintaining system sustainability through improved nutrient cycling and soil surface protection by the inclusion of trees in the production system. Specific objectives are to evaluate the influences of VA mycorrhizal roots on the success of various agroforestry species, to quantify and compare mycorrhizal infection among different soil management systems and to measure the dynamics of P among different agroforestry systems by modifications of the Hedley fractionation method.

PROGRESS REPORT

In a study of mycorrhizal root infection in plants in various cropping systems, it was found that high infection was associated with 7 or 18 year-old secondary forest and multistrata tree crop systems while the lowest infection was associated with continuous cropping, including both high and low-input systems. Infection of roots in plantation-grown peach palms was intermediate. Results suggest that a loss of soil productivity may be at least in part associated with the lost of mycorrhizal inoculum. This may either be caused by loss of topsoil through erosion or through mortality of the beneficial fungi through the absence of optimum host plants.

The question of inoculum loss or absence was addressed in a study of mycorrhizae and rhizobia in an alley cropping system on sloping land. Soil from a low-input cropping system, a secondary forest, and bare soil were used for comparison. Cowpeas were grown in all soils. Biomass production, nodulation, and mycorrhizal infection were all high in the low-input and alley cropping systems. No nodulation occurred in soil from either the secondary forest (none present) and bare soil (loss due to erosion).

Peach palm *(Bactris gasipaes)* seedlings produced in a nursery have been found to survive and grow better in new plantations when the roots of the seedlings were well-inoculated with mycorrhizal fungi. A study of possible mycorrhizal inocula

was conducted using (1) leaf mold from a secondary forest, (2) leaf mold from a Kudzu stand, (3) peach palm roots, (4) *Andropogon bicornis* roots, and (5) a non-inoculated check. Two of the inocula (secondary forest and kudzu) were very effective in stimulating growth of both roots and tops of the peach palm seedlings. Following in order, but at a much lower level of productivity, were the peach palm roots, the *A. bicornis* roots, and the non-inoculated check.

All three of the above studies show the impact of proper management of the root environment on crop production. These are all simple procedures that the farmer with the most modest of resources can practice. The capital and labor investments are minimal while the potential benefits in food production and oil resource protection are large.

Phosphorus is very important in plant nutrition and mycorrhizal roots are the principal means of P uptake by nearly all plants (annuals and perennials). However, P occurs in the soil in several fractions and little is known about the dynamics of the various P-fractions in soils under various low and high-input systems. A study has been initiated using soil from low and high input and a multistrata tree crop system of the dynamics of the various P fractions over time.

4. DETOXIFYING ALUMINUM AND REDUCING P FIXATION IN VARIABLE-CHARGE SOILS WITH ORGANIC AMENDMENTS

Project Number:

UH-03

Constraint Addressed:

Soil acidity
Phosphorus deficiency

Project Leader:

Nguyen Hue-University of Hawaii

Project Collaborator:

Russell Yost, University of Hawaii

GOALS AND OBJECTIVES:

The goal is to increase soil productivity while maintaining environmental quality. The objective is to define rules on liming with organic materials. Last year's work focused specifically on the amelioration of subsoil acidity by surface applications of calcium fulvates derived from common organic materials.

PROGRESS REPORT

Calcium fulvates were prepared from chicken manure, cowpea green manure, and anaerobically digested sewage sludge by titrating HCl-soluble fulvic acids from pH 2.0 to 7.0 with $Ca(OH)_2$-saturated solution. The fulvate solutions were adjusted with water such that all contained 833 mg CaL^{-1}. subsequently, 300 mL of each fulvate solution, containing 250 mg Ca, were applied slowly (50 ml/20 min.) to the top of cylindrical columns (length = 50 cm, diameter = 5.8 cm) filled with 1.1 kg soil of a high Al, low Ca, acid Ultisol. Equal volumes of water $CaCl_2$ solution, and $CaCO_3$ suspension of 833 mg CaL^{-1} were similarly applied for comparison. Following the treatments, 100 mL of H_2O were applied the first day and another 400 ml the second day to each column. The leachates were collected for chemical analysis. Then the columns were dismantled and the soils were sectioned into 10 5-cm long segments from which exchangeable Ca, Mg, K, Na, and Al, and soil pH were measured.

The results demonstrate the following points:

(1) The surface-applied Ca from $CaCl_2$ or Ca fulvates, of which the associated anions were mobile, moved effectively into the soil profile, virtually doubling exchangeable Ca (from 0.5 to 1.0 $cmol_c\ kg^{-1}$) at any given depth. On the contrary, Ca from $CaCO_3$, which produced OH^- to be neutralized quickly by soil acidity, remained mainly in the top 15-cm layer.

(2) KCl-extractable Al in the 0-5 cm layer decreased from 1.6 $cmol_c\ kg^{-1}$ in the water treatment to 1.3 $cmol_c\ kg^{-1}$ in the $CaCl_2$ treatment, 0.4 $cmol_c\ kg^{-1}$ in the Ca fulvate from green manure, and $\leq$ 0.1 $cmol_c\ kg^{-1}$ in the $CaCO_3$, and the remaining Ca fulvate treatments. Extractable Al in soil layers deeper than 10 cm was little affected by treatments other than the Ca fulvate from sewage sludge. The latter treatment significantly decreased extractable Al in all but the lowest (45-50 cm) soil layer, suggesting sludge-derived fulvates reacted more strongly with Al than those from chicken manure or green manure.

(3) Because of the increased Ca and/or decreased Al. Al saturation was decreased by all treatments relative to the water control. However, the magnitude and pattern of this decrease varied with the treatments. The $CaCO_3$ treatment reduced Al saturation from 60% to practically zero in the 0-5 cm layer, and from 60% to 50% in the 5-10 cm layer, but Al saturation in deeper layers was unaffected. The $CaCl_2$ treatment reduced Al saturation by about 15% throughout the profile. The Ca fulvates reduced Al saturation as effectively as $CaCO_3$ in the top layer and much better than $CaCl_2$ in any soil layer, with sewage sludge or chicken manure-derived Ca fulvates being most effective.

(4) Soil pH (1:1 in water) was lowered by the $CaCl_2$ treatment by as much as 0.5 unit at the 35-50 cm depth. apparently, added Ca^{2+} displaced some exchangeable Al, which in turn hydrolyzed to yield H^+ and to lower the soil pH. By contrast, the $CaCO_3$ treatment raised soil pH from 4.3 to 5.9 in the 0-5 cm layer, but did not affect soil pH below this depth. The Ca fulvates, having initial pH of 7.0,

raised soil pH from 4.4 to ≥ 5.0 in the 0-10 cm layers (or 0-15 cm for Ca fulvate from sludge). Below this depth, soil pH was either similar to or lower than that of the water control. Although no clear explanation can be given at this time, it seems logical that Al fulvates resulted from reactions of exchangeable Al and Ca fulvates in the upper soil layers were responsible for the pH lowering effect at lower depths.

(5) Indeed, leachate Al was 10 to 25 times greater in the Ca fulvate treatments than in the control or $CaCl_2$ treatment. it was also noted that approximately 25% of the added Ca (or 62.5 mg Ca) from the Ca fulvates had moved through the soil column as measured in the leachates. By contrast, only 5% of the added Ca from the $CaCl_2$ treatment and virtually no added Ca from the $CaC0_3$ treatment were detected in their respective leachates.

In conclusion, surface application of organic material-derived Ca fulvates as an ameliorant for acid and Ca-deficient subsoils is very promising, providing some leaching is available.

5. SYNCHRONY BETWEEN SOIL NUTRIENT AVAILABILITY AND PLANT NUTRIENT UPTAKE

Project Number:

NCSU-07

Constraints Addressed:

Nutrient deficiencies and losses

Project Leader:

M. G. Wagger, North Carolina State University

Project Collaborators by Institution:

K. Glasener, NCSU
S. Funderburk, NCSU
C. Mackown, UKY
G. Romero, PDAR/Cochabamba
R. Delgadillo, IBTA/Chapare

GOAL AND OBJECTIVES:

The goal is to develop improved technologies for management of nutrient inputs to increase uptake efficiencies. Objectives are to determine the effects of organic additions having variable polyphenolic, lignin and N contents on N release

patterns, soil N dynamics and crop N budgets and to determine the effects of organic nutrient supplies having variable release patterns on crop uptake and yield.

PROGRESS REPORT

A preliminary site visit to the Chapare region of Bolivia in March 1993 enabled the delineation of the experimental area and collection of soil samples for baseline chemical characterization. In September 1993, Mr. Karl Glasener arrived in Bolivia to begin his dissertation research. Two field experiments were established shortly thereafter and collaborative efforts with IBTA Chapare counterparts are underway. The field research component will continue for approximately two years. Results from this research will provide information of N budgets in various cropping sequences that initially rely on tropical legumes for sustainable production.

ADDITIONAL FUNDING AND SUPPORT:

Support through cost sharing was provided by IBTA-Chapare by the provision of a vehicle for use by project personnel and the provision of field labor, field supplies and laboratory reagents. On campus investigations of laboratory procedures to quantify different polyphenolic and lignin fractions are relevant to project objectives but are not funded by the Soil Management CRSP. Isotope ratio analyses for ion determinations will be conducted with collaborators at the University of Kentucky.

6. MAIZE/LEGUME/RHIZOBIUM SYSTEMS: INTERSPECIFIC INTERACTIONS, NITROGEN FIXATION, AND YIELD RESPONSES ON ACID SOILS

Project Number:

UH-04

Constraints:

Inability to integrate basic process-level information for solving applied problems.

Project Leaders:

Robert Caldwell, University of Hawaii
Paul Singleton, University of Hawaii

Research Collaborators:

Basil Acock, ARS-USDA, U.S.A.
Abdul Ghani, Sukarami Agricultural Research Institute for Food Crops, Indonesia
Robert Grant, University of Alberta, Canada
C. Allan Jones, Texas Agricultural Experiment Station, Temple, Texas
James W. Jones, University of Florida
Susan Miyasaka, University of Hawaii
Tasman Naim, Sukarami Agricultural Research Institute for Food Crops, Indonesia
Agus Sofyan, Center for Soil Research, Indonesia
I P. G. Widjaja-Adhi, Center for Soil and Agroclimate Research, Indonesia

GOALS AND OBJECTIVES:

The goal is to increase the sustainability and resource-use efficiency of cereal/legume cropping systems, applying simulation-based decision support tools to improve system management. The objectives are (1) to quantify processes that are central to understanding and modeling cereal/legume/ rhizobium systems, especially interspecific interactions such as biological nitrogen fixation, resource competition, and root systems interactions, (2) to evaluate cereal/legume multiple cropping systems and (a) identify the levels of lime and fertilizer substitution to be expected by either rotating or intercropping, and (b) identify optimum cropping patterns (i.e. sequences to use for double or triple cropping), and (3) to compare contrasting agroecosystem models for their ability to simulate and screen multiple cropping systems on acid soils. Train researchers and implementers in the capabilities and requirements of the models.

PROGRESS REPORT

The project has concentrated during the last year on two activities: (1) obtaining data sets from scientists around the tropics to test the agroecosystem models, and (2) developing a user interface to the models so that the Soil Management CRSP can apply the models to agricultural development. Data set collection has been pursued through an informal network of scientists located throughout the tropics. To develop the user interface to the models, a half-time research associate was hired. The programmer has created a small suite of computer programs which, when combined with an agroecosystem model, allows novice computer users and non-modelers to experiment with simulated multiple cropping systems. The software creates an information system for teaching principles of soil management discovered through Soil Management CRSP research, especially from field work in Sitiung, Indonesia, and from the NifTAL project. Beyond training, the information system can also be used by field scientists to help design experiments (*i.e.*, assist in selecting rates of lime and nitrogen, plant spacings, and planting dates for a given soil/weather combination). This capability was developed in part because of discussions with Thai agronomists based on their experience of

problems designing intercrop treatments for experiments in Upland Rice Research Consortium (*i.e.*, they lost one year of data because of a poor choice in selecting a row spacing for a maize intercrop). Travel to Thailand, to work with agronomists in their Department of Agriculture and at Chiang Mai University, was sponsored by the Soil Management CRSP.

While data sets are not yet available to quantitatively test and compare the various agroecosystem models, an in-depth review of the models has been completed and is in press. The review high-lights the qualitative differences among the models--differences that determine much of their usefulness for solving agricultural problems.

Graduate students associated with Project UH-04 at the University of Hawaii completed another cycle of field experimentation in early 1993 (under funding from other sources). A preliminary assessment of their data reveals crop resources in intercrops that have not been documented in the past. The results should lead to improvements in all of the current models.

ADDITIONAL FUNDING AND SUPPORT:

Caldwell, R.M., S. El-Swaify, and G. Uehara. Sustainability of taro cropping systems in Hawaii and the American-affiliated Pacific. USDA Special Grant, Section 406, managed by the Pacific Basin Advisory Group ($93,023 for three years, 1990 to 1993; this grant is the principal source of funds being used to support field experimentation in Hawaii).

(Three graduate students working in conjunction with UH-04 receive their basic support from sources other than TropSoils.)

7. SOIL FERTILITY MANAGEMENT FOR SUSTAINABLE AGRICULTURE IN THE SEMIARID TROPICS

Project Number:

TAMU-03

Constraints Addressed:

Nutrient deficiencies and losses
Soil acidity

Project Leaders:

L. R. Hossner, Texas A&M University, College Station, TX
A. B. Onken, Texas A&M University, Lubbock, TX

Research Collaborators:

M. Doumbia, Texas A&M University, College Station, TX
K. Franzluebbers, Texas A&M University, College Station, TX
M. Gandah, DRE-INRAN, Niger
A. Bationo, (IFDC) ICRISAT Sahelian Center, Niger
Z. Kouyate, IER, Cinzana Research Station, Segou, Mali
A. Toure, IER, Mali
M. Traore, IER, Mali
A. Manu, Texas A&M University, Niamey, Niger
A. Juo, Texas A&M University, College Station, TX
D. Rosenow, Texas A&M University, Lubbock, TX
L. Rooney, Texas A&M University, College Station, TX
G. Peterson, Texas A&M University, College Station, TX
R. W. Weaver, Texas A&M University, College Station, TX
T. W. Boutton, Texas A&M University, College Station, TX
R. Caldwell, University of Hawaii
R. Yost, University of Hawaii

GOALS AND OBJECTIVES:

The overall goal of this project is to develop sustainable, low-input management strategies which improve and/or maintain soil fertility to permit an increase in yields and reduce year to year and within-farm variability. The specific objectives relating to the ongoing studies during this reporting period were to:

(1) To evaluate low-input soil management practices to overcome short distance spatial variability in crop development.

(2) To characterize biotic and abiotic processes affecting the transformation of organic matter in selected agroecosystems in the semiarid tropics.

(3) Provide soil management expertise in support of INTSORMIL plant breeding and agronomy research programs.

(4) Develop analytical procedures for determining chemical and physical properties of Sahelian soils and diagnostic techniques to use in predicting crop response and need for fertilizer or corrective amendments.

PROGRESS REPORT

Low-input soil management practices

A nutrient deficiency and toxicity study was initiated in 1990 to assess the growth of sorghum in response to differing soil amendments (manure, Tilemsi rock phosphate, Diamou lime, and a water soluble P source). Four field experiments

were conducted for two consecutive growing seasons to evaluate potential inputs to alleviate P deficiency and Al toxicity.

Large variabilities in stand establishment, crop growth and yield existed with most experimental units, between replications, and years of experimentation. All soil amendments increased plant concentration of P above the deficient level (2 g P kg^{-1}) only during the first growing season. Aluminum concentration in seedlings was below the toxic level (500 mg Al kg^{-1}) during the first growing season. However, sorghum seedlings contained as high as 1300 mg Al kg^{-1}) in the second growing season. Nitrogen, Ca, Mg, K, Fe, Mn, Zn, Cu, Si, B, Co, and Mo have also been determined in plant digests.

Soil data have shown significant improvements in soil pH, Bray-1 P, exchangeable Al and organic C resulting from amendments. Exchangeable bases and selected micronutrients have been determined in soil samples. In addition, P sorption characteristics of selected surface soils of the Cinzana toposequence were determined. Phosphorus requirements (P sorbed at 0.2 μg P mL^{-1}) of the different soil positions ranged from 5 to 135 mg P kg^{-1}. Phosphorus sorption in these surface soils was strongly correlated with clay content, Fe oxides, organic C, and Bray-1 P.

Biotic and abiotic processes affecting the transformation of organic matter.

In a field study conducted during the rainy season in 1991 at N'Dounga, Niger, addition of plant material to a sandy Alfisol cropped to millet was made in the form of millet and cowpea residues and as cowpea green manure. The field experiment was repeated during the rainy season in 1992. The objective of this study was to estimate rates of decomposition of added plant materials by measuring release of carbon as CO_2 and release of inorganic nitrogen.

Laboratory analyses of soil and plant samples from field and growth chamber experiments were completed. Results have been statistically analyzed and the first draft of the dissertation was completed. Two manuscripts have been submitted for publication and are currently undergoing review.

Soil Management/INTSORMIL Inter CRSP

The overall goal of this project is to provide soil management expertise in support of INTSORMIL plant breeding and agronomy programs in Mali. The present study consists of an interdisciplinary research project for screening sorghum genotypes under nutrient and water stressed soils in Mali. Specific objectives that are being addressed include (1) the development of analytical procedures for determining chemical and physical properties of Sahelian soils and diagnostic techniques to use in predicting crop response and need for fertilizers or corrective amendments and (2) the identification of sorghum genotypes with varying levels of tolerance to drought and chemical stress in Sahelian soils and the determination of how each trait is inherited.

A 46 paired plot grain sorghum screening nursery for soil toxicity was established jointly with INTSORMIL on the Cinzana Experiment Station at a previously selected site. Bagoba was used as the resident check and Malisor 84-5 was used as the susceptible check. This nursery was evaluated on October 14, 1993 by Drs. A. Toure, G. Peterson, and A. Onken. A Gadiaba selection from the Cinzana Station was rated higher than the resistant check. It was concluded that this technique of paired planting coupled with appropriate soil analyses will be useful in screening for tolerance to the soil toxicity problem. Soil samples have been taken and analyses will be performed when the samples are transported to Lubbock. The difference in response between sorghums in these semi-arid acid soils and humid acid soils will be evaluated.

Chemical and physical properties of Sahelian soils

Soils developed in two contrasting agroecological zones of West Africa were fertilized with commercial water soluble P fertilizers and native phosphate rock in both the ground and partially acidulated forms. Levels of labile P in these soils were evaluated using five different methods: Bray P-1, Bray P-2, Mehlich 1, Olsen method, and water. Further work to determine P sufficiency levels and P amounts from phosphate rock required for optimum yields is in progress.

ADDITIONAL FUNDING AND SUPPORT

This project is funded by TropSoils (50%) and INTSORMIL (50%) and implemented by IER personnel. In addition, INTSORMIL also purchased a computer and printer with software for use by project personnel in the execution of this project. Project personnel of IER indicate that it is difficult to estimate the monetary value and human resource commitments provided by IER. However, the support provided by IER is substantial and includes staff salaries, office and work facilities, animal traction, laboratory services, obligations of equipment and some vehicle maintenance.

8. Soil and Water Management and Conservation for Sustainable Agriculture in the Semiarid Tropics

Project Number:

TAMU-02

Constraints Addressed:

Water stress
Nutrient deficiencies and losses
Soil physical limitations
Topographic limitations

Project Leaders:

A.S.R. Juo, Texas A&M University, College Station, TX
C.W. Wendt, Texas A&M University, Lubbock, TX

Project Collaborators by Institutions:

C. Zaongo, Texas A&M University, College Station, TX
A. Sow, Texas A&M University, College Station, TX
R. Schwartz, Texas A&M University, College Station, TX
Z. Kouyate, IER, Cinzana Research Station, Segou, Mali
S. Traore, IER, Cinzana Research Station, Segou, Mali
M. Ouattara, INRAN, Niamey, Niger
M. Gandah, INRAN, Niamey, Niger
W. Payne, ICRISAT, Sahelian Center, Niger
C. R. K. Prashar, PRAAN, Maradi, Niger
R. J. Lascano, Texas A&M University, Lubbock, TX
B. A. Stewart, USDA/ARS, Bushland, TX
L. R. Hossner, Texas A&M University, College Station, TX
P. W. Unger, USDA/ARS, Bushland, TX
D. W. Fryrear, USDA/ARS, Big Spring, TX
B. L. Harris, Texas A&M University, College Station, TX
J. T. Bilbro, USDA/ARS, Big Spring, TX

GOAL AND OBJECTIVES:

The overall goal of this project is to conduct research pertaining to the development of soil and water management practices for sustainable food, fodder, and fiber production under semi-arid conditions. The specific objectives relating to the ongoing studies during this reporting period were to:

(1) Assess the water use efficiency of crops as influenced by applied plant nutrients and soil amendments under semiarid conditions.

(2) Assess the interactive effects of water and nutrients on crop growth and integrate them into a model capable of simulating the hydrodynamics and crop performance under different Sahelian conditions.

(3) Assess the long-term effects of crop residue, green manure and tillage on crop yields and determine the influence of organic inputs on soil chemical and physical properties.

(4) Evaluate the use of physical models for simulating the water balance under rainfed conditions in the Sahel.

PROGRESS REPORT

Sorghum production under reduced tillage in a semiarid environment

In many areas of the semiarid zone, there is not enough precipitation during the growing season to meet a crop's water demand. Efficient water use is absolutely essential for dryland production. The effects of furrow diking and residue management on runoff, water extraction, rooting depth, growth and yield of sorghum [*Sorghum bicolor* (L.) *Moench*] were evaluated on gently sloping land at Bushland, TX. The final data for this study were collected during the summer of 1992.

The principal objectives of this study were to (1) study the effects of tillage and residue on rooting depth, growth and yields of grain sorghum (2) compare the effects of tillage and residue on water extraction, runoff and water use efficiency of sorghum (3) determine tillage and residue effects on soil nitrate and (4) evaluate the potential of GIS to assist in all stages of modeling storm water runoff.

Field and laboratory work was completed at the research site. Storm water runoff, water extraction and water use efficiency were quantified. Soil samples were collected at flowering and harvest for soil nitrate analysis.

Diking and no-tillage with residue treatments reduced runoff as compared to conventional tillage practices and no-tillage without residue. Increased water availability in the no-tillage with residue treatment increased sorghum yields about 320 kg ha^{-1}. Additional plant-available water at planting time was found to be effective in the early deep rooting of sorghum. Diking resulted in higher harvest indexes since plants on the diked treatment had more available water during panicle development stage of plant growth.

At flowering as well as at harvest, there was much greater leaching of nitrate beyond the root zone. Diking and conventional tillage had higher nitrate levels than no tillage treatments. The higher amount of nitrate in ploughed soils can be explained by the large number of soil properties changed by tillage. The low levels of nitrate in no tillage plots were probably due to higher rates of denitrification.

Interactive effects of water and nutrients on crop growth.

Field and laboratory experiments were undertaken to characterize the water plant-soil-atmosphere relationships of a site at Maradi, Niger in 1991. During this reporting period, Mr. Zaongo (graduate student) analyzed the data and prepared the Ph.D. manuscript.

The objectives of this study were to use supplemental irrigation, fertilizer applications and mulch to manipulate the system energy and soil water balance in order to improve crop water use efficiency and to integrate the soil-plant-

atmosphere continuum water relationships into a model capable of predicting evapotranspiration.

Soil evaporation accounted for a major part (40-50%) of the total water losses. In addition, the water supplied by irrigation was equivalent to seasonal water loss by evaporation. During the growing season, mulch caused a significant (33%) reduction in evaporation thereby increasing the available moisture supply for crop use.

Results from this study also suggest that soil water balance can be manipulated with nitrogen applications. Nitrogen was found to significantly improve the water use efficiency with respect to evapotranspiration.

Long-term effects of crop residue, green manure and tillage.

A study was initiated in 1990 on sandy loam and loam soils at the Agronomy Research Station at Cinzana, Mali. The objective of this study is to determine the combined effect of different cereal/legume rotations, tillage and crop residue management on soil physical and chemical properties and crop yield. Treatments implemented on each soil were: (1) continuous sorghum - residue removed; (2) continuous sorghum - residue incorporated; (3) cowpea-sorghum rotation - residue removed; (4) sesbania-sorghum rotation - residue incorporated; and (5) dolichos-sorghum rotation - residue incorporated. These treatments were superimposed on areas with and without tied ridges.

For the 1992 season of this study, both grain and dry matter yields obtained for the sandy loam soil were significantly higher in sorghum/legume rotations than in continuous sorghum treatments. Tillage treatments alone did not significantly affect yields. In general, the dry matter yields were higher in the tied ridge treatments than treatments with ridging alone.

The cause of positive yield effects of rotations is not known. Since the yields from the cowpea/sorghum rotation with residue removed are equal to those of the sesbania/sorghum and dolichos/sorghum, residue effects in this case (for this soil) may not be of importance. It is possible that there is an allelopathy effect from continuous sorghum cropping schemes that is minimized when rotations are used.

The only yield parameter affected by treatment on the loam soil was dry matter. The dry matter production was significantly lower on the continuous sorghum treatment where the residue was incorporated than the other treatments.

Although this study is not completed, the future impacts are obvious. Yields from the rotations are over 100% greater than those of continuous sorghum. If a cowpea/sorghum rotation is used, farmers can realize a cowpea crop (grain and hay) and also receive an equal yield of sorghum that can be received with continuous sorghum. Presently we are considering the extension of preliminary results to producers farms before the multi-year study is completed.

Simulation of water balance under rainfed conditions in the Sahel

During the summer of 1992, an experiment of soil moisture balance was initiated at the Hamdallaye IMAW site in Niger. The objective of this study was to evaluate the ENWATBAL model for simulating the water balance under rainfed conditions in the Sahel. Eight plots of 100 m^2 each and instrumented with neutron probe access tubes to a depth of 270 cm were planted to millet. Four of the plots were fertilized as recommended by INRAN and the other four plots were not fertilized. Soil moisture was measured weekly by gravimetric sampling and probe readings. Daily weather data was also recorded.

Plant data, soil moisture from neutron probe readings, evapotranspiration and bare soil evaporation after harvesting were analyzed. With a rainfall of about 592 mm from planting to harvest, no statistically different yield (grain and total dry matter) was observed on fertilized and unfertilized plots. Evapotranspiration of the crop was high for the millet in the two treatments (490-570 mm), but drainage has not been accounted for. A more detailed analysis will be performed using a maximum rooting depth of 150 cm. Bare soil evaporation plus drainage after harvest for a period of 60 days has given 45-56 mm in the plots (measured to a depth of 270 cm). There was no difference in the evaporation and drainage of the residual soil moisture between the fertilized and unfertilized plots.

Data obtained from the 1992 data are currently being analyzed. The same study conducted in 1992 could not be repeated in 1993.

ADDITIONAL FUNDING AND SUPPORT:

Project personnel of IER indicate that it is difficult to estimate the monetary value and human resource commitments provided by IER. However, the support provided by IER in connection with objective 3 is substantial and includes staff salaries, office and work facilities, animal traction, laboratory services, obligations of equipment, and some vehicle maintenance.

9. GENETIC TECHNOLOGIES FOR IMPROVEMENT OF THE *RHIZOBIUM*-LEGUME SYMBIOSIS

Project Number:

NifTAL Program 1

Constraint Addressed:

Inadequate quality and quantity of rhizobia to maximize BNF processes

Project Leader:

D. Borthakur, University of Hawaii

Project Collaborators:

United National Microbial Resources Centers (MIRCEN) Network
University of Hawaii, Department of Microbiology

GOALS AND OBJECTIVES:

The ultimate goal of this program is to product rhizobia with enhanced performance in inoculants, soil, on the seed, or in symbiosis with legumes. The approach is to maximize the genetic potential of the symbiotic system by using modern and conventional biotechnological tools. Program objectives are to: (1) exploit the genetic diversity of the microsymbiont to identify highly successful plant-microbe partnerships, (2) maintain a rhizobial germplasm resource as a United Nations Microbial Resource Center (MIRCEN) for researchers and industry, and (3) identify genetic characteristics relevant to agriculture and industry and describe the molecular basis of these genetic characters. This objective is funded largely by external funds.

PROGRESS REPORT

Program activities included the maintenance, preservation, and distribution of rhizobial germplasm, collection and evaluation of new strains, and genetic analysis of selected strains. Highlights include:

NifTAL germplasm and inoculants were distributed to 43 countries.

The NifTAL Microbial Resource Center (MIRCEN) maintains one of the largest and most active collection s of tropical rhizobial germplasm. This collection continues to be an important resource for producers and scientists who request rhizobial cultures or research-quality inoculants. The program provided 711 cultures and 763 inoculant units in response to 64 and 94 requests, respectively. In addition to the collection of about 2,000 rhizobial strains MIRCEN has a repository of valuable and unique germplasm for the preservation of microbial diversity. The program produced and distributed a catalogue of selected strains, and updated ACCLAIM, computer software that accesses the Niftal MIRCEN germplasm database.

Genes for nodulation competitiveness in Rhizobium etlii were identified

Competition between indigenous rhizobia and superior inoculant strains can hinder benefits from inoculation. This project focuses on the feasibility of overcoming competition through genetic manipulation. We identified a region of DNA that contains genes involved in nodulation competitiveness, and isolated mutants defective in nodulation competitiveness. Problems complementing these mutants

were overcome. A restriction map of the 25 kb region was developed, and cosmid fragments containing the competition genes were subcloned.

Genes for mimosine catabolism by Rhizobium sp. (Leucaena leucocephalia) were identified.

Mimosine is a toxic amino acid present in leucaena. We discovered that among the rhizobia and bradyrhizobia, only a few *Rhizobium* strains that nodulate leucaena can catabolize mimosine and use it as a sole source of nitrogen. This ability may contribute to rhizosphere competitiveness. We isolated mutants that fail to degrade mimosine, but not pyridone, a toxic degradation product of mimosine. These results indicate that at least two genes are required for complete degradation of mimosine.

Genetic control of exopolysaccharide (EPS) production in leucaena Rhizobium

EPS plays an important but poorly understood role in nodule development. Mutants defective in EPS synthesis and nodulation were isolated. One mutant was studied in detail and the position of the mutation mapped. A restriction map of a 25 kb region of the chromosome containing genes for EPS synthesis was developed.

ADDITIONAL FUNDING AND SUPPORT:

Grants, contracts, and grants

McIntire-Stennis grant. "Quantifying, characterizing, and maximizing BNF by fast-growing nitrogen fixing trees." $28,700, October 1992 to September 1993, $163,200 since October 1987. P. Somasegaran, PI.

USDA National Research Initiative Competitive Grant. "Genetics of nodulation competitiveness in *Rhizobium leguminosarum* bv. *phaseoli*." $120,000, September 1992 - September 1994, D. Borthakur, PI.

University of Hawaii Office of Research Administration seed grant "Genetics of mimosine resistance in *Rhizobium* strain TAL 1145." $10,000, August 1992 - June 1993, D. Borthakur, PI.

Support through cost-sharing and leverage

The University of Hawaii's Biotechnology Program provides salary, facilities and institutional support for Molecular Biologist, D. Borthakur.

The Organization for Economic Cooperation and Development (OECD) supported the training of J. Hacin (Slovenia).

10. METHODOLOGIES FOR MONITORING MICROORGANISMS IN INOCULANTS AND ENVIRONMENTS

Project Number:

NifTAL Program 2

Constraint Addressed:

Inadequate inoculant quality control
Poor ability to monitor rhizobial populations in soils

Project Leader:

P. Somasegaran

Project Collaborators:

University of Minnesota

GOAL AND OBJECTIVES:

Successful adoption of BNF technologies in developing countries is contingent on the maintenance of inoculant quality and the ability to assess the performance of introduced nitrogen-fixing microorganisms in the environment. The goal of this program is to develop and promote microbial monitoring methods that will lead to improved inoculant quality and the efficient use of microbial inoculants.

Program objectives are to: (1) improve methods for monitoring the fate and performance of microorganisms introduced to the environment as inoculants, or for evaluating native microbial resources and (2) develop simple, economical methods for monitoring the quality of rhizobial inoculants during production, distribution, storage, and use. These methods benefit the inoculant industry and agencies enforcing quality standards.

PROGRESS REPORT

NifTAL has had a history of developing low-cost, reliable procedures for identifying and enumerating rhizobia. In this reporting period the Program made major progress toward overcoming constraints to enumerating rhizobia for inoculant quality control.

A selective medium for soybean rhizobia was developed.

Conventional methods of enumerating rhizobia by plating on nutrient media are not practical for soils or batch-inoculants where other microorganisms are present. Through collaboration with the University of Minnesota, a selective

medium (BJSM) for *Bradyrhizobium japonicum* and *B. elkanii*, symbionts for soybean, was developed. BJSM is a novel product that includes the metal ions Zn^{+2} and Co^{+2}, which allow for the selective recovery of soybean rhizobia from non-sterile peat inoculants and soil. The research is being published and the product will be field tested through international collaborators in 1994. This product can greatly reduce the costs of quality control procedures for inoculant producers and simplify estimates of soil rhizobial resources.

Economical enumeration methods using plant-infection tests were identified.

Enumeration of rhizobia in non-sterile matrices generally requires indirect estimates by Most-Probable-Number (MPN) plant-infection procedures. We studies the growth and nodulation of selected, small-seeded bean, chickpea, and soybean varieties in compact, highly-controlled cultures. A modified, economical enclosed tube-culture system provided accurate MPN counts for bean. Chickpea did not nodulate normally in the tube system. Modifications to the culture system and their effects on enumeration accuracy are being tested.

Development of a simple kit for the identification of inoculant strains of rhizobia for use in developing countries is in progress.

The kit will contain ingredients to perform serological tests based on the enzyme linked immunosorbant assay (ELISA). The kit can monitor inoculant quality for one productive season, and does not require expensive equipment or supplies. Selection of chromophores for high temperature tolerance is underway. The kit will be field tested by a network of inoculant producers in developing countries.

ADDITIONAL FUNDING AND SUPPORT:

The University of Minnesota contributes the salary of M. Sadowsky, thesis advisor for NifTAL-sponsored graduate student Z. Tong, and provides institutional and facilities support for the research on selective medium for rhizobia.

11. ENVIRONMENTAL AND MANAGEMENT DATA COLLECTION TO MAXIMIZE THE PERFORMANCE OF BIOLOGICAL NITROGEN FIXATION

Project Number:

NifTAL Program 3

Constraints Addressed:

Low legume yields and BNF
Poor conservation of BNF products

Project Leader:

B. Linquist

Collaborating Institutions:

International Rice Research Institute (IRRI)
International Institute for Tropical Agriculture (IITA)
International Fertilizer Development Council (IFDC)
Philippine Council for Agriculture Resources Research and Development (PCARRD)
Mariana Marcos State University (MMSU), Philippines
Tarlac College of Agriculture (TCA), Philippines
Thai Department of Agriculture (DOA)
Khonkaen University
University of Hawaii
University of California, Davis

Goal and Objectives:

The ultimate goal of this program is to identify comprehensive, sustainable land management strategies that meet the demands for enhanced soil productivity and the conservation of natural resources. The contributions of biological nitrogen fixation by legumes to sustainable agro-ecosystems are integral to this goal. This program emphasizes the environmental and management impacts on symbiotic performance or the fate of symbiotic products.

The objectives of this program are to: (1) identify microbial, environmental, and management constraints to legume productivity and subsequent fixed nitrogen inputs into cropping systems, (2) evaluate and develop management strategies for legumes to overcome identified performance constraints, and (3) synthesize information from research activities to assist crop model and decision support systems development for legume management.

PROGRESS REPORT

Through collaborative linkages, NifTAL Program 3 continues to be highly integrated with efforts of crop modelers, international agricultural centers, and researchers in U.S. and foreign universities. Highlights include:

NifTAL-IRRI collaboration for managing tropical uplands initiated.

For several years, NifTAL has posted a scientist at IRRI. Collaborative work on the conservation and use of soil and fixed-nitrogen for lowland rice-based cropping systems was completed, resulting in recommendations for the management of fallows. A new program to develop long-term P management strategies and identify effects on the carbon and nitrogen cycles for the acid

uplands of Southeast Asia was initiated, and data are being collected at various IRRI upland sites.

NifTAL and IITA collaborate on Grain Legume Improvement Program.

NifTAL scientist posted at IITA continued evaluation of nitrogen-fixing potential of legumes selected for Africa, specifically soybean varieties selected for their "promiscuous" nodulation with indigenous rhizobia. Although these varieties are selected for "free-nodulating" traits, trials at eight locations in four agroecological zones of Nigeria showed that inoculation caused yield responses of 100 to 500 kg per ha in 14 of 32 genotype-location combinations. A second year of farmer field trials was completed in southern Nigeria. These efforts will show the frequency and magnitude of response to inoculation of promiscuous soybeans. The persistence of introduced rhizobia is being monitored at three sites.

Farmers increase income with recommendations from rice-legume research in Philippines.

The final crop season of this four year collaborative experiment (NifTAL, PCCARD, MMSU, TCA) was completed this year in Tarlac and Ilocos Norte. Data was consistent with pervious years' results indicating that in certain agroecosystems, rice yields can be maintained by using early mature rice varieties which conserve soil moisture for a following legume crop. Following field demonstrations, up to 80% of the farmers in some areas have adopted this technology, which requires no increase in farmer spending, but has raised farmer income.

Models of rhizobial use in tropical cropping systems in progress.

Data from 96 farms across four different Thai ecosystems has been compiled. A consultant has been hired to develop models which predict rhizobial population dynamics based on climate, soil, and management factors. NifTAL and Thai collaborators are also using this study to test NifTAL's selective media.

Inoculants provide yield increases in Togo.

NifTAL collaborated with IFDC-Togo on field trials to compare benefits of inoculation with the application of starter-nitrogen fertilizer on cowpea and groundnut. A trial at Koukombo indicated that the use of inoculant, a less expensive input, can replace starter N on groundnut. At Davie, inoculation and starter N treatments both increased crop yields on cowpea. In both trials, benefits of BNF were restricted by low yield potentials of the crops.

Database for crop models improved.

Field experiments continued to develop a data base for early season soybean, peanut, and common bean growth in relation to BNF and N availability. NifTAL

and IFDC are collaborating to incorporate data from these experiments into their models. These data significantly improve the precision of growth models.

Identification of selection criteria for agroforestry species in acid, infertile soils in progress.

Tolerance by nitrogen fixing tress (NFTs) to soil stresses is critical to their growth and contribution of nitrogen to agroforestry system. A greenhouse study was completed that showed species differences among NFTs in their tolerances to low P conditions may be due to differences in mycorrhizal infection of differential partitioning of dry matter. A long-term field study was initiated to identify strategies for enhanced performance and nitrogen fixation in infertile soils.

Strategies for managing phosphorus nutrition for legume productivity in infertile tropical soils identified.

Long-term field experiments were completed, and findings show that on certain high P-fixing soils, it may not be economically beneficial to apply large quantities of P to quench the fixation capacity of the soils as has often been proposed. Results indicate that large quantities of P can be fixed into unavailable forms, and optimal yields can be attained with relatively small applications. NifTAL, UC Davis, and IRRI staff are working with TropSoils-PDSS (University of Hawaii) to discover the mechanisms regulating P availability in these soils, which are common in Asia.

ADDITIONAL FUNDING AND SUPPORT:

Grants, contracts, and gifts

USDA/USAID Limiting Factors grant. "Optimization of rice-based systems in Negros Occidental," $73,000, May 1991 to April 1993, P. Singleton, PI.

World Bank McNamara Fellowship. "Improving nitrogen and phosphorus cycling through legumes in degraded upland agro-ecosystems," $30,000, awarded to T. George.

SEARCA grant. "Studies on utilization of *Sesbania rostrata* as biofertilizer for corn and upland rice, September 1992 to September 1997, P. Singleton, PI.

Support through cost-sharing and leverage

University of Hawaii provides salary for P. Singleton.

IITA provides institutional and research support for NifTAL researcher R. Abaidoo stationed at IITA. He is investigating the rhizobial affinities of promiscuously nodulating soybeans developed by GLIP.

IRRI provides institutional support for NifTAL researcher T. George stationed at IRRI, and for the program on the conservation and use of soil and fixed N in lowland rice-based cropping systems.

IFDC/Togo supports research in Togo on response of legumes to inoculation.

Research on ecological models to predict the response to legume inoculation in cropping systems in Thailand is supported by grants from (1) the Science and Technology Development Board (STDB, Thailand, "Developing and adapting *Rhizobium* technology for legume cultivation in NE Thailand in support of E-SARN KHEOW Project" awarded to Khon Kaen University and Department of Agriculture [DOA], Thailand); and (2) Program in Science and Technology Cooperative (PSTC, USAID, "Ecologically based models to predict legume inoculation requirement," awarded to Thai DOA and the BNF Resource Center, Thailand).

The Nitrogen Fixing Tree Association supported travel and expenses for P. Nakao to attend the International Conference on Erythrinas in the Old and New Worlds in Turrilba, Costa Rica.

12. PATHWAYS OF NUTRIENT FLOW IN RELATION TO PLANT UTILIZATION OF NITROGEN AND PHOSPHORUS

Project Number:

CU-02

Constraints Addressed:

Nutrient deficiencies and losses
Land-clearing pressure
Production-demand pressure

Project Leader:

John M. Duxbury, Cornell University

Research Collaborators:

Jean Fruci, Cornell University
Ken Schlather, Cornell University
Alfredo Alvarado, University of Costa Rica
Jorge Briceno, University of Costa Rica
Elemer Bornamisza, University of Costa Rica
Martha Rosemeyer, Organization of Tropical Soils

GOAL AND OBJECTIVES

The long-term goal of this project is to provide information on nutrient management that will enable farmers to derive maximum benefit from their production systems, while maintaining the long-term productivity. Specific objectives are to (1) develop a better understanding of N transformations in soil-plant systems so that sound recommendations can be made to farmers regarding management of both endogenous and applied N, and (2) explore the potential benefits of slash/mulch systems of crop production and develop methodologies for P management in mulch and organic surface layers of such systems to avoid P fixation in underlying mineral horizons.

PROGRESS REPORT

Analytical work and data analyses in the nitrogen project being carried out by Jean Fruci were completed during this period. Experiments with ^{15}N tracers in pasture and wheat fields showed that microbes compete effectively with plants for both NH_4^+ and NO_3^- sources of N in the short-term, but that much of the N is recycled into plants in the longer-term. Fruci will complete her Ph.D. thesis in January 1994.

The first year of experiments comparing the traditional slash mulch (frijol tapado) system of bean production with clean culture (frijol espequeado) in an Andisol and an Ultisol in Costa Rica were completed. Yields were higher in the tapado system compared to espequeado across all fertilizer levels and there was a significant increase in yield due to fertilizer P. *In situ* analysis of P availability using an anion exchange resin membrane (membrane-P) showed greater availability of P in the tapado system, and post season soil-test analyses of litter and soil P by the same technique found that membrane-P was highly correlated with the previous crop yields.

Significant effects of mulch species were found on emergence and establishment of beans in the tapado system but no effects were observed on bean yields due to better growth of plants at low populations. Mulch species from the same field were found to contain different P contents and exhibit different P release patterns in a pot decomposition study.

A second set of experiments was begun in the fall. These include (i) a repeat of the first year field experiment but including a single versus triple split application of P, (ii) a fertilizer movement and availability study in 40 x 90 cm boxes containing well-mixed, high-P fixing soil (both the Andisol and Ultisol) to better characterize the role of the mulch and litter layers, and (iii) a residual P availability experiment in a 3-year-old experiment where P rate was varied.

ADDITIONAL FUNDING AND SUPPORT

A NSF Research Training Grant to Ken Schlather, in the amount of $25,085.00, made his participation possible.

13. UTILIZATION OF GREEN MANURES IN CROPPING SYSTEMS

Project Number:

CU-03

Constraints Addressed:

Zn and P in Cameroon
Leaching and recycling of nutrients in Costa Rica

Research Leader:

D.R. Bouldin, Cornell University

Research Collaborators:

Titus Ngoumou, Cameroon
Raphael Salas, University of Costa Rica

GOAL AND OBJECTIVES

The long term goal is to develop useful cropping systems which utilize legume green manures to supply N, reduce erosion, enhance organic matter content, suppress nematodes (where they are troublesome), and perhaps recycle nutrients leached from the surface layers of soil. The specific objective of the work in Cameroon is to reduce the yield limitations of Zn and P on growth of legume green manures and maize. The specific objective of the work in Costa Rica is to study water and nutrient uptake by maize and legume green manures from the lower horizons of the soil. This is a continuation of the work begun by Dr. Cahn in Manaus, Brazil.

PROGRESS REPORT

During the summer of 1993 Mr. Ngoumou set out 14 experiments in Cameroon. Each experiment contained 12 treatments and 4 replications so that interactions between Zn and P could be measured. Soil and plant samples were taken and are in Ithaca being analyzed. The final yield data are now in Ithaca but we have not analyzed them.

A field experiment with maize in Costa Rica was completed this past summer. We monitored water use under the crop using TDR equipment. The experiment is now planted to a legume green manure with the objective of measuring differential water utilization in the subsoils which vary in acidity and measuring nutrient recycling.

Soil samples from these experiments are now being analyzed in Ithaca. We are also measuring sorbed nitrate, chloride and sulfate by desorption with phosphate. All three ions are sorbed to some degree. This is an important property of soils since it retards leaching and it has important implications for interpretation of nitrogen and sulfur cycling in highly weathered tropical soils.

ADDITIONAL FUNDING AND SUPPORT

Most of the costs of the field experiments was provided by the Cameroon and Costa Rican cooperators. Without this support the projects would have been impossible.

14. LIGHT, WATER AND NUTRIENT DYNAMICS IN AGROFORESTRY SYSTEMS

Project Number:

CU-01

Constraints Addressed:

Production-demand pressures
Climatic variability
Water stress
Nutrient losses

Research Leader:

Susan J. Riha, Cornell University

Research Collaborators:

Beverly McIntyre, CU
Chin Ong, ICRAF, Nairobi, Kenya

GOAL AND OBJECTIVES

Although total world grain production has increased at a rate of approximately 3% per year for the last three decades and average yield per unit land area has doubled (USDA, 1985), there is heightened concern that the techniques used to achieve these increases can not be applied to many parts of the developing world. This is because much of the natural resource base available to poorer farmers has severe agronomic limitations and because few of the external resources that are necessary to increase productivity are available to them (Kidd and Pimentel 1992). This has logically led to the desire to identify, understand and develop agricultural systems that can achieve a modest, sustained level of productivity given limited natural and man-made resources. The urgency of this

quest has increased because in many areas of the developing world, the most widespread traditional "low-input" agriculture system, forest fallowing, is breaking down due to population and other pressures and is leading to accelerated degradation of the natural resource base.

Within this context, agricultural systems can be considered in terms of their ability to utilize both spatially and temporally as fully and efficiently as possible light, water and nutrients. Enhanced utilization of these critical resources might be achieved through the use of intercropping systems. Agroforestry systems are of particular interest where specific tree products are desired by farmers. But from a systems context, they may also be of interest where greater exploitation of the vertical dimension of space (both above and below ground) is feasible and where the short and/or long term dynamics of their growth may impart certain advantages for the growth of crops and the maintenance of the resource base (Cannell 1991).

The manner in which trees may be used to more fully utilize and protect the resource base will differ depending on the agroecological zone of interest. In the humid tropics, the more complete and efficient use of the vertical dimension of space (including multiple storied canopies and deep-rooted species) is considered of interest (Cannell 1991). In the semi-arid tropics, the use of agroforestry systems to extend the time over which plant canopies can capture radiation, utilize soil water and provide protection of the soil surface has been considered, as well as modifications by trees of the agronomic crop microclimate. Although it is often assumed that agroforestry systems will be productive due to enhanced interception of light in multiple-storied canopies and due to the ability of deep-rooted trees to intercept water and nutrients, these is little evidence to date to support these assumptions (Squire 1990, Ong 1991). Additionally, the response of understory crops in agroforestry systems needs to be considered in terms of quantifiable alterations in microclimate and soil environments, rather than only to a qualitative association with a particular tree crop. Without such research, it would be difficult to evaluate the long term potential of agroforestry systems and to extrapolate research results from one location to another. The objective of this project, therefore is to continue both to the immediate development of small farmer cropping systems and to building a quantitative understanding of the light, water and nutrient dynamics in agroforestry systems.

References:

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Kidd, C. V. and D. Pimentel. 1992. Integrated Resource Management: Agroforestry for Development. San Diego, CA: Academic Press. 223 pp.

Ong, C. K. 1991. Interactions of light, water, and nutrients in agroforestry systems. *In* Avery, M. E., M. G. R. Cannell and C. K. Ong, eds. Biophysical Research for Asian Agroforestry. USA: Winrock International, pp. 107-124.

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PROGRESS REPORT

Collaborative research on resource use in agroforestry systems is being conducted at ICRAF's station in Machakos, Kenya. We want to determine if, and under what conditions, agroforestry systems can enhance biomass production and yield (per unit land area) of the agronomic crop and utilize this knowledge in the development of tools to aid in the planning and evaluation of agroforestry systems. Previous intercropping experiments suggest that reduction in radiation may enhance the ability of C3 crops, such as legumes, to convert radiation to biomass. Thus lower radiation levels may actually increase crop productivity. However, experiments in agroforestry systems using the tree *Leucaena leucocephala* indicate that any enhancement in crop growth due to altered light environments is likely to be severely offset by strong below ground competition for resources by tree roots. Will other tree species compete with agronomic crops as effectively as *L. leucocephala*? Will this competition be particularly severe on shallow soils? The experiments we are currently conducting are designed to address these questions. The tree *Cassia spectabilis* is being grown with cowpea and maize in rotation in both shallow and deep soil. Early results indicate that cowpea biomass (per unit land area) is enhanced in the agroforestry system. We are now investigating whether this biomass increase will be maintained as the tress become older and possibly more effective competitors. Specifically, we are measuring biomass production in relation to radiation intercepted by cowpeas to determine if increased productivity is actually the result of improvement in the conversion of radiation to biomass. In addition, we are measuring soil water use in these systems to ascertain whether competitive or complimentary use of this important resource is occurring. These experiments should provide very useful direct information and also provide a basis for the development of tools to aid in the design and assessment of agroforestry systems.

ADDITIONAL FUNDING AND SUPPORT

This project is being conducted in collaboration with ICRAF and Cornell University. ICRAF is providing support for Dr. Chin Ong, and is contributing experimental space, equipment and supplies, office space for the Cornell research associate and technical support. Cornell is providing support for Dr. Susan Riha and is providing equipment. The Soil Management CRSP is supporting the Cornell post doctoral associate, providing equipment, and paying for travel.

C. OUTREACH

1. CRSP COMMUNICATION SERVICES

Project Number: Com-1

Constraints Addressed:

Number and diversity of users
Number and diversity of soils
Lack of local expertise
Information-knowledge gap
Lack of skills and research capability

Project Leader:

Tim McBride

GOALS AND OBJECTIVES

The Management Entity has set forth two broad goals for the Soil Management CRSP's program-wide communications effort: (1) to help focus diverse information gleaned from individual projects and bring it to bear on the practical solution of soil-management problems of global significance; (2) to convey the program's objectives and accomplishments to a non-technical audience of public officials and policy-makers.

To fulfill these goals, three objectives have been outlined:

Objective 1. To apply the best available soil management information to the solution of problems of global and regional import; toward this objective Com-1 is to plan and produce a special-topics publication series and a series of single-topic technical bulletins. Com-1 is also to maintain mailing lists for the circulation of these materials.

Objective 2. To convey the program's achievement's to public officials, university administrators, and other decision-makers; toward this objective Com-1 is to prepare regular news briefs and respond to requests for publications and information.

Objective 3. To assist and improve internal communication; toward this objective, Com-1 is to help plan and conduct technical workshops and to provide communications materials as requested by the Management Entity Director.

PROGRESS REPORT

Objective 1.

In 1992, the Management Entity agreed to produce the second entry in a special-topics series. In early 1993, a partial draft of *Groundworks 2, Managing Soil Phosphorus* was reviewed by a number of scientists working on the PDSS system. As of September 1993, *Groundworks 2* is on hold, pending refinements in the PDSS system.

500 copies of a the technical bulletin *Soil Structure Effects on Hydrologic Processes and Crop Water Availability in Ultisols and Oxisols of Sitiung, Indonesia* were published in October of 1992.

1000 copies of the technical bulletin *Legume Green Manures: Dry-Season Survival and the Effect on Succeeding Maize Crops* were published in January of 1993.

As of September 1993, *Land Clearing and Reclamation of Ultisols and Oxisols* was entering the final stages of editing and layout.

Availability of all new CRSP publications were announced in the bimonthly *Newswire.* Com-1 responded to several hundred requests for these publications.

Objective 2.

In January of 1993, two Impact Sheets were prepared for the Management Entity Director's visit to Washington: *Soil Restoration and Sustainability in the Sahel* and *Sustainable Savannas: A New Role for Legume Green Manures.*

In February 1993, Com-1 published an article in USAID's *Front Lines*, "Hillside Erosion: A Threat to the Philippines."

A bimonthly *Newswire* was initiated in 1992. Mailing lists are updated with each issue. Based on recommendations of the Management Entity Director, Com-1 established an initial list of 420 readers. That number has now grown to over 1,000 readers.

In April of 1993, Com-1 edited, redesigned, and printed the CRSP Council Publication *Global Research for Sustainable Development.*

In May of 1993, Com-1 published an article in USAID's *Front Lines,* "Niger Field Day Tests Soil, Crop Treatments."

At the request of USAID Program Coordinator, Com-1 began sending weekly "sil.er bullets" to Washington; these consist of brief summaries of CRSP activities and impacts. A compendium of these summaries are on file in the ME Director's office.

As of September 1993, the text for a 12-year summary of program achievements was nearing completion. The tentative title for the document was *Looking to the Earth: A Foundation for Sustainable Development.*

Objective 3.

The Management Entity Director (Dr. Roger Hanson) and the Interim Planning Coordinator (Dr. Charles McCants) have been provided with slides and overheads as requested for a variety of public appearances.

Com-1 worked extensively with the ME and NCSU's McKimmon Center in preparation for the January 1993 Global Planning Workshop. Activities ranged from preparing the preliminary workshop documents, to obtaining computer setups for software displays, to designing caps for workshop participants.

A 117-page *Workshop Record* was compiled, edited, designed, printed, and circulated in March of 1993.

Com-1 helped to write, edit, and design numerous preliminary drafts of the *1994-1999 Proposal for Extension,* due for submission in December of 1993.

2. TECHNICAL SUPPORT FOR RESEARCH NETWORKS IN THE HUMID TROPICS

Project Number:

NCSU-05

Constraints Addressed:

Number and diversity of soils and users
Information knowledge gaps
Lack of skills and research capabilities

Research Leader:

T. J. Smyth, North Carolina State University

Research Collaborators:

S. W. Buol, NCSU
F. R. Cox, NCSU
R. S. Yost, UH
E. Fernandes, NCSU
W. R. Raun, Oklahoma State Univ.
K. Pond, SM-CRSP/NCSU

E. Duron, NCSU
A. Ferrufino, NCSU
J. Bolaños, CIMMYT
J. Espinosa, INPOFOS/Potash & Phosphate Institute
B. Name, IDIAP
R. Sanchez, IDIAP
S. Jaramillo, IDIAP
E. Molina, UCR/CIA
A. Alvarado, UCR/CIA
O. Garcia, SRN

GOAL AND OBJECTIVES

The goal is to provide technical support for participating institutions. The objectives are to strengthen capabilities of personnel at network collaborating national research institutions to conduct, interpret and report user-oriented research and to systematically validate and extrapolate available soil management technologies to regions beyond Soil Management CRSP sites.

PROGRESS REPORT

In-house English translation and typesetting of the proceeding for the RISTROP workshop, held in Costa Rica in 1990, is 80% complete. Through direct grants to IDIAP, INPOFOS has assured continuation of K and P fertilization studies for Ultisols in Calabacito, Panama. Critical soil K for corn was established at 0.10 cmol kg^{-1} for both the Mehlich 1 and ammonium acetate extraction; despite maintaining crop residues in the field, effects from 210 kg K ha^{-1} only lasted for four years, but annual applications of 42 kg K ha^{-1} have maintained near maximum yields. The long-term P rates and placement trial was designed to provide yield and soil P dynamics data according to input requirements of the current PDSS prototype.

Elio Duron's collaborative field trials on the comparative effectiveness of North Carolina phosphate rock (NCPR) and triple superphosphate completed their first year in Ultisols of Costa Rica and Panama, and their second in an Andisol in Honduras. Although yields were increased with applied P, preliminary analysis of yield data suggest no difference in yield response between P sources in either Honduras (with corn) or the unlimed Ultisol in Panama (with rice). For the Ultisol in Costa Rica, low but measurable rice yields were only obtained in either the NCPR or limed treatments, which suggested a low tolerance to high soil Al by the locally recommended variety.

Initial greenhouse screening for Al tolerance was conducted with non-CRSP funds on purified rice lines collected by the IDIAP from shifting cultivators in Ultisols of Panama. Relative to rice cultivars provided by several national and international centers, root growth under high solution Al concentration suggested

that the Panama lines would be promising materials for low input management systems.

Additional Funding and Support:

Texasgulf, Inc. contributed $50,000.00 for project support during 1990-1993. INPOFOS funding of IDIAP investigations, related to technical backstopping by this project, is considered as support through cost sharing and leverage. Support in kind was provided by IDIAP, Panama, by greenhouse screening of rice lines.

3. PHOSPHORUS DECISION SUPPORT SYSTEM

Project Number:

PDSS-01

Constraint Addressed:

Phosphorus deficiencies
Lack of calibration of soil tests
Insufficient information for expert systems

Project Leaders:

Russell Yost, University of Hawaii
Fred Cox, North Carolina State University
Shaw Reid, Cornell University
Art Onken, Texas A&M University

Research Collaborators:

Puntipa Vichiensanth, Khon Kaen University, Thailand
B. T. Kang, IITA, Nigeria
I Putu Gedjer Widjaja-Adhi, Centre for Soils and Agroclimate Research, Indonesia
A. Bationo, IFDC/ICRISAT, Niger
Jose Espinosa, Potash and Phosphate Institute, Costa Rica
Mamadou Doumbia, Texas A&M University

GOALS AND OBJECTIVES

The goal is to develop the Phosphorus Decision Support System so that it will implement the best diagnostic and predictive methodology in a form useable by those with little formal training but with great responsibility for planning and executing agricultural development. The objective is to develop the Phosphorus Decision Support System software and associated documentation that will use

observations, previous cropping history, and soil and plant analysis in making economically viable fertilizer predictions.

PROGRESS REPORT

The PDSS program consists of diagnosing of phosphorus deficiencies and excesses. A method using Bayesian probability was adapted to combine two or more of the following evidences: regional expectations, soil taxonomy, previous crop yield, indicator plants, plant symptoms, plant analysis and soil analysis. If phosphorus is diagnosed as deficient then a recommendation is generated. The minimum dataset for a phosphorus recommendation is the intended crop, existing soil P level together with the P extraction method, soil clay percentage, and bulk density.

Buffer coefficients will be predicted from data provided by CRSP scientists. Some preliminary studies indicate that clay percentage alone may not be sufficient predictor at high clay percentages. Amorphous oxides as estimated by ammonium oxalate appears to be a useful additional predictor in such cases. Further data are needed to confirm these relationships. Short term incubation techniques are being compared for situations in which buffer coefficients cannot be predicted.

Work continues moving towards a December 1993 distribution of an initial test and evaluation.

A partial budget economic analysis has been prepared and implemented that uses a linear response to a maximum yield occurring at the critical level. Residual availability of applied phosphorus is optionally included in the economic analysis.

ADDITIONAL FUNDING AND SUPPORT

Analysis of Nitrogen, Phosphorus, and Carbon cycles in upland farming systems in S. E. Asia, International Rice Research Institute, Ken Cassman, Thomas George, and Guy Kirk.

Predicting P availability in Natural and Agricultural Ecosystems. USDA Section 406 Project.

4. ACIDITY DECISION SUPPORT SYSTEM

Project Number:

ADSS-01

Constraints Addressed:

Soil acidity
Technology transfer

Project Leaders:

Russell Yost, University of Hawaii
John Day, ERS, USDA

Research Collaborators:

Le Istiqlal Amien, Center for Soil and Agroclimatic Research, Bogor, Indonesia
Sharifuddin Abdul Hamid, University of Agriculture, Malaysia
Ailin Ton Dato Isahak, Mardi, Malaysia
Abdullah Tengah, Mardi, Malaysia

GOALS AND OBJECTIVES

The project goal is to improve the user-interface and knowledge base of the Acidity Decision Support System (ADSS). Objectives for this phase are to (1) develop an awareness and acceptance of ADSS (and expert systems as a whole) as a useful soil management decision-making tool by conducting demonstrations and training in S. E. Asia, and (2) to obtain published data from various sites/countries to test and validate ADSS soil and crop data.

PROGRESS REPORT

This phase of ADSS-01, carried by Dr. Thomas Dierolf, was completed and the final report is currently being written. The consultant spent most of his time working with the Center for Soil and Agroclimate Research (CSAR) in Bogor, Indonesia, but also travelled for 10 days to Malaysia.

Although ADSS has been known around CSAR for several years, mainly due to the influence of Dr. Istiqlal Amien, ADSS has not been widely used. The current project resulted in a renewed interest in ADSS such that the Director of CSAR is using SM-CRSP products like ADSS (and eventually the Phosphorus Decision Support System) to promote the service nature of CSAR to other institutions in Indonesia.

Several staff (13) at CSAR were trained in ADSS, and two in particular have a very good understanding of ADSS and an appreciation for expert systems. Thus, ADSS has been pulled out of the ranks of the higher level staff (Ph.D.'s) and brought to lover level (B.S. degrees) staff at CSAR. The lower level staff are the ones more likely to eventually implement decision support aids.

One day training (9) and two hour demonstrations (2) on ADSS were conducted at a total of 11 out of the 27 provinces in Indonesia. A total of over 200 agricultural extension agents and planners attended these events. The training was formally arranged between CSAR and the Agency for Agricultural Training and Education. Since SCAR is under the Agency for Agricultural Research and Development this was a lateral arrangement cutting across two different agencies in the Ministry of Agriculture. This training allowed for exposure of the potential clientele to ADSS and expert systems and provided an opportunity to evaluate client needs.

To update and expand the knowledge base of ADSS, data has been collected from researchers and publications in Southeast Asia, as well as from international publications. These data are currently being compiled and will be included in the final report.

5. OUTREACH ACTIVITIES IN THE SEMIARID TROPICS

Project Number:

TAMU-10

Constraints Addressed:

Site-specificity of management practices
Lack of local expertise and information
Number and diversity of potential users
Gap between new information and useable knowledge

Project Leaders:

A.S.R. Juo, Texas A&M University, College Station, TX
A. Manu, Texas A&M University, Niamey, Niger

Research Collaborators:

Collaborators from IARC's, Host Government Research Organizations, and USAID as listed under other projects

GOALS AND OBJECTIVES

GOALS AND OBJECTIVES

The overall goal of this project is to synthesize and translate TropSoils research results from the semi-arid tropics into user-oriented products and disseminate these products to national users through networking, training and workshops. The principal objectives during this reporting period were to (1) identify national and international research organizations and establish effective links and (2) synthesize and translate some of the more promising technologies into user oriented products.

PROGRESS REPORT

One of the major objectives of the outreach program is to promote and maintain close ties with national and International Research Organizations, Non-Governmental Organizations (NGO's) and Universities. Over the past year, collaborative research has been initiated with (1) USAID/LUPE Project and MNR, Honduras, (2) JARP/JADF, Jamaica, (3) IER and INTSORMIL/Mali, (4) the National University, Heredia, Costa Rica, (5) CIMMYT, Mexico, (6) IITA, Nigeria, and (7) ICRAF, Kenya and Peanut CRSP/Burkina Faso. The estimated contributions of these organizations to the SM-CRSP in support of collaborative research with TAMU is valued at $100,000 during the past year.

The initial work (1991) on developing soil and crop indicators to assess the effectiveness of 3 to 5 year-old stone retention walls on the hillside farms in southern Honduras (Marc Thompson's M.S. Thesis) has led to the extension of the on-going TropSoils/TAMU activity (1993-1995) on steepland hydrological studies in collaboration with NMR and the USAID/Lupe Project to assess the effects of deforestation and hillside farming on siltation of coastal wetland and aquatic ecosystems. Local expenses and logistic support of this joint project is provided by NMR and USAID-Honduras.

Following the Management Entity's MOU with Jamaica, the Jamaica Agricultural Development Program (JARP) requested TropSoils/TAMU to design and implement a collaborative project on restoration of bauxite mined-out land (1993-1995). JARP has paid for nearly all of the local expenses incurred under this project, some of the air fare expenses and a graduate assistantship for one Jamaican student.

At the invitation by the respective national and international institutions, TropSoils/TAMU PIs participated and contributed to (1) the UNU/UNEP International Training Course on African Natural Resources Management in Nairobi, 1992, (2) ICRAF soils laboratory planning mission in Nairobi, 1993, (3) Technical assistance to the National University of Costa Rica/EEC collaborative project on nutrient cycling and water runoff studies on steepland farming systems, 1993, and (4) Planning joint research on restoration of degraded Vertisols at the CIMMYT Research Station in Mexico, 1993. Items (1) and (2) were fully funded by host institutions while items (3) and (4) were partly funded by TropSoils.

USAID Mission support for the second phase of IMAW (Integrated Management of Agricultural Watersheds) project is continuing at a funding level of $500,000 (ending July 1, 1993) plus an extension amount of $56,200 (ending February 28, 1994). This project has developed methodologies to integrate soil conservation, agroforestry, crop and livestock production on the basis of land management units within a small watershed near Niamey, Niger. It has created increasing awareness among farming communities, national and international researchers and planners and USAID officers regarding the need for a landscape approach to agricultural and natural resources management in the region. The project reports were published in English and French. Many national and international centers, CRSPs, and USAID missions in Africa and other organizations (including IARI/India, IIA, IRRI, CIRAT/France, FAO/Rome) have requested copies of the reports.

Currently work is underway in the preparation of two technical bulletins resulting from TropSoils/TAMU research in West Africa. A bulletin detailing soil related spatial variability of crop yields reviews and synthesizes the results of nearly ten years of research conducted in Niger and Mail by TAMU/SM-CRSP researchers. The final report for the *Integrated Management of Agricultural Watersheds* project is also being prepared. The bulletin resulting from this project will include the evaluation and synthesis of some of the more promising soil management technologies utilized in the project.

6. TECHNICAL SUPPORT/DATA BASE MANAGEMENT

Project Number:

UHTX-02

Constraints Addressed:

Inadequate access to technical information and data bases

Project Leaders:

G. Y. Tsuji, University of Hawaii
G. Uehara, University of Hawaii

Research Collaborators:

I. Amien, CSAR, Bogor, Indonesia
W. T. Bowen, IFDC
R. M. Caldwell, UHM
H. Eswaran, USDA/SCS/SMSS
D. Hellums, IFDC
H. Ikawa, UHM

D. I. Imamura, UHM
J. W. Jones, University of Florida
J. Kimble, USDA/SCS/SMSS
Z. C. Li, UHM
R. M. Ogoshi, UHM
U. Singh, IFCD/IRRI
P. K. Thornton, IFDC
T. Vearasilp, Land Development, Thailand
R. S. Yost, UHM

GOALS AND OBJECTIVES

The goal is to establish a commonly accessible computerized data base management system for multiple applications among SM-CRSP projects. The objectives are to (1) provide technical and logistical support for on- and off-campus research projects and to collaborating scientists, (2) adopt and establish acceptable format for soil and weather data bases for coupling to decision support systems, and (3) establish screening procedures to test reliability of input soils data sets.

PROGRESS REPORT

The data base structure established for the decision support system software, DSSAT, was used as the basis for developing, acquiring, and storing soil and weather data sets in a standard manner. The World Benchmark Soils data base of the USDA/SCS/SMSS program containing pedon information and analytical data sets was used as the initial set of input data. Included in this data set were collected and characterized for sites in Sitiung, West Sumatra.

The minimum weather data set established by IBSNAT was used as inputs to the weather data base. Historical weather records from West Sumatra are rare but available. Weather data from the Gunung Medan station of the Central Research Institute for Food Crops (CRIFC) were combined with those collected by SM-CRSP on-site staff. Daily weather records were collected at the SM-CRSP headquarters adjacent to the Gunung Medan station and at sites established in the conduct of field experiments for the UH-07 project.

Collaborative activities with IFDC included organizing soil and weather data sets to be used in conjunction with PDSS activities and IFDC's phosphorus model. The latter will be coupled to the crop simulation models contained in the DSSAT program. Previously completed experiments with maize and accompanying soils and weather data are being organized for evaluation. The phosphorus analysis commonly used in laboratories at the University of Hawaii for P-fertilizer inputs was the modified-Truog method adopted and modified by the sugar industry.

As part of the outreach activities under ADSS-01, reliable soil and weather data bases with crop response information were stressed in training programs carried out in Indonesia with scientists from the Center for Soils and Agroclimate

Research, Bogor. Similar activities are anticipated in coordination with IRRI and IFDC.

ADDITIONAL FUNDING AND SUPPORT

Support in kind was received through collaborative activities with IFDC and SCS/SMSS. Data bases were shared with both organizations.

Graduate student stipends are provided by the World Bank and USAID.

7. BNF REGIONAL RESOURCE CENTER (BNFRC, THAILAND)

Project Number:

NifTAL Program 4

Constraints Addressed:

Lack of BNF resources on a regional basis

Project Leaders:

H. Keyser, NifTAL Coordinator
N. Boonkerd, Director, BNFRC

Collaborating Institutions:

Thai Department of Agriculture
Khon Kaen University, Thailand
United Nations Food and Agriculture Association

GOAL AND OBJECTIVES

The BNFRC in Bangkok, Thailand, was initiated in 1983 as a regional extension of NifTAL to serve South and Southeast Asia. The BNFRC is jointly supported by the Thai Department of Agriculture (DOA) and NifTAL. It is located in the Rhizobium Building on the Bangkhen campus of Kasesart University. The overall goal of the BNFRC is to develop and transfer BNF resources to meet regional needs.

BNFRC objectives are to: (1) support the Thai DOA's BNF program to meet Thailand's national needs, (2) provide regional BNF outreach to researchers and commercial inoculant producers, and (3) support NifTAL and other BNF training programs.

PROGRESS REPORT

The BNFRC has been in transition this reporting period as Dr. Nantakorn Boonkerd, BNFRC Director, accepted a position as Head of Research at Suranaree University, a new government university in Korat. This new position may mean that Suranaree will participate as a collaborator with the BNFRC, although formal arrangements have not been made. BNFRC accomplishments include:

Thai national BNF program continues. The BNFRC, Thai DOA, and Thai DOA Extension Department (DOAE) have maintained an integrated program to promote, produce, and distribute inoculants. The BNFRC has been instrumental in providing extension and technical training for the DOAE, as well as continued technical assistance to the private sector.

BNF outreach services provided. The BNFRC provided material resources and training support to BNF scientists, private voluntary organizations (PVOs), and inoculant producers. The BNFRC responded to requests for 51 books, 65 inoculant units, 11 antisera, 7 cultures, and 3 seed lots. The BNFRC also consulted on an evaluation of a BNF program in China for the Potash and Phosphate Institute of Canada (Hong Kong Office).

Development of ecological models of predicting legume inoculant requirements continues. The BNFRC continued data collection to develop models to predict where, when, and to what extent legumes will respond to inoculation in tropical cropping systems. This research is integrated with NifTAL's Program 3 goals (see NifTAL Program 3).

Collaboration on rhizobial technology for legume cultivation in NE Thailand in support of E-SARN KHEOW Project continues. The BNFRC, Thai DOA, Khon Kaen University continued collaboration on a project support by the Thai STDB to increase farmer income by the adaption of appropriate BNF technologies. This program concentrates on the North East zone of Thailand, but is integrated in the development of a rhizobial database for predicting legume inoculant requirements (see above and Program 3). Other project activities included research on *Sesbania* sp. as green manure, and on inoculation response by tree legumes *Acacia mangium, A. auriculiformis,* and *Sesbania grandiflora.*

ADDITIONAL FUNDING AND SUPPORT:

Grants, contracts, and gifts

Program in Science and Technology Cooperative (PSTC, USAID). "Ecologically based models to predict legume inoculation requirement," $150,000 awarded to Thai DOA and the BNF Resource Center, Thailand.

The Potash and Phosphate Institute of Canada (Hong Kong Office) contracted Dr. Boonkerd to provide a consultancy on the status of BNF technologies in People's Republic of China.

Support through cost-sharing and leverage

Research on ecological models to predict the response to legume inoculation in cropping systems in Thailand is supported in part by a grant from the Science and Technology Development Board (STDB, Thailand), "Developing and adapting *Rhizobium* technology for legume cultivation in NE Thailand in support of E-SARN KHEOW Project" awarded to Khon Kaen University and Department of Agriculture, Thailand.

The Thai Department of Agriculture provides office and laboratory facilities, staff, and institutional support to the BNFRC.

The Thai Department of Agriculture and Suranaree University supported Dr. Nantakorn Boonkerd.

UNFAO provided support for visiting scientist from Ethiopia and for training courses in inoculant production.

8. TECHNICAL ASSISTANCE TO INOCULANT PRODUCERS (PRIVATE ENTERPRISE DEVELOPMENT)

Project Number:

NifTAL Program 5

Constraints Addressed:

Lack of high quality legume inoculants in developing countries
Inadequate awareness, information and capacity to exploit biological nitrogen fixation (BNF) technologies

Project Leaders:

T. Carr

Collaborating Institutions:

Agricultural Cooperative Development International (ACDI)
Winrock International
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
International Center Agricultural Research in the Dry Areas (ICARDA)

Appropriate Technology International (ATI)
Innovative Technology Associates (ITA)
AgroForester Tropical Seeds
LiphaTech, Inc.
International Fertilizer Development Center

GOAL AND OBJECTIVES

Government institutions introduced inoculant technologies to many developing countries, and some have developed technical and research capabilities in BNF. However, in many cases, these efforts have not been translated into viable industries that can assure delivery of inoculant to the farm gate. A lack of incentives and poor logistical support may limit the efficiency and potential growth of government facilities. As a result, these facilities often have difficulty meeting quality standards, satisfying product demand, and promoting market development.

NifTAL's Program 5 focuses on stimulating the private-sector's involvement in inoculant production and increasing market demand in developing countries. Experience has shown that profitable, sustained commercial enterprises insure high-quality, readily available products. Assistance to the private sector is the means to the end: to renew farmer confidence in BNF technology by delivering a quality product.

The Program's broad objectives are to (1) provide assistance to facilitate private sector involvement in inoculant industries and (2) develop innovative products for commercial applications.

PROGRESS REPORT

Program 5 activities involved USAID Missions, national governments, private voluntary organizations (PVOs), non-government organizations (NGOs), and private firms. Impacts and accomplishments included:

A review of BNF activities in Zambia revealed that an initial USAID investment of $300,000 for NifTAL technical assistance to establish inoculant production capabilities has resulted in $20 to $30 million in economic benefits. Program 5 staff joined USAID on an impact assessment of the agronomic and economic impacts of legume inoculant. USAID/Lusaka through the ZAMARE Project contacted NifTAL 1984/85 to establish public sector production of inoculants. The review showed annual production and sale of inoculant is now 16,000 kg, used on 20,000 ha. Research data indicate that inoculants greatly increase legume yields, providing a return on investment of $95 for each dollar spent on inoculants.

Partnership to facilitate private-sector inoculant production in Uganda was established. An investment proposal for inoculant production, prepared by NifTAL in collaboration with ACDI and Winrock International under the On-

Farm Productivity Enhancement Project (OPEP), attracted the interest of the Madhvani Group, an Ugandan company. NifTAL is expected to provide facilities design and technical assistance to install an inoculant Micro-Production Unit (MPU) for the facility in 1994.

Partnership to facilitate private-sector inoculant production in Nepal was established. NifTAL assisted Winrock International with the development of the proposal for the Nepal BNF Project, submitted to the AID/Kathmandu office. NifTAL will provide technical assistance and training for commercial inoculant production and marketing components of the project.

Partnership to facilitate private-sector inoculant production in Asia was established. NifTAL, ICARDA, and ICRISAT are collaborators in an Appropriate Technology International (ATI) project to promote commercial inoculant production and marketing in Sri Lanka, Philippines and India. The project is expected to start in late 1993.

Financial analysis and inoculant production facilities design for a private seed firm in Kenya was prepared. The analysis indicates that potential legume inoculant demand was sufficient for a profitable enterprise at the Kenya Seed company in Kitale, Kenya. The company is considering the investment.

Partnership with U.S. firm established to manufacture, distribute, and improve NifTAL-developed fermentors (NDF) was established. NDF technology was transferred to a U.S. manufacturer via a Memorandum of Understanding between NifTAL and the manufacturer, Innovative Technology Associates (ITA). NifTAL assisted with technical aspects and produced operational manuals to meet orders for fermentors to India and myanmar. ATI is working with NifTAL to test different electronic sterilization systems for the NDF fermentor that will provide more flexibility for inoculant producers.

Technical assistance was provided to U.S. inoculant producers. Program 5 staff were invited to Yellowstone Valley Chemical of Billings, Montana (affiliate to United Agri-Products), to review production, packaging and quality control methods. UAP staff made a reciprocal visit to NifTAL. LiphaTech, Inc. of Milwaukee, Wisconsin contracted NifTAL to test inoculant products in tropical soils of Maui. A Memorandum of Agreement was signed with AgroForestor Seed Company to establish a NifTAL micro-production-unit at their headquarters in Hawaii.

Product development included novel packaging, quality control, and inoculant production technologies, and updated computer software. A patent is pending on SAFTI-PAK, NifTAL's novel packaging system for inoculants. Technical options were tested for the NifTAL Micro-Production Unit (MPU), and economical production system. New methods to improve quality control were developed (see Program 2). Computer programs FAIML (Financial Analysis of Inoculant Manufacturing Enterprises), RESPONSE (for predicting response to inoculation), and ACCLAIM (germplasm resource) were updated.

Database of inoculant producers and BNF resource persons established. Surveys were sent to approximately 140 inoculant producers worldwide to identify the global resources and needs for inoculant production, and to identify resource persons for international BNF development programs (see Training and Communication Section).

ADDITIONAL FUNDING AND SUPPORT:

Grants, contracts, and gifts

"Inoculant product performance in acid and moisture stressed soils," LiphaTech, Inc., Milwaukee, Wisconsin, 1993, $7,500.

IFDC paid expenses for Singleton at meeting in Belgium, 1 week, June 1993. $1,000.

USAID grant "African Association for Biological Nitrogen Fixation (AABNF) logistical support." August to October, 1992. P. Singleton, PI. $20,780.

9. TRAINING AND COMMUNICATIONS (NifTAL)

Project Number:

NifTAL

Constraints Addressed:

Lack of trained personnel in BNF technologies
Lack of awareness of BNF technologies

Project Leaders:

H. Hoberr
S. Westley

Collaborating Institutions:

Nitrogen Fixing Tree Association (NFTA)
UN Food and Agriculture Organization (UNFAO)
BNFRC, Thailand
Thai, Department of Agriculture
Agricultural Cooperative Development International (ACDI)

GOAL AND OBJECTIVES

The goal of NifTAL's training and communications programs is to bridge the gap between scientific knowledge on BNF and the actual application of proven technologies in the field. The transfer of useful BNF technologies is accomplished through education and the dissemination of information. Our clients include extension personnel and PVOs who will in turn transfer these technologies to other extension specialists and farmers; researchers from government institutions; inoculant producers and technicians; and administrators who facilitate the adoption of BNF technologies in regional and national programs.

Objectives are to (1) develop BNF curricula appropriate for needs of specific client groups including extension personnel and PVOs, scientists, inoculant producers and sales persons, and resource administrators, (2) develop human resources by increasing the pool of persons capable of adopting and transferring BNF technologies in developing countries, (3) maintain a graduate student program through the University of Hawaii and other collaborating universities, (4) develop and disseminate informational resources on NifTAL technologies, programs and services, and (5) develop database of human and institutional resources for BNF technology transfer.

PROGRESS REPORT

NifTAL's Training and Communications Programs are actually separate, though highly integrated programs. They are combined for purposes of this report. Both programs support NifTAL's Programs 1 to 5, and activities are coordinated with these other programs. In addition to those supportive roles, accomplishments included:

Comprehensive training in inoculant production and quality control was provided to 26 developing country scientists and technicians. NifTAL provided two intensive five-week courses with the collaboration of the BNFRC in Thailand. Most of the training participants were sponsored through an UNDP/FAO program with the Indian government to support the Indian Biofertilizers Program.

A training program in BNF technologies in Uganda has continued under NifTAL-trained personnel, training a total of 120 NGO, PVO, and government extension specialists. A consortium led by ACDI initiated training of extension specialists in 1989. NifTAL provided the curriculum, course materials, and resource personnel for the first two courses. During this reporting period, NifTAL-trained personnel used the curriculum and materials to conduct two more courses in the Lira and Tororo districts.

Visiting scientist and graduate student programs continued. NifTAL and BNFRC hosted four visiting scientists. Two students received graduate degrees in 1992, and eight students are currently degree candidates.

Informational resources were extended worldwide. The Communications Program published and distributed two issues (Volume XI, no. 2; Volume XII, no.1) of the biannual *BNF Bulletin* and *Continuing Bibliography* (Nos. 21 and 22) to inform approximately 1,800 readers in more than 100 countries of BNF-related activities. A survey of international readers in this reporting period revealed more than 95% of the respondents used the *Continuing Bibliography,* which contains citations and contacts for BNF articles. The Communications section also responded to 517 requests for NifTAL journal articles, brochures, software, manuals, and technical information.

Informational resources expanded. The Communications Program maintains databases of BNF documents, BNF resource persons interested in international development, and inoculant producers. These databases were expanded and updated as NifTAL surveyed its international readers of the *BNF Bulletin,* BNF resource persons, and inoculant producers.

ADDITIONAL FUNDING AND SUPPORT:

Grants, contracts, and gifts

UNFAO, paid participants and instructors costs for two 5-week training sessions in inoculant production at the BNFRC. $166,000.

Support through cost-sharing and leverage

Thai Department of Agriculture provided facilities, logistical, and technical support for two 5-week training courses at the BNFRC in Thailand.

Egypt's Soils and Water Research Center, funded intern training for Dr. S. A. Wahab.

International Institute of Tropical Agriculture, Nigeria, funded training of Dr. M. Musoko.

USAID/Kampala, Uganda supported the BNF training workshops in Lira and Tororo, Uganda.

The Nitrogen Fixing Tree Association provided salary and equipment support to Communications Program leader Sidney Westley.

10. TECHNOLOGY FOR SOIL MOISTURE MANAGEMENT (ARS)

Project Number:

TSMM-ARS

Constraints Addressed:

Physical limitations
Water stress
Nutrient deficiencies and losses
Information knowledge gap

Project Leader:

James F. Parr, USDA-ARS

Research Collaborators:

Dr. Ismail Cakmak, Principal Investigator, University of Cukurova, Soil Science Department, and Coordinator for NATO/Science for Stability Project, Adana, Turkey
Dr. Chaitat Pairintra, Coordinator, Asia-Pacific Natural Agricultural Network (APNAN), Bangkok, Thailand
Dr. Teruo Higa, Professor, Faculty of Agriculture, University of the Ryukyus, Okinawa, Japan
Dr. Valdis Mezainis, Director, USDA-OICD, Far Eastern Regional Research Office (FERRO), New Delhi, India
Dr. A. M. Elgala, Professor, Department of Soil Science, Ain Shams University, Cairo, Egypt
Dr. R. I. Papendick, Research Leader, USDA-ARS, Land and Water Conservation Research Unit, Washington State University, Pullman, Washington

GOAL AND OBJECTIVES

The overall goals of TSMM are to increase the productivity and long-term sustainability of rainfed/dryland agricultural systems in developing countries while maintaining or enhancing the natural resource base, specifically the soil and water resources, and to improve output and income in crop and livestock production systems. More specifically, the goals of TSMM are to:

1. assist in the assessment and improvement of soil, water, and crop/livestock management systems under dryland or rainfed conditions,
2. develop effective strategies and approaches for increasing dryland and rainfed agricultural productivity through research and technology transfer and

3. strengthen the capability of developing country scientists and institutions for conducting research that would lead to more effective and efficient management practices for dryland and rainfed farming systems.

PROGRESS REPORT

In the past year, TSMM (USDA-ARS) has played a key role in the management of five major research projects (26 sub-projects) on dryland agriculture in India. These 5-year projects were implemented in early 1990 under the PL-480 Program and administered by USDA-OICD's Far Eastern Regional Research Office (FERRO) in New Delhi. Scientist-to-scientist linkages are emphasized. A mid-term review of all projects was recently conducted by the U.S. Dryland Farming Team at various locations in India. The Principal Investigator (J. F. Parr) continues to serve as Team Leader and Coordinator of these research projects.

The Principal Investigator (J. F. Parr) continues to serve as Technical Advisor to the Asia-Pacific Natural Agriculture Network (APNAN) that is conducting research on low-input/sustainable farming systems in 13 countries of the Asia-Pacific Region. Regional workshops were held during 1993, and the Proceedings are currently being prepared for publication.

The Principal Investigator (J. F. Parr) served as Technical Editor of the Proceedings of the Second African Soil Science Society Conference that was held in November 1991 in Cairo, Egypt and published in 1993.

TSMM (USDA-ARS) provided partial funding during 1993 for laboratory and field research on aspects of dryland agriculture conducted by an Indian soil scientist Washington State University under the direction of Dr. R.I. Papendick, Research Leader, USDA-ARS.

Served as Technical Consultant to NATO on a major research project that started (1993-1997) in Turkey under the auspices of the NATO Science for Stability Program. The project is being conducted by the Department of Soil Science, Cukurova University, Adana, and is entitled "Selection and Characterization of Cereal Genotypes with High Resistance to Zinc and Iron Deficiencies and Boron Toxicity for the GAP Region (Southeastern Anatolia) and Central Anatolia."

Planned and organized a U.S.-Middle East Workshop on "Dryland Farming Systems and Technologies for a More Sustainable Agriculture." The workshop was requested by the State Dept./Bureau of Oceans, Environment and Science (OES) to enhance the Middle East Peace Initiative and was held in Moscow, Idaho, during October 18-22, 1993. The workshop brought together Palestinian, Israeli, and Arab scientists from the Middle East Region to discuss possible cooperative research initiatives.

Planned and organized a workshop on "Production of Composts from Coconut Coir and Other Organic Wastes for Use as Biofertilizers and Soil Conditioners" in

Sri Lanka in February 1993. This workshop was requested by USAID Mission in Colombo in an effort to utilize coconut coir waste in the rehabilitation of degraded agricultural lands in Sri Lanka.

ADDITIONAL FUNDING AND SUPPORT

India: The FERRO Office provided the equivalent of $20,000 in rupees to support the travel and per diem of U.S. dryland scientist visits to India during 1993.

APNAN: The APNAN provided approximately $30,000 USD to support the travel and per diem of two U.S. technical advisors to technical meetings during 1993.

U.S. State Dept/USAID: The U.S. State Department provided $50,000 and the Asia-Near East Bureau of USAID provided $75,000 to support travel, per diem and local arrangements for the U.S. Middle East Conference/Workshop on Dryland Agriculture that was held in October in Moscow, Idaho.

III. APPENDIXES

A. Referred Papers

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Wilding, L. P. and C. E. Coulombe. 1993. Expansive soils: distribution morphology and genesis. *In*, P. Baveye and M. B. McBride (eds.), Proceedings of the NATO-Advanced Research Workshop on Clay Swelling and Expansive Soils, Kluwer Academic Publ.

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Wolff, A. B., P. W. Singleton, M. Sidirelli and B. B. Bohlool. 1992. Influence of acid soil on nodulation and interstrain competitiveness in relation to tannin concentrations in seeds and roots of *Phaseolus vulgaris*. Soil Biol. Biochem 25(6):715-721.

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D. Graduate Student Theses Completed

Lokugam Gunaratne. Simulation of canopy dimensions in intercrops. M. S. degree. Advisor: R. Caldwell.

Huang Xuexin. Effects of green manure, rock phosphate, and lime in plant growth in highly weathered acid soils. M. S. degree. Advisor: N. V. Hue.

Dierolf, Thomas. 1993. Cation and water movement in an Indonesian Ultisol. Ph.D. Dissertation. Advisor: Russell Yost.

Castedo, L. R., Hoag, D. C. Technical, Financial and Marketing Assistance to Enhance Farmer Incomes in Bolivia: A feasibility study. Masters Thesis, NCSU, May 1993.

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Janez Hacin. University of Ljubljana, Slovenia. Photosynthate partitioning and regulation of soybean (*Glycine max* L. Merr.) nodule development. Advisor: P. Singleton. Ph.D. graduate, 1992.

Shahriar Pooyan. University of Hawaii, Department of Microbiology. Identification and characterization of chromosomal genes in rhizobia required for nitrogen fixation in beans. Advisor: D. Borthakur. M.S. graduate, 1992.

E. Graduate Student Theses Work in Progress

Fengmao Guo. Predicting phosphorus residual effects in a wide range of soils. Advisor: R. S. Yost.

James Jackson. Predicting phosphorus sorption by varied soils in Hawaii. Advisor: R. S. Yost.

Wang Xinmin. Predicting phosphorus residual effects in a range of soils due to aggregate, organic, and mineralogical effects. Advisor: R. S. Yost.

Bruce Linquist. Analysis of carbon and phosphorus budgets with grain legumes in a highly weathered soil. Advisor: K. G. Cassman.

Martinus Pundutama. Extent and residual phosphorus availability in over-fertilized paddy rice soils of Java. Advisor: R. S. Yost.

Sk. Ghulam Hussein. Decision support system for risk management in Bangladesh. Advisor: G. Uehara.

Richard M. Ogoshi. Genetic coefficients for crop simulation models. Advisor: G. Uehara.

Hemarit Prasad. A crop simulation model for taro. Advisor: G. Uehara.

San-Gwang Hwang. Simulation of phenology and dry matter partitioning in intercrops. Advisor: R. Caldwell.

Jon Kamemoto. Phenology of intercrops. Advisor: R. Caldwell.

Angel Salazar. Tree-Crop Competition Effects and phosphorus Dynamics in Agroforestry Systems. Ph.D. Advisor: A. G. Wollum.

Kathrin Franzluebbers. Release of carbon and nitrogen during decomposition of cowpea green manure and millet residue. Ph.D. Advisors: A. S. R. Juo and Richard W. Weaver.

Mamadou D. Doumbia. Nutrient deficiency and toxicity studies at the Cinzana Station, Mali (West Africa). Ph.D. Advisor: L. Hossner.

Jordan Caldwell. Above and below ground competition in alley cropping systems. Ph.D. Advisor: A. S. R. Juo.

James Smith. Effectiveness of soil and water conservation technologies on steepland tropical farming systems. M. S. Advisors: A. S. R. Juo and T. Thurow.

Deborah Wagner. Gender Roles and Resource Management Decisions in Senegal. Ph.D. Dissertation, VPI, 1995. Advisor: Daniel C. Taylor.

Beth Scott. Willingness to Pay for Soil/Water Conservations in Mali. 1994. M. S. Advisor: Fred O. Boadu.

K. Glasener. Synchrony of nutrient availability of tropical legume mulches and green manures with crop demand. Ph.D. Advisor: M. Wagger.

Abdoul A. Sow. Tillage and residue effects on water extraction, rooting depth, growth and yield of dryland sorghum. Ph.D. Advisor: L. Hossner.

Fahmuddin Agus. Soil processes and crop production under contour hedgerow systems on sloping Ultisols. Ph.D. Advisor: D. K. Cassel.

Bir Thapa. Alternative tillage practices under contour hedgerow systems to reduce soil erosion and rejuvenate degraded lands. Ph.D. Advisor: D. K. Cassel.

April Horowitz. Biological control of soil erosion and land rejuvenation. M. S. Advisor: D. K. Cassel.

Steve Monteith. Soil-geomorphic relationships in the Chapare region of Bolivia. Advisor: S. W. Buol.

John Schmidt. Mineral nutrient potentials in major soil groups. Advisor: S. W. Buol.

Mike Beck. Relationship of soil mineral suites to phosphorus supplying potential. Advisor: S. W. Buol.

Pedro O. Rufz. Interactions of mycorrhizae, rhizobia, and phosphorus in agroforestry systems in acid Ultisols of the Amazon. Ph.D. Advisor: C. B. Davey.

Elio Duron. Agronomic effectiveness of North Carolina phosphate rock in phosphorus deficient Central American soils. Ph.D. Advisors: T. J. Smyth and F. R. Cox.

A. Ferrufino. Diagnosis and prescription of nutrient requirements for predominant fruit crops in the Bolivian Chapare. Ph.D. Advisor: T. J. Smyth.

P. Luna-Orea. Managed fallows in low-input systems in Bolivia. Ph.D. Advisor: M. Wagger.

Zhaokun Tong. University of Minnesota. Department of Microbial Engineering. Selective media for the direct recovery of rhizobia from soils and inoculants. M.S. Advisor: M. Sadowsky.

Clement Coulombe. Structural degradation and rejuvenation processes of Vertisols. Ph.D. Advisor: L. Wilding.

Wendy Greenberg. Characterization of pedological and biological processes of rejuvenation of bauxite mined-out soils. Ph.D. Advisor: L. Wilding.

Justin Heil. Soil properties influencing hydraulic sealing of the surface of Alfisols in the Sahel. Ph.D. Advisors: A. S. R. Juo and K. McInnes.

Hugh Lambert. Evaluation of biological methods for rejuvenating bauxite mined-out land in Jamaica. Ph.D. Advisors: Mark Hussey and A. S. R. Juo.

Nikhat Parveen. University of Hawaii. Department of Microbiology. Genetics of exopolysaccharide synthesis by *Rhizobium* strain TAL 1145 that nodulated tree legumes. Ph.D. Advisor: D. Borthakur.

Xuefeng Gao. University of Hawaii. Department of Microbiology. Genetics of nodulation competitiveness in *Rhizobium etlii* on bean. Ph.D. Advisor: D. Borthakur.

Muchdar Soedarjo. University of Hawaii. Department of Microbiology. Genetics of mimosine degradation by *Rhizobium* strains that nodulate tree legume leucaena. Ph.D. Advisor: D. Borthakur.

Robert Abaidoo. University of Hawaii. Department of Agronomy and Soil Science. Population dynamics of bradyrhizobia and efficiency of nitrogen fixation with promiscuously-nodulating soybeans. Ph.D. Advisor: H. Keyser.

Veronique Lambert. University of Hawaii. Department of Agronomy and Soil Science. Early growth of tree legumes at different phosphorus levels in an acid soil. M. S. Advisor: H. Keyser.

Bruce Linquist. University of California at Davis. Agronomy and Range Science Department. Legume root and nodule response to soil phosphorus. Ph.D. Advisor: B. Rains.

S. Tewari. University of Hawaii. Department of Agronomy and Soil Science. Growth, development and N-uptake of soybeans, peanuts and common bean grown under different levels of soil N: Validation of the LeGRO crop model. Ph.D. Advisor: P. Singleton.

Simeon Numbem Tchatchoua. Ph.D. Advisors: A. Van Wambeke, D. Lewis, and R. Barker.

F. Special Activities

R. Caldwell accepted leadership for the intercrop (and 'complex agroecosystem') modeling activities of the International Geosphere-Biosphere Programme / Global Change and Terrestrial Ecosystem core project, IGBP/GCTE. The IGBP/GCTE is a large international research activity organized by the International Council of Scientific Unions. The IGBP/GCTE is applying systems analysis to the ecological problems of global climate change. The invitation for the Soil Management CRSP to participate in this activity is a result primarily of the design of Project UH-04, which is using a network of international scientists to compare a variety of simulation models.

There were 195 reported activities in the categories of technical assistance and technical backstopping. A large number of these reports came from NifTAL and SMSS but nearly all projects reported some activities in technical assistance to personnel in cooperating countries.

G. Training Activities

1. Short Term

One day trainings in the use of ADSS were given to provincial level extension agents and planners at 9 of the 27 provinces in Indonesia. Cooperators included CSAR and the Agency for Agricultural Education and Training under the Ministry of Agriculture. Individual institutions represented at each of the trainings included the food crops, estate crops, fisheries, and livestock extension services (each is a separate office), provincial agricultural coordinating office, agricultural information office, office for agricultural education and training of government and extension staff, and local state universities.

Date	Location	Attendees
21 Aug 93	Central Kalimantan	26
23 Aug 93	South Kalimantan	22
25 Aug 93	East Kalimantan	35
27 Aug 93	West Kalimantan	16
13 Sep 93	Jambi	23
15 Sep 93	South Sumatra	26
17 Sep 93	Riau	23
20 Sep 93	West Sumatra	17
19 Oct 39	North Sumatra	22

Two-hour demonstrations of the ADSS were presented to various groups in Indonesia. The dates, cities, numbers of attendees and locations for these demonstrations were:

Date	City	Attendees	Location
31 July 93	Jakarta	19	Head office of Agency for Agricultural Education and Training
07 Aug 93	Yogyakarta	21	Provincial level extension office
19 Aug 93	Bogor	8	Researchers at the National Agricultural University (Institute Pertanian Bogor)
01 Sept 93	Jakarta	13	Provincial level extension office
09 Sep 93	Bogor	36	CSAR office (also present were information officers from several other centers under AARD, including the centers for Food Crops, Livestock, Industrial Crops, and the Central Agricultural Library)

Dr. Herve Sinoquet, French scientist with INRA in Guadeloupe, the French Antilles, visited in the laboratory of R. M. Caldwell for two weeks. Dr. Sinoquet studied the details of CropSys in preparation for a series of maize/phaseolus intercrop trials to be conducted in Guadeloupe.

R. M. Caldwell organized and led a second "Miniworkshop on Intercrop Modeling" as part of the 23rd Annual Workshop on Crop Simulation, in Phoenix, Arizona. The morning session included presentations by Dr. Basil Acock and his colleagues on 2-dimensional soil models. Dr. Acock, a project collaborator, also shared his experience modeling maize/tree alleycropping with Dr. Tony Juo, Texas A&M University. Dr. R. Grant, another project collaborator, participated in the Miniworkshop and shared his experience with agroecosystem models run on supercomputers.

Two short training courses (total of 6 hours over 3 days) in the use of the Acidity Decision Support System were given for personnel of the Center for Soil and Agroclimatic Research in Bogor, Indonesia. The course on June 15-17 had six students and the one in August had seven. Two of the students received further in-depth training and assisted in some of the training conducted at provincial extension offices.

Mr. Ibrahim Zanguina, the in-country (INRAN) counterpart for the IMAW project, spent three weeks at Texas A&M University to receive training pertaining to the hydrological studies within the watershed. Among his several activities at TAMU, he underwent an intensive short-term training in the use of a drip-type rainfall simulator which has been shipped to Niger to determine the infiltration rates of the different components of the five land management units identified in the watershed.

"Symbiotic nitrogen fixation," D. Borthakur mentored one participant in the NSF Young Scholars Program through the University of Hawaii, College of Tropical Agriculture and Human Resources, 21 June to 28 July 1993.

Research-extension-private sector linkages for improved soil management practices. Dr. Rafael Pinto of the Ministry of Agriculture, Venezuela. Visiting Scientist at NCSU. September 1992 - August 1993.

Review of pertinent literature and software, assessment of procedures for soil, plant, water and fertilizer analysis, and tour of in-site operations for analysis, data interpretations, and recommendations to farmers in North Carolina. Dr. Sahlemedhin Sertsu from the National Soil Service Project, FAO Regional Office, Addis Abeba, Ethiopia. 23 August - 10 September, 1993. North Carolina State University, FAO and USDA/OICD.

NifTAL hosted two visiting scientists who learned basic rhizobial methodologies involved in inoculant production. Another visiting scientist was hosted at the BNFRC, Thailand.

Dr. Samir Abdel Wahab from Soils and Water Research Institute, Giza, Egypt, 2 weeks, March 1993.

Dr. Mbangu Musoko, from International Institute of Tropical Agriculture (IITA), 4 months, April to July 1993.

BNFRC provided training in rhizobial technologies to Dr. Mohammed Abebe from Ethiopia, 31 March to 30 June 1993.

Soil Resources in Tropical and Subtropical Areas. IFDC. International Training Course, 22 September 1993.

Maintaining Soil Chemical and Physical Properties. IFDC. International Training Course, 22 September 1993.

Soil Functions in Sustainable Food Productions. Asian Int. Tech, Bangkok, Thailand, 13 December 1993.

2. Workshops

The U.S. Dryland Farming Team conducted a series of workshops in India during 1993 for Indian scientists involved in Indo-U.S. cooperative research. These included computer training for using models recently developed for (a) the Revised Universal Soil Loss Equation (RUSLE), (b) the Water Erosion Prediction Project (WEPP), and (c) comparative plant stress physiology with improved instrumentation for field measurements of photosynthesis, respiration, transpiration, and instantaneous water use efficiency (WUE).

Singleton, P. W. "Biological N_2 Fixation: Processes, Environmental Influences, and Management" presented to University of Hawaii course on Mineral Nutrition of Tropical Crops, 12 participants, 30 March 1993.

"Legume Rhizobia Technology for Research and Application." 16 September to 17 October 1992. Training program in inoculant production sponsored by UNFAO, NifTAL, BNFRC, and Thai Department of Agriculture. 12 participants.

"Legume Rhizobia Technology for Research and Application." 26 July to 27 August 1993. Training program in inoculant production sponsored by UNFAO, NifTAL, BNFRC, and Thai Department of Agriculture. 14 participants.

"Third Training Workshop in BNF Technologies." 26 - 30 October 1992. Lira, Uganda. Training for extension specialists. Sponsored by USAID/CAAS Project. 30 participants.

"Fourth Training Workshop in BNF Technologies." 6 - 12 June 1993. Tororo, Uganda. Training for extension specialists. Sponsored by USAID/CAAS Project. 28 participants.

3. Technical Support

Supply of software and technical suggestions on use of the Fertility Capability Classification system in the Mekong Delta region by faculty of the Soil Science Department, University of Cantho, Vietnam.

Supply of software and technical suggestions on use of the FCC system in M.Sc. thesis research at the University of Cochabamba, Bolivia by Alex Quiroga Montalvo (J. Aldunte, principal advisor).

Steve Monteith, consultant work with DAI for 24 days. Made Fertility Capability Classification (FCC) map of 4000 hectare area in Chapare, Bolivia and made interpretations for soil management and fertilization for priority crops.