SOIL MANAGEMENT COLLABORATIVE RESEARCH SUPPORT PROGRAM

PROJECT YEAR 7
ANNUAL PROGRESS REPORT

Cornell University
Montana State University
North Carolina State University
University of Florida
University of Hawaii

2003-2004

Soil Management C•R•S•P

USAID
FROM THE AMERICAN PEOPLE

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EXECUTIVE SUMMARY

Land is an aggregate of spatially varying soils where the nutrient, carbon and hydrologic cycles meet and interact to support life on earth. In this 7th Annual Report, the Soil Management CRSP describes how it enables customers to make better nutrient, carbon, water and overall land management decisions on a global scale. The problem domain associated with global land management is nearly infinite because our wide-ranging customers use soils for different purposes on lands that vary with climate, geology, biota, topography and age. The Soil Management CRSP deals with this huge problem domain by providing its customers with decision support tools that have been designed to operate globally and locally. Science-based knowledge that applies everywhere and is captured in decision support systems renders our tools globally applicable. Knowledge, like an engine, can do useful work only when supplied with fuel. The fuel that powers inference engines such as decision support systems is customer-relevant, using local data such as climate, soil and socio-economic conditions. Global knowledge, combined with local data, produces information our customers need to make better economic and environmentally sound choices.

The Nutrient Management Decision Support System or NuMaSS is an example of a globally applicable, knowledge-based tool that operates on a site-specific basis (see *Nutrient Management Support System (NuMaSS)* section). NuMaSS enables customers to diagnose nutrient deficiencies, prescribe alternative corrective actions and enable growers to achieve food security or remain competitive in the market place. By adding only the required quantity of nutrients, NuMaSS prevents excess nutrients to contaminate groundwater, stream, lakes and oceans. Unlike NuMaSS, which is a rule-based decision support systems, the Trade-off Analysis or TOA (see *Trade-Off Analysis* section) is based on simulation models that mimic natural processes and their outcomes. By simulating outcomes of alternative land use decisions, TOA enables customers to explore the future and analyze the cost and benefit of pursuing one alternative versus another. This approach enables customers, particularly policy makers, to make informed decisions concerning the dual role of agricultural production and safeguarding the environment.

The nutrient, carbon and hydrologic cycles come together and are inextricably linked in the soil. The gain or loss of one from the soil affects gains and losses of the others and in the land itself. Organic carbon is the glue that binds sand, silt and clay particles into larger aggregates. If the aggregates are large and stable, the pores between them will also be large and stable, enabling water, during heavy rains, to seep into the soil for storage and subsequent use by crops rather than to flow over and erode the land. Thus the capacity of sloping land to withstand the erosive forces of wind and rain largely depends on carbon. Carbon is also the sponge that adsorbs and stores water and nutrients and slowly releases them to crops. Carbon is a resource, and like income, can be spent or saved to earn more income. Subsistence farmers have little choice but to "spend" their carbon supply as fuel, fodder or fertilizer. They till their land, not so much to loosen the soil but to expose buried humus so that microorganisms can mineralize and release nutrients for their nutrient-starved crops. This unsustainable practice of mining soils for carbon and nutrients diverts water for soil erosion and downstream flooding of towns and villages instead of recharging groundwater and stabilizing stream flow. Sequestering carbon in soils (see *Carbon Sequestration* section) is, therefore, a major focus of the CRSP.

A sustainable production system requires constant monitoring to maintain its resilience. Resiliency is the ability of a production system to maintain productivity when affected by one or more stresses such as depletion of a micronutrient, build up of salt or pests, or changing markets for goods produced on the land. The rice-wheat cropping system of the Indo-Gangetic plains of Pakistan, India, Nepal and Bangladesh shows clear signs of stress and the Soil Management CRSP is working with local institutions and agencies to enable them to identify emerging stresses and find ways to remove them in ways acceptable to farmers (see *Rice–Wheat Systems* section). This represents a case where small investments in research can make a big difference in one of the world's largest food production systems.

How can biotechnology be applied to improve soil-plant relationships in the rhizosphere and what effect is genetic engineering having on the rhizosphere ecology? These are the questions the Soil Management CRSP is investigating in the new area of biotechnology (see *Biotechnology* section). Most plants maintain symbiotic associations with microorganisms in the rhizosphere. Are these symbiotic relationships affected in any Bt crops such as cotton, rice or maize? Answers to these and other biotech-related questions would soon be forthcoming from these newly established activities.

Finally, the Soil Management CRSP continues to respond to Mission requests for field support. It is probably no accident that the CRSP is involved in building human and institutional capacity in land resource management in the two former Portuguese colonies of East Timor and Angola (see *Field Support to Missions* section). Two Portuguese-speaking faculty members who learned the language as former CRSP graduate students in Brazil now help to bridge the language barrier in these countries. As in all CRSP efforts, the field support focuses on enabling host country staff and institutions to make better land use decision in a cost-effective and timely manner.

PROGRAM AREA PROGRESS REPORTS

Global Plan, Objectives and Program Areas

The global plan of the Soil Management CRSP is directed toward achieving food security in regions of the world where hunger and poverty are highest and enabling its clients to do so without compromising the sustainability of agro-environments. The plan gives priority to the food insecure regions of Africa, Asia, and Latin America where most of the 700 million food-insecure people live.

The three objectives of the Soil Management CRSP contribute to the on-going international effort to reduce food insecurity by focusing on the following:

1. Enable developing country institutions to apply information technology and knowledge-based tools to increase agricultural productivity.
2. Enable developing country institutions to scale-up technology adoption from local to regional scales by farmers.
3. Strengthen human and institutional capacity to combat poverty, land degradation and food insecurity.

To achieve these objectives, the Soil Management CRSP will focus on five program areas plus a sixth to respond to requests from USAID missions globally. Each of the program areas, projects and countries involved, principal investigators and host country institutions are listed in the following Table 1.

Table 1. List of participating U.S. universities with project title, principal investigators, collaborating countries and participating institutions.

Project Title	Countries	Principal	Participating Institutions Investigators
Program Area 1. Nutrient Management Support System			
Testing, Comparing and Adapting NuMaSS: The Nutrient Management Support System	Mali, Senegal, Ghana, Mozambique, Thailand, Philippines	Russell Yost, Tasnee Attanandana, Madonna Casimero	University of Hawaii Kasetsart University Philippine Rice Research Institute
Adoption of the Nutrient Management Support (NuMaSS) Software Throughout Latin America	Honduras, Ecuador, Brazil, Panama	T. Jot Smyth and Deanna L. Osmond	North Carolina State University
Program Area 2. Trade-Off Analysis			
Trade-Off Analysis Project Phase 2: Scaling Up and Technology Transfer to Address Poverty, Food Security and Sustainability of the Agro-Environment	Kenya, Senegal, Peru, Ecuador	John M. Antle	Montana State University
Program Area 3. Rice—Wheat Systems			
Enhancing Technology Adoption for the Rice-Wheat Cropping System of the Indo-Gangetic Plains	Nepal, Bangladesh	John Duxbury and Julie Lauren	Cornell University Cornell University
Program Area 4. Carbon Sequestration			
Measuring and Assessing Soil Carbon Sequestration by Agricultural Systems in Developing Countries	Ghana, Mali, Senegal, The Gambia, Cabo Verde, Nepal, Bangledesh	Russell Yost, James W. Jones and John Duxbury	University of Hawaii University of Florida Cornell University
Program Area 5. Biotechnology			
Assessing the Effects of Bt Crops And Insecticides on Arbuscular Mycorrhizal Fungi and Plant Residue Carbon Turnover and Fate in Soil	United States, China, Colombia	Medha Devare and Janice Thies	Cornell University Cornell University
Genetic Characterization of Adaptive Root Traits in the Common Bean	United States	C. Eduardo Vallejos and James W. Jones	University of Florida University of Florida
Program Area 6. Field Support to Missions			
Agricultural, Rehabilitation, Economic Growth and Natural Resource Management	Timor-Leste	Goro Uehara and Harold McArthur	University of Hawaii University of Hawaii
Improving Maize Productivity In the Planalto Area of Angola	Angola	Russell Yost	University of Hawaii

NUTRIENT MANAGEMENT SUPPORT SYSTEM (NUMASS)

Project: Testing, Comparing and Adapting NuMaSS: The Nutrient Management Support System

Project: Adoption of the Nutrient Management Support System (NuMaSS) Software Throughout Latin America

During Phase 1 of this SM CRSP, the investigators developed the NuMaSS software with the specific intent of facilitating the transfer and access of soil nutrient management information between research centers and decision makers at the farm and policy levels, i.e., from farmers and extension personnel to government ministries.

This phase of the project is intended to enhance the adoption of integrated nutrient management strategies by adapting NuMaSS through a network of ongoing programs in Africa, Latin America and Southeast Asia. This has the potential to benefit collaborators in many ways, from improved access to data to available information on the integration of nutrient management-related activities for N, P and/or soil acidity. In our approach to nutrient management issues, implementation and methodology, numerous parallels exist among various world regions. Shared activities among collaborators from different countries should lead to improved understanding of these issues and consequently improved diagnosis and prescription to meet the needs of the decision makers.

Africa and Southeast Asia Activities

Testing and adapting NuMaSS software and concepts in Africa has very different requirements than in SE Asia. For example, in Senegal, the implementation of NuMaSS and NuMaSS concepts begins with an inventory of local farmers' and growers' identification and awareness of nutrient management limitations. A survey was conducted to assess local opportunities and constraints for improving nutrient management. One of the results of the survey was that access to diagnostic tools was very limited. Interest was great in the possibility of extension officers and selected and trained farmers to learn to use soil test kits. A soil test kit workshop is being planned and several kits have been purchased for local use at research institutes in the peanut basin in the south, the peanut/millet area in the center and in the irrigated rice production area in the north. Test kit materials have been translated into French and will be available for other francophone countries. NuMaSS predictions are also scheduled for field testing. Interest is high in testing the K module that was developed in Thailand and incorporated into PDSS (Phosphorus Decision Support System).

In Mozambique, the SM CRSP in collaboration with National Institute of Agricultural Research (INIA) and Eduardo Mondlane University organized a training-workshop on soil and nutrient management. The three main objectives of the workshop were 1) to exchange experiences on soil and nutrient management among Portuguese-speaking scientists, 2) introduce soil test kit as a diagnosing tool and 3) develop a national research plan on soil and nutrient management. The workshop created great interest among participants as well as awareness about site-specific nutrient management concepts. Mozambican scientists, extension agents and NGOs have proposed follow-up activities of testing and adapting the soil test kit and predictions of nutrient requirements in different agroecological zones.

In Ghana, exploratory surveys were conducted at the Wa Station of the Savanna Agricultural Research Institute (SARI) in the upper west region of Ghana to elucidate farmers' perception of causes of low soil fertility. The intent is to apply NuMaSS to diagnose whether a given nutrient is lacking and if so, how much of it. A total of 85 farmers were interviewed. These included 19 females and 66 males. There were eight groups of approximately 10 farmers per group.

In Angola, discussions with the USAID mission in Luanda are near the final stage for developing a project on site-specific nutrient management that extends the work begun in Mozambique with the soil test kit training. Three Angolan scientists were sent to the Mozambique workshop and they have promoted the development of this program upon their return to Angola. A workshop on soil test kits and the use of NuMaSS is tentatively planned for August 2004.

In Thailand, the primary SM CRSP NuMaSS activity relates to the testing and confirmation of the NuMaSS N Prediction. Last year's testing suggested that NuMaSS over-estimated the crop N requirement. A more extensive study in the field in 2003-2004 also revealed that NuMaSS overestimates the N requirements of all 13 plots in the six provinces tested in Thailand. In contrast, previous tests of NuMaSS N prediction in the Philippines for upland rice were not greatly in error. An analysis of potential factors in the over-estimate occurring in Thailand failed to reveal the reasons for the NuMaSS and DSSAT over-estimates of N fertilizer requirement in the case of Thailand.

The K response study of field experimental data in 2003 revealed no response of K although the initial amount of both ammonium acetate and Mehlich 1 K was low. This might be due to the high non-exchangeable K present in some soils. All calculations of the K recommendations have been implemented in the PDSS version 3.1 and further testing will take place as part of a dissertation in progress by a student at Kasetsart University. The K predictions will also be field-tested in the Philippines, Mali, and possibly Mozambique in the 2004-2005 season.

The rock phosphate module of PDSS is being field-tested in paddy rice production systems in acid sulfate soils in Thailand with support from the Thailand Research Fund. If results are promising the algorithm probably should be tested in the extensive, but scarcely used acid sulfate soils of West Africa.

In the Philippines, on-farm experiments were established in five municipalities of four provinces (Ilagan, Isabela, Matalom Leyte, Tampakan and Tupi, South Cotabato and Antipaz, North Cotabato) to test, compare and adapt the NuMaSS. A baseline survey was carried out at all sites to gather pertinent sociological, economic and demographic information that will be used in the impact studies. Farmers and sites were selected based on set standards and protocols. NuMaSS recommendations consistently resulted in the highest yields in all on-farm trial sites. The ADSS, NDSS and PDSS in NuMaSS had very good prediction of the lime, nitrogen and phosphorus requirements, respectively, particularly during seasons without inclement weather in Isabela and Mindanao. Results indicated that the yield in plots applied with P at rates determined with NuMaSS-P were comparable to that of the no fertilizer control in both rice and corn. This demonstrates the important role of P in both crop (corn and rice) growth and development.

Despite the presence of ample supply of N and K, plants cannot sustain their normal growth without P. However, plants can grow without fertilizer N applications as demonstrated in plants in treatment NuMaSS-N. In all of the sites it was observed that corn grain yield based on NuMaSS recommendation did not significantly differ from the regional recommendation (RR). In many of the recommendations generated by NuMaSS, the N and P needed to obtain a target yield of 2.5 t/ha for rice and 4.0 t/ha in corn was lower than the RR. This result indicates that for the two crops to obtain substantial yields, they do not need such high amounts as the regional recommendation. This will be beneficial to farmers as they can save on the cost of inorganic fertilizers.

NuMaSS was able to predict the yield of corn in North Cotabato and South Cotabato. The grain yield of corn in North Cotabato was comparable among the three treatments, NuMaSS, RR, and NuMaSS-N implying that the absence of N in this area is not a very limiting factor for corn to produce good yields probably because of the high soil organic carbon present in the soil

During the project year, various papers were presented in local conferences and a chapter that discussed the previous work on extensive testing of the NuMaSS was published. A regional workshop participated in by local and international researchers and scientists in ASEAN was conducted in April 2004 to discuss the progress of the project and to plan for the Year 2 of Phase 2.

Latin America Activities

The goal in Latin America is to support the adoption of NuMaSS-based knowledge via a network of on-going programs throughout Latin America with potential to benefit from the improved access to information on soil N, P and/or acidity management. The primary target groups within the policy-to-farmer decision-making continuum are the national research/extension services, a group that provides, interprets and has immediate access to the location-specific soil and crop data required to develop nutrient recommendations and economic evaluations from the NuMaSS knowledge base.

Data with grain crops in the Amazon and pastures in the ‘Cerrados’ of Brazil suggest that lime recommendations based on the soil’s percent base saturation of CEC at pH 7 overestimates lime needs for sandy soils, thus increasing the risk of micronutrient problems and decreasing economic returns to liming. NuMaSS lime recommendations to neutralize exchangeable acidity in sandy Oxisols of the Amazon matched field-observed data in trials at two of three sites. As predicted by NuMaSS, cowpea and maize responses to N supplied by various manures and legume residues in a sandy Oxisol are constrained by a P deficiency. The exception, however, is chicken litter with contains a significant amount of available P. We suspect that maize and upland rice response to fertilizer N in a sandy Oxisol was limited by an S deficiency. If confirmed with ongoing tests, this illustrates another soil constraint (like K) where auxiliary information is needed for local NuMaSS adoption. Good yield response data is being acquired through N, P, K and lime trials at multiple sites, but backlogs in soil sample analyses are limiting our progress in data interpretations. Farmer adoption of experimental results in the humid tropics, through field observations, is out-pacing the rate at which we test and compare data with NuMaSS predictions.

The database-editing module has been programmed into NuMaSS and will be distributed to collaborators for further testing before the end of 2004. An interim version 2.1 of NuMaSS will also be released by the end of 2005, with corrections of several errors that existed in NuMaSS 2.0.

Collaborator interests throughout the network in adjusting NuMaSS to local conditions have been identified, as well as subgroups with common goals. Dissemination at the local level of NuMaSS-related results to farmers, extensionists and the agri-business sector continue through a combination of field day tours and their direct participation in ongoing activities.

Test and Compare NuMaSS Predictions on Nutrient Diagnosis and Recommendations with Existing Soil Nutrient Management

Africa

NuMaSS specifically facilitates transfer and access to information on soil nutrient management for researchers, farmers, extension services and decision makers. It is based on answers to questions related to soils, crops, available sources of fertilizers and input and output prices from stakeholders.

Senegal

To adapt NuMaSS to Senegalese agricultural realities, it is necessary to have baseline data to compare diagnosis with economical implications of management recommendations throughout multiple scenarios on soils, crops, and amendment and fertilizer sources.

On-Farm Survey

An on-farm survey to identify farmers' points of view, limitations and challenges for soil fertility management in the central and southern peanut basin was carried out in 10 rural villages, and 148 household heads were interviewed. It covered two agroecological zones: central and southern peanut basin of Senegal.

Among 148 farmers surveyed, respondents identified three soil types: sandy (27 percent), clayey (14 percent) and association sandy-clayey (57 percent). These are generally degraded (67 percent) and low in nutrient content and pose serious limitation to crop production. So, yield of crops are very low (millet 350-550 kg/ha, maize 600-800 kg/ha, sorghum 150-300 kg/ha, peanut 300-600 kg/ha, cowpea 100-200 kg/ha) and decreased during the last four years (1999-2002).

To restore soil fertility and increase yields, farmers utilize mainly manure alone (38 percent) with chemical fertilizers (54 percent). However, the quantity of available manure in each farm was small (3465 kg /year) and composting was not widely practiced (9 percent). Chemical fertilizers were also used by 63 percent of farmers and all respondents who use fertilizers indicated that it was purchased. The fertilizer types in use include compound fertilizer (NPK) and urea but the amount of fertilizers available on the farm are still low (341 kg/farm/year). The main constraint was the costly nature of fertilizers. The survey revealed that, in order to characterize poor soils, farmers use indicators based on: a) land appearance (the soil is light, sandy, white color), b) vegetation type growing in the field, c) signs shown by the growing crop. These are: (i) Millet: small and dwarf plants with thin stems, yellow leaves, thin no fully filled and thin heads with small and light grains; (ii) Maize: dwarf and stunt plants with thin stems, high mortality of plants, low height of cob insertion, yellow canopy, often lack of cob formation, bad cob filling and small grains; (iii) Sorghum: dwarf and stunted plants with thin stems, high mortality of plants, yellow canopy, often lack of head formation, head shielding, bad head filling and small grains; (iv) Peanut: dwarf and stunt plants, yellow canopy, early leaf falling, lack of gynophore's formation, small badly filled pods with immature grains; (v) Cowpea: dwarf and stunt plants, yellow canopy with small leaves, early leaf falling, low pod formation, small badly filled pods with immature and stunted grains.

Effects of Piliostigma on Soil Quality and Crop Yield

Given the high demand of crop residues and the insufficiency of animal manure, native plants can be used to supply organic materials to provide input to the soil organic matter, and therefore to improve soil quality. One such plant, *Piliostigma reticulatum* (*PR*), a shrub species, can grow on sandy, clayey and lateritic soils. After cutting, it can regrow up to 90 cm with a mean canopy diameter of 135 cm. Annually, 1270 g of anhydrous biomass/shrub are produced, for an average density of 317 shrubs per ha. If left uncut, the shrubs will continue to grow. Data from a survey show that PR is the third most appreciated species by farmers after *C. pinnata* and *A. albida*. Management consists of one cut for soil preparation and 2-3 more cuts depending on crop (weeding). A decomposition study of *PR* biomass has shown a greater mass loss under field than under controlled conditions. The decomposition study also showed *PR* (k) suitable for a continuous application of the biomass to the soil for cover and organic matter build up. The objective of the study was to determine the impact of *PR* on the soil physical, chemical and biological properties and the crop yield.

The trial has been ongoing since 2000, and the applied *PR* amendment consists of aerial biomass (stem + leaves) and the soil site characterized from initial soil samples analyses.

Results obtained on millet during the 2003 rainy season (3 year) are shown in Table 2.

Table 2. Results of millet trial using PR amendment during the 2003 rainy season.

Treatment	Plant Density no. plant/ha	Grain Yield (kg/ha)	Stover Yield (kg/ha)
Control	5478	138	848
T1: Mineral fertilization (at recommended rate)	11343	1435	2972
T2: 2.5 t PR dry matte/ha applied at clearing	7753	223	1057
T3 = T1 + T2	10494	1435	2775
T4: 2.5 t PR dry matter PR/ha at harvest	6096	150	758
T5 = T1 + T4	10108	1188	2578

Soil samples collected after harvest are being analyzed at ISRA-CNRA Soil, Plant and Water laboratory (Bambey), mainly for soil carbon.

Mozambique

A collaborative study with INTSORMIL CRSP was initiated in Mozambique. Over 100 soil samples were collected from the provinces of Cabo Delgado, Nampula, and Manica from cotton, sorghum, cassava, and maize production systems. These soil samples will be used to prepare maps of nutrient status and the NuMaSS diagnosis of nutrient status.

Mali

A modification and update of the NuMaSS/PDSS is in progress as the dissertation work of Ms. Aminata Sidibé-Diarra at the University of Hawaii. She has completed a laboratory study on a rock phosphate module, published the results, and now has conducted the first of several field studies in Mali.

Ghana

Exploratory surveys were conducted at the Wa Station of the Savanna Agricultural Research Institute (SARI) in the upper west region of Ghana to elucidate farmers' perception of causes of low soil fertility. The intent was to apply NuMaSS, to diagnose whether a given nutrient is lacking and if so, how much of it is recommended bearing in mind the eight cultural practices listed below. A total of 85 farmers were interviewed. These included 19 females and 66 males. There were eight groups of approximately 10 farmers per group.

The study catalogued the following farmer soil fertility management options:

1. All farmers practice natural bush fallow between 3 to 6 years.
2. Farmers use animal manure, especially cow dung for soil fertility maintenance, even though not every farmer owns a cow.
3. Crop residues, especially groundnut and cowpea vines are spread on the fields after harvest.
4. Most farmers apply small quantities of inorganic fertilizer due to high cost. We suggest that they combine the manure and limited fertilizer to increase efficiency of the latter.
5. The District Assemblies should encourage farmers to plant trees, especially legumes on their farms. Some NGOs, Suntaa Nuntaa, a Canadian Development Agency and the Ministry of Agriculture are already helping farmers in this effort.
6. Rotation of legume and cereal is one of major cropping systems in the region. Farmers who apply this method benefit from the rotational and crop residue effects if the residues are retained on the field after harvest.

7. Use of urban waste as manure for crop production is a recent development at the Wa district. Again, the District Assemblies and the Environmental Agency should encourage farmers to sustain this initiative.
8. Composting of crop residues and household refuse are part and parcel of farmers in the savanna areas. They do composting to reduce the amount of crop residue that is often bulky and difficult to transport over long distances to their farms. The resulting compost is also high in plant nutrients.

If the above eight management alternatives could be programmed in one of the NuMaSS modules, it would give producers the flexibility to select and test a given technology or a combination of technologies they often apply more rapidly. The automated approach, if it works, saves time and reduces production costs.

Farmers, community extension agents, policy makers and other stakeholders have been reminded of the various strategies to enhance soil fertility and farmers and extension agents informed about the need to apply inorganic fertilizers to supplement existing soil fertility management practices to increase crop yields.

Southeast Asia

Thailand

Nitrogen fertilizer is agronomically and economically the most important input into maize production. There are several software programs available to predict the amount of nitrogen (N) fertilizer required for crops. Among those are the DSSAT-N and NuMaSS decision-aids.

To test NuMaSS Nitrogen Recommendation treatments, a study was done to compare the two approaches and develop response curves to N and then compare the software predictions. The objective was to test the N fertilizer requirement for maize as predicted by NuMaSS using field experiments in the major maize producing provinces of Thailand.

The field experiments were designed to quantify N response by developing an N response curve at each site. These data will ultimately be used to refine the new N simulation. Thirteen experiments were conducted in six provinces. The soils were tested for NPK using the KU soil test kit and N recommendations were generated from DSSAT V. 3.5 and NuMaSS version 2.0. Nitrogen treatment levels were as follows:

Treatment 1: Check
Treatment 2: Recommendation from DSSAT v. 3.5
Treatment 3: 1/2 of treatment 2
Treatment 4: 1.5 of treatment 2
Treatment 5: An additional higher or lower rate to verify the response curve

Thirteen representative soil series were used in the N response study of six provinces. Nitrogen predictions using the DSSAT 3.5 and NuMaSS 2.0 were compared on 13 sites. In many cases both software predictions were higher than the field-estimated N requirements obtained from the response curves.

NuMaSS appears to over-estimate the N fertilizer requirement in nearly all cases. An analysis of the possible reasons for this over-estimate was made using the 13 field experiments from 2003. The check yield, or the yield of maize without the addition of N fertilizer, was considerably higher than expected in nearly all cases. In analyzing the errors in NuMaSS prediction, we proposed two reasons for the higher than expected maize yields: 1) The mineralization rate of organic N was higher than expected, or 2) residual nitrate was present in the soil profile at the beginning of the crop season.

The results indicate that substantially more N was found in the soil than expected in 12 of the 13 sites as indicated by estimates of soil N from check plot yields. Nonetheless, a correlation of the over-estimate with soil N levels was not significant, suggesting that other factors were also involved. Target yields were different in many experiments than those expected or used in the N calculation of NuMaSS-N module. However, no strong correlation was found between the over-estimate and differences in target and actual yields. We propose measuring residual soil N prior to planting to determine if initial soil N estimates are accurate. At present we are unable to determine the cause of the higher than expected yields on the control plots and the associated over-estimate of N requirement by both NuMaSS and DSSAT v. 3.5

Philippines

The on-farm testing of the NuMaSS was established on the three larger Philippine islands of Luzon, Visayas and Mindanao. Planting dates varied in the test sites. Two cropping seasons were covered in Luzon and Mindanao while in Visayas the trial commenced during the 2003 wet season. The results of the trial presented are from the 2002-2003 dry and wet

Table 3. Mean of soil chemical properties from the selected sites for NuMaSS on-farm testing in the Philippines.

Soft Chemical Properties	Critical Level	Luzon Area			Visayas Area			Mindanao Area		
		San Antonio	Sta. Victoria	Morado	Sta. Paz	Zaragosta	Elevado	Antipas	Tampalan	Tupi
Soil pH (1:1 soil-water ratio)	5.5-6.5	4.07	4.13	4.23	4.70	4.70	4.89	4.29	4.56	4.84
Organic Carbon (%)	2.0-3.0	1.10	1.13	1.50	1.28	0.92	1.18	2.91	4.29	6.13
Phosphorus (mg kg^{-1} soil)	> 10.00	0.64	1.62	0.50	1.54	1.89	1.74	17.32	97.62	18.18
Exchangeable (me $100g^{-1}$ soil)										
a. Acidity		2.48	2.58	2.68	5.34	3.58	1.37	4.31	3.20	1.40
b. Al	< 0.75	2.40	2.02	2.29	4.21	3.45	1.07	3.05	0.80	0.40
Exchangeable (me $100g^{-1}$ soil)										
K	> 0.45	0.10	0.06	0.14	0.45	0.20	0.04	0.38	0.12	0.07
Ca	< 8.00	1.02	1.88	1.03	2.37	0.93	1.31	0.30	0.14	0.47
Mg	> 3.00	0.32	0.44	0.70	1.60	1.30	1.53	0.49	0.34	0.32
ECEC (me $100g^{-1}$ soil)	> 20.00	3.92	4.96	4.55	9.76	6.01	4.25	5.48	3.80	2.26
Al Saturation	30.00	61.2	40.73	50.33	43.14	57.40	25.52	55.66	21.05	17.70
Clay (%)		53.0	55.0	48.0	42.0	44.0	42.0	44.0	34.0	22.0

season data in Luzon and Mindanao. Only the 2003 WS data are presented for Visayas (see Table 3).

Most of the selected sites have a high percentage of Al saturation ranging from 40 to 61 percent, (critical Al saturation level is 30 percent) except in three sites, one in Visayas (Elevado, Matalom) and two in Mindanao (Tampakan and Tupi), where the exchangeable Al are lower resulting in an aluminum saturation below 30 percent. Most of the areas have a clayey texture with percentage clay content ranging from 42 to 55 percent, an indication of a highly weathered and nutrient depleted soil.

Rice

Rice was the test plant in Ilagan, Isabela (Luzon) and in two sites in Mindanao, Antipaz, North Cotabato and Tampakan, South Cotabato during the 2003 wet season (WS).

The NuMaSS Recommendation treatment had significantly taller plants than the control, NuMaSS-N, NuMaSS-P and NuMaSS-lime. Significantly more tillers and longer panicles were obtained in the NuMaSS Recommendation compared to all other treatments. More filled grains/panicle were also observed in the NuMaSS treatment compared to the control, NuMaSS-P and FP. Owing to the weather conditions during the cropping season, the predicted yield of 2.5 t/ha was not attained but a trend was established wherein the NuMaSS recommended treatment consistently performed better than all the other treatments.

Fertilizer usage among farmers in Mindanao was higher than by that of farmers in Isabela. Our studies indicate that farmers are not well informed on proper fertilizer management in rice as they lack the necessary tools for diagnosing and predicting the right fertilizer rate. With the initial findings using NuMaSS, farmers can save on fertilizer costs with the reduced fertilizer rate applied and, at the same time, obtain higher rice yields.

Corn

Two sets of treatments for corn were set up in Ilagan, Isabela during the 2003 dry season. The actual yield obtained was slightly higher by 0.2 t/ha from the targeted yield of 5 t/ha indicating that NuMaSS predicted the N, P and lime requirement of corn during this season. Comparable yields were obtained among the NuMaSS, RR and NuMaSS + higher K recommendation. This result indicates that K may not be the critical factor affecting the yield of corn in Isabela. Yields obtained from these treatments were comparable to the farmer practice, which may reflect the greater importance of P than N for corn production in acid upland areas.

The wet season corn was planted in June 2003 in Matalom, Leyte (Visayas) and in Antipaz, North Cotabato and in Tampakan and Tupi, South Cotabato (Mindanao). NuMaSS treatments consistently produced the heaviest seed weight/cob and most number of seeds/cob. Grain yields in the control and NuMaSS-P were similar, indicating that P is the most critical nutrient at this. Only plots with NuMaSS recommended application rates yielded significantly higher than the control.

Also noted were the soil chemical properties after the cropping season. The results indicate that the acidic soil, when applied with the right combination of lime and inorganic fertilizers, can be ameliorated for crop production. Without this information and NuMaSS as a tool to help manage fertilizers in upland areas, farmers will continue with their old practices such as applying either very high or very low amounts of fertilizers and without lime application

NuMaSS recommended treatments consistently obtained the highest yield in all on-farm trial sites. In some sites, however, grain yield was lower than the target yield due to factors such as adverse weather conditions (water stress in the case of Isabela, Leyte and North Cotabato) and a typhoon (Isabela). Results indicated that the yield in plots applied with rates determined with NuMaSS-P were comparable to that of the control in both rice and corn. This demonstrates the important role of P in both crops on growth and development. Despite the presence of ample supply of N and K, plants cannot sustain their normal growth without P.

In all of the sites, it was observed that corn grain yield in NuMaSS recommended treatments did not significantly differ from the RR. In many of the recommendations generated by NuMaSS, the N and P needed to obtain a target yield of 2.5 t/ha for rice and 4.0 t/ha in corn were lower than the RR. This result indicates that for the two crops to obtain targeted yields, they do not require such high amounts of fertilizer as the regional recommendation (RR). This will be economically beneficial to farmers as they can save on the cost of inorganic fertilizers.

Latin America

NuMaSS uses various soil and crop coefficients in diagnosing nutrient constraints and recommending their corrections. Existing coefficients in the software come from extensive reviews of published and gray literature throughout the tropics. Field trials may be necessary to ensure that local crop cultivars and soil conditions are adequately represented by existing coefficients. Outcomes of such trials should be site-specific to meet the needs of the user groups.

INIFAP, Mexico

Research with NuMaSS in northern Mexico is on highly alkaline, relatively unweathered soils (Aridisols, Mollisols, and Vertisols). Because of the distinct differences of soils in this area compared to those used to develop the NuMaSS decision support system, nutrient recommendations may have to be modified, especially for P. No fertilization recommendation/calibration research has been conducted in the Tamaulipas province since 1985. Refinement of N and P recommendations is focusing on dryland and limited irrigation grain sorghum on selected major soil types of the region.

A series of five dryland and five irrigated on-farm N x P fertilization trials are being conducted throughout the Tamaulipas province in this project year and five on-farm strip tests using grain sorghum were also established in March under dryland (2) and limited irrigation (3) to compare the effectiveness of NuMaSS vs. other fertilizer recommendations. Treatments compared were NuMaSS recommendations, those of the Texas Agricultural Experiment Station in Weslaco, current local INIFAP recommendations, and a control with no added N or P.

All recommendations resulted in higher chlorophyll leaf meter readings for N than controls, except for the last irrigated site where leaf meter readings for the TAMU treatment were not different. NuMaSS treatments resulted in the highest readings, local treatments were intermediate, and TAMU treatments tended to be lowest.

Nitrogen
The first crop of corn and upland rice were harvested from two separate replicated N trials at the Terra Alta Exp. Station in June 2003. For corn there was a significant yield response to N ($LSD_{0.05}$=316) and the interaction between N and varieties ($LSD_{0.05}$=363), but no difference between mean yields for varieties. For rice, there was no significant yield difference between varieties, but mean yield response to N was significant ($LSD_{0.05}$=316).

A troubling aspect of the yield data for both crops is the small yield increment (~ 1 t/ha) across the entire range of fertilizer N, despite the split-applications to increase crop N use efficiency. An initial suspicion, which was not verified after further inspection, was that an old stock of fertilizer N had been used. Upon a subsequent site visit to these trials during the 2004 season, however, the light green leaf colors with even the highest N rate suggested the presence of a sulfur deficiency. If an S deficiency is eventually confirmed for these sandy Oxisols, then NuMaSS guidance on nutrient management will need to be revised to include occasional applications of fertilizer P as ordinary superphosphate.

Potassium

The first crop of corn and upland rice were harvested from two separate replicated K trials at the Terra Alta Exp. Station in June 2003. Potassium rates in each experiment ranged from 0 to 100 kg/ha as KCl, applied broadcast at planting. There were significant yield responses up to 25 kg K/ha with rice and 25-50 kg K/ha with corn. Fertilizer K increased significantly plant height and number of tillers and panicles in upland rice. Mean yield of rice variety Talento (2732 kg/ha) was superior to that of Bonança (2311 kg/ha), as were number of tillers and panicles. Soil test K levels at flowering stage of both crops were in the range of 0.04-0.06 cmolc/kg and are indicative of a high potential for losses by leaching in sandy soils under the humid tropical rainfall regime. These experiments are being repeated in 2004 with fresh applications of broadcast P. In 2004, upland rice was harvested from a replicated trial in the sandy Oxisol at Mr. Dutra's farm near Tracuateua and it is currently in a second crop of cowpea. Soil test K data for the cowpea crop confirm our interpretation of yield data, wherein delayed application of fertilizer K limits uptake of this nutrient by the 65-day crop, and there was a build-up of soil K as the proportion of fertilizer K was delayed from planting to 25 days.

Liming

At the request of farmers in the Terra Alta region, a lime trial was conducted at the Experiment Station in 2003/2004 to determine if an edible cassava ('macaxeira') tolerated the acidity in the sandy Oxisols. This is a cash crop for local farmers and, despite the cultivars origins in the high base status alluvial floodplains, there have been no investigations on acidity tolerance.

An experiment with three replications was initiated in 2003 at the Terra Alta Experiment Station to compare crop yields with three methods of lime recommendation: percent Al saturation, Minas and percent base saturation. Lime was applied in amounts equal to 0.5, 1, 1.5 and 2 times that recommended by each method. Uniform rates of N, P, K and micronutrients were applied to all plots and corn was planted as the first crop.

Despite considerable variation in the experiment, yield response to lime occurred up to 1 t/ha in the initial corn crop. The residual effects of these lime treatments will be monitored during subsequent cropping seasons to determine critical percent Al saturation values for crops and the dynamics of soil acidity regeneration.

CIAT-MIS Consortium, Honduras and Nicaragua

Last year, to test the NuMaSS Diagnosis, corn yield response to N, P and K fertilization in 31 site years of on-farm replicated field trials was evaluated for watersheds in Tascalapa, Honduras and Calico, Nicaragua. Predictions by NuMaSS Diagnosis of the presence or absence of a P deficiency, based on estimated Bray 1 P levels, matched the field data on 5 of 8 farm sites. Predictions by NuMaSS Diagnosis with the actual Olsen-extractable P data, and a fixed critical value of 15 mg/kg P, matched field-observed yield responses in seven of eight farm sites.

Identical NPK trials were conducted on a total of 23 farm sites in the Calico watershed in Nicaragua, during 2001 and 2002. NuMaSS Diagnosis of soil N constraints matched corn yield-based results on 22 of 23 farm sites. NuMaSS Diagnosis of the presence or absence of a P deficiency, based on estimated Bray 1 P levels, matched the field data on 16 of 23 farm sites. Phosphorus Diagnosis based on the actual Olsen-extractable P data and a fixed critical value of 15 mg/kg P, matched field-observed yield responses in 12 of 23 farm sites.

The number of "mis-matches" in the Nicaragua watershed between NuMaSS Diagnosis of a P constraint and field-observed corn yield responses to fertilizer P, raise questions about the software's estimates of critical soil P levels in these soils. Since very little field data on soil critical P levels was found in the existing literature for the region, new P fertilization trials were designed and are being installed during the current year.

Sites are being selected in Yorito, Honduras and Masaya, Nicaragua to initiate long-term P and N fertilization trials during the current year. The intent of the N x P factorial is to further investigate potential interactions between these nutrients that were observed in the on-farm NPK trials with single rates of each nutrient.

During the short rainy season of 2003/2004, an N fertilization and cover crop experiment was conducted at the Calico watershed in Nicaragua. Results from this experiment were presented at the CIAT-MIS Annual Planning Meeting in March 2004 to illustrate a network approach for testing and adjusting soil and crop coefficients related to fertilizer N recommendations. All of these N-related crop and soil coefficients will eventually be added to the NuMaSS database for use as default values when making N recommendations for the Calico watershed in Nicaragua. Members of the CIAT-MIS consortium are initiating similar trials at various locations throughout Honduras and Nicaragua. Each site will use corn varieties or hybrids that are commonly grown in their region. In some locations, where rainfall prior to the corn season is not sufficient for growing legumes, only the fertilizer N treatments will be used. These experiments will be conducted for two consecutive crop-years.

A two-day workshop was held at Zamorano, Honduras in September 2003 with representatives from eight soil-plant-water laboratories in Guatemala, Honduras and Nicaragua. Its purpose was to a) inventory lab procedures and services, and 2) explore development of a laboratory network for Central America. Representatives from seven laboratories either attended the meeting or provided information requested in a survey questionnaire: CURLA, FHIA, IHCAFE, UNA and Zamorano in Honduras, UCA and UNA in Nicaragua and ICTA in Guatemala.

Bolivia, Costa Rica and Ecuador

Activities in these three countries are reported jointly because they are related to potato-based production systems and project efforts to adapt NuMaSS P Diagnosis and Recommendations to soils from volcanic materials. The existing database for P in NuMaSS is based on knowledge developed in soils dominated by clays with crystalline mineralogy. In such soils, clay content is a useful proxy variable for site-specific adjustments of soil P critical levels and buffer coefficients. During development of NuMaSS, laboratory P incubation studies with soils derived from volcanic materials throughout Central and Northern South America indicated that differences in P buffer coefficients correlated with differences in amorphous Al extracted with either oxalate or KOH (IntDSS Project Annual Report for 2000-2001). Field trials with potato in Costa Rica and Ecuador will test the use of soil amorphous Al as a proxy variable for P diagnosis and recommendations in Andisols. Field trials in Bolivia on Inceptisols provide a reference point for soils with crystalline clay mineralogy and will test current NuMaSS diagnosis and recommendations of N and P for potato.

The first potato crop in Bolivia was harvested from N and P experiments at the Toralapa Experiment Station in April 2004. The optimum yield of potato was achieved with the recommended rate of urea-N by NuMaSS, but at a yield level that was 6 t/ha lower than initially targeted. This discrepancy could be due to a lower fertilizer N use efficiency or higher N uptake in tubers and tops of Waych'a variety than the default values currently used by NuMaSS for potato. Values for these crop coefficients will be determined once N analysis for plant tissues are completed.

For fertilizer P treatments, yield responses to broadcast and banded P match very well with the recommendations by NuMaSS, although there was poor agreement between the predicted critical soil P level and Olsen-extractable soil P in samples collected at flowering stage. There was essentially no significant difference in soil P among treatments. Anecdotal evidence exists of similar crop yield responses to fertilizer P without changes in soil test P for other upland crops in both Toralapa and smectitic soils of Guanacaste, Costa Rica. These soil test P results will be further investigated by comparing other P extractants (Mehlich-1 and Mehlich-3) as well as data for samples collected from the same plots at potato harvest.

IDIAP, Panama

N-fertilization trials for upland rice were conducted in Ultisols at the Calabacito Experiment Station and on farms at Mariato and Tonosi. There was a significant response to fertilizer N at all sites. Maximum grain yields ranged from 3.3 t/ha at Mariato to 5.7 t/ha at Tonosi. Optimum N rates ranged from 44 kg/ha with variety IDIAP-2503 to 84 kg/ha with variety CR-5272, both at the Tonosi site. The low yield response to N and the higher yield in the zero-N treatment at Calabacito relates to prior land-use; the site having been used for several years as a forage legume protein bank for cattle.

For corn, we continued to synthesize and interpret the data set that Roman Gordon assembled for 15 site-years of N fertilization and chlorophyll meter readings with corn in Alfisols of the Azuero region (see report for 2002-2003). One of our interests is the potential applications of the chlorophyll meter (SPAD) as an auxiliary tool for diagnosis and recommendation of fertilizer N. We have developed a new relationship, using SPAD readings at 65 days, which could be useful for predicting adjustments in site-specific fertilizer N rates for a subsequent corn crop. On-farm, replicated trials with multiple rates of banded fertilizer P allowed evaluations of NuMaSS P recommendations for corn in Azuero. Despite mean yields in the 7-8 t/ha range, there were no consistent trends of a response to banded P for any of the sites. These findings are consistent with NuMaSS recommendations, provided that due attention is given to the uncertainties (± values) associated with the predictions.

EMBRAPA, Brazil

At the request of EMBRAPA, a memorandum of agreement is under development with North Carolina State University. This agreement will be structured such that collaborative activities with any center can be added as Technical Cooperation Projects. We hope to have the agreement and projects finalized by the end of 2005.

Collaborative activities with CPATU focus on applications of NuMaSS in the State of Para for cassava and grain crop production, in both sandy Oxisols of the coastal region and clayey Oxisols in the degraded pastures region surrounding Paragominas. Field trials in the coastal region are concentrated at the Terra Alta Experiment Station and Mr. Dutra's farm near Tracuateua.

Because many of the farmers in the State of Para use soil analytical services and lime recommendations from South Brazil, the potential exists that some farmers may be overliming their soils, which can minimize short-term economic returns and lead to problems with micronutrient deficiencies.

Phosphorus
A long-term experiment near Tracuateua evaluating fertilizer P and organic inputs, and funded by the Brazilian National Research Council, is approaching harvest of cassava as the fourth crop. Preceding crops during 2002-03 were cowpea, corn and cowpea. The experiment had 20 treatments and 4 replications. There was a significant yield response to fertilizer P and yield difference between fertilizer P and organic sources in all three initial crops. Among the organic sources, higher yields with chicken litter were attributed to additions of both P and K in this material. Corn yields following Carnavalia, Mucuna and peanut, without N, P and K fertilizer, were between 800 and 1100 kg/ha and are indicative of the need to overcome soil P and K deficiencies to allow food crops to benefit from N supplied by legumes. Results from these experiments will be used to estimate the P buffer coefficients.

A second field estimate of the P buffer coefficient for these sandy Oxisols comes from a trial with banded P applications (0-176 kg/ha) at Mr. Dutra's farm near Tracuateua. As reported in the Year 6 (2003) report, there was a significant yield response by cowpea to 22 kg/ha of banded P. This matches the predicted P buffer coefficient for this soil by NuMaSS. A new long-term P experiment was initiated in 2003 on Mr. Dutra's farm with broadcast treatments of 0-88 kg P/ha and 4 replications. In 2004, upland rice variety Bonança was recently harvested in this experiment and residual fertilizer P continues to be evaluated with a current crop of cowpea.

A similar long-term experiment with broadcast P rates of 0-176 kg P/ha was initiated during the current cowpea cropping season at the Paragominas Experiment Station on an Oxisol with 65-70 percent clay.

Identify and Refine the NuMaSS Components that Aid Its Adoption and Usefulness

Southeast Asia and Africa

Potassium Test and Addition to the PDSS Software

To develop site-specific potassium (K) fertilization rates for the maize soils in Thailand, varying levels of K were applied to two soils, selected for their low initial K status, one in Nakhon Sawan province and the second in Nan province. The soils were collected and tested for NPK by both the soil test kit and standard laboratory methods.

Results from the two experiments indicate no response to increasing amounts of K although the initial soil contained 50 mg/kg of K by ammonium acetate extraction. This might be due to the non-exchangeable K in the Ln series, a Mollisol, in Nakhon Sawan.

The K buffer coefficient was expected to vary with the clay mineralogy. Quantitative clay mineralogical analysis was not available for all of these soils, thus another alternative as sought. We calculated the CEC/100g clay, which is often used to approximate mineralogy in soil taxonomic investigations. The results indicate that there were, indeed, large differences in the CEC/100g clay. As expected, soils with highly weathered clay minerals, such as the Ultisols and Oxisols, exhibited very low CEC/100g clay, while soils with less weathered clay minerals such as smectites and vermiculites were well represented in the high values. These results suggest that, indeed, there is a wide range of clay mineralogy represented in the maize soils of Thailand.

The influence of these properties on predicting the field estimates of the buffer coefficients was estimated using regression analysis. The resulting regression equations were used to predict the buffer coefficients for the 38 primary soil series under maize production in the four provinces.

Implementation of the K Algorithm in the PDSS (Phosphorous Decision Support System) Software

All calculations of the K recommendations have been implemented with three modifications to algorithms in PDSS version 3.1. First, the input data format of PDSS was modified to accommodate the K content of the soil and the K extraction method.

The second modification was the addition of the K diagnosis information to the Diagnosis report. The Diagnosis of K deficiency, although largely based on the soil test K levels, also includes some photos that were added to illustrate the symptoms of K deficiency.

A third change was the addition of a specific form for users to provide necessary information to calculate the K fertilizer requirement.

Finally a summary presentation of the last four components in PDSS (Diagnosis, Prediction, Economic analysis, and the summary Recommendation) was developed for K and can be printed, emailed or stored.

The K predictions will be field-tested in the Philippines, Mali, and possibly Mozambique in the 2004-2005 season. The rock phosphate module of PDSS is being field-tested in paddy rice production systems in acid sulfate soils in Thailand with support from the Thailand Research Fund (Royal Thai government). If results are promising the algorithm probably should be tested in the extensive, but scarcely used, acid sulfate soils of West Africa.

In Mali, a study on an implementation of the K algorithm has been proposed as an addition to PDSS and the NuMaSS software. This study will be carried out under the supervision of Dr. M. Doumbia with funds from IER/Mali.

Protocol for Field Testing and On-farm Evaluation of NuMaSS in the Philippines

The present prototype of the integrated decision-aids of the Soil Management CRSP has been developed from a limited set of data from Latin America, Asia and the US. Field testing of the NuMaSS software is required to determine whether nutrient management options developed within it provide useful management improvements for regions other than those from where the original datasets came. Testing agricultural management options must include tests in real situations if the options and choices are to be effective. One of the best ways to do this is to implement the options together with farmer practice; an objective of on-farm testing. This not only leads to an important and challenging test of the technology, but also generates new ideas and options for follow up. In effect, on-farm experiments can become an integral part of the research process.

A minimum of 10 and a maximum of 15 farms/farmers will be evaluated per season. Farms and farmers are to be selected to provide the maximum diversity of production situations. The following criteria are to be employed in the selection of farmers and farms:

1. With and without off-farm income;
2. Gentle (0-8%) and moderate slopes (8-16%);
3. With and without exposed Mn concretions;
4. Low and high pH;
5. Upland rice and maize;
6. Location of farm is accessible and near to the road or highway.

Selection of on-farm cooperators in three areas (Luzon, Visayas and Mindanao) will be based on the following criteria. The cooperators will 1) be barangay or community leaders with at least a high school diploma, 2) have been engaged in rice or corn farming in the previous three years, and 3) have a willingness to implement the project based on the memorandum of agreement (MOA) and demonstrate outcomes from the NuMaSS project to farmers in the local area. Ideally, an equal number of rice and maize farmers would be selected and yields and changes in cropping practices would be monitored for the same set of farmers for the next two to three years.

All operations other than nutrient recommendations would follow the farmers' practice. It will be important to identify farmers and the fields and crops to be used two to three months before the start of the crop season, conduct preliminary discussion with the farmers collect soil samples, complete soil analyses and use PDSS, ADSS and NDSS to calculate decision aid recommendations before crop seeding.

Treatment plots will be established and liming, where needed, incorporated one month before seeding. Fertilizer will be applied before or at seeding, and for both NuMaSS and regional recommendations, standard practices fertilizer management followed. Crop stands will be monitored after establishment and managed weekly. Farmers will be periodically interviewed.

Yield and biomass from a 5 m x 5 m sampling area should be collected at harvest, and fresh weight of bulk and fresh samples recorded, and oven-dry weight recorded after drying for 48 hours at 70° C. Farmers will be interviewed for their assessment of best treatment and reasons for their choices. Diagnostic tissues and harvest grain and straw samples will be analyzed for N, P and K (in the extreme/unusual observation of the treatment plots but in selected sites only). And finally, farmers' cost and prices noted for economic analysis.

The diagnostic discussion with the farmer before the crop season was to assess how and why the farmers make decisions on what to grow and how to grow it.

Climatic data in each locality such as *rainfall*, *temperature* and *evaporation* needs to be gathered.

Data on the prices of inputs, farm produce/products, interest rate of the loan money for farming, cost of rentals on the farm machinery if it was used and payment of the hired labor will also be needed to analyze the economic aspect of the project.

Latin America

Evaluations and interpretations of results obtained during testing and comparing NuMaSS predictions will identify the software components that should be refined to improve their performance at the local level. In some cases, refinements may be as simple as adding values to the software's database to serve as default coefficients for targeted regions of Latin America. Other refinements, that would require more extensive software modification, include revisions of guidance and caution statements about the management of recommended nutrients.

Scheduled activities for this objective will begin in 2004. Milestone events are network wide identification of NuMaSS weaknesses and refinement strategies in 2004 and 2005, and a revised software release in 2007. Nevertheless, we have identified and corrected several problems in the software that merit the release of an interim version. The database-editing module has also been programmed and is ready for testing by collaborators.

Interim Version 2.1 of NuMaSS

Version 2.1 of NuMaSS (Deanna Osmond and Jot Smyth of N.C. State Univ., Will Branch of Understanding Systems, Inc. and Russ Yost and Hu Li of the Univ. Hawaii) was ready for release in September 2004. As we have continued to work with NuMaSS under a variety of our collaborators' location-specific conditions, we have identified crop-soil-ecosystem combinations where the algorithms do not work as expected. The primary corrections/adjustments for Version 2.1 are as follows:

1. Nitrogen module—corrected how existing algorithms in "Prediction" addressed certain legume cover crop or organic N sources when combined with inorganic N sources; revised how harvest index values used in "Prediction" are retrieved from data tables for certain crops.
2. Phosphorus module—corrected registry access to information the user provides in "Geography" by clicking on the map; corrected the reset of a value associated with P application method in "Prediction."
3. Economics—corrected an error in the ranking of most limiting nutrients which caused the module to stop when N was recommended under the condition of a fixed lime rate and P was only needed to sustain soil P levels.

The interim version of NuMaSS can be obtained by contacting Jot Smyth at Jot_Smyth@ncsu.edu. Since NuMaSS 2.0 was available for download from the website in January 2003, tracking of the countries from which download requests originate has been possible. During the last 18 months, 113 downloads with unique identifiers from Africa (11), Asia (26), Europe (2), Latin America (68) and North America (6) have occurred. The countries involved are 8 in Africa, 11 in Asia, 2 in Europe, 6 in Latin America and 2 in North America. Over half of these downloads have been from Argentina (61). As public domain freeware, each of these downloads can potentially be distributed to a number of local users.

NuMaSS Module to Customize the Software's Data Bases

NuMaSS 2.0 (Deanna Osmond and Jot Smyth of N.C. State University and Will Branch of Understanding Systems, Inc.) has fourteen different data files with information on crops, soils, fertilizers, manures, legume cover crops and diagnostic probabilities of nutrient deficiencies. Specificity of recommended default values by the software depend on how much data is available in these tables. Users can improve local performance of the software and reduce repetitive tasks of data input by adding their local values to the software's data tables. In NuMaSS 2.2., users will be able to customize selected coefficients in these NuMaSS data tables: crop yield, crop critical level, legume cover crops, manure, fertilizers, soils and references, and data base customization will be implemented through the current "Options" tab in NuMaSS.

Feedback from collaborator testing of the data base editor module, during the next project year, will be used to determine whether any refinements or corrections are needed prior to the public release of version 2.2 of NuMaSS.

Adapt NuMaSS Database and Structure to Users and Regions

Africa

Mozambique

The SM CRSP in collaboration with National Institute of Agricultural Research (INIA) and Eduardo Mondlane University organized a training-workshop on soil and nutrient management. The workshop took place in Maputo, from March 22–26. The participants came from Angola, Cape Verde and different provinces of Mozambique representing governmental and NGOs entities. The three main objectives of the workshop were 1) to exchange experiences on soil and nutrient management among Portuguese-speaking scientists; 2) introduce soil test kit as a diagnosing tool and 3) develop a national research plan on soil and nutrient management. The workshop created great interest among participants and generated awareness about site-specific nutrient management concepts. Mozambican scientists, extension agents and NGOs have proposed follow-up activities of testing and adapting the soil test kit and predictions of nutrient requirements in different agroecological zones.

Angola

Discussions are near the final stage of developing a project on site-specific nutrient management in Angola that extends the work begun in Mozambique with the soil test kit training. Three Angolan scientists were sent to the Mozambique workshop and they have promoted the development of this program upon their return to Angola. A workshop on soil test kits and the use of NuMaSS is tentatively planned for August 2004.

Southeast Asia

On 20-21 April 2004, the 2nd Annual Workshop on Decision Aids—NuMaSS On-Farm Testing in SE Asia—was held at the Philippine Rice Research Institute, Maligaya, Munoz, Nueva Ecija, Philippines. Approximately 30 researchers and extension workers from the Philippines, Laos and the USA participated. Progress made in 2003 for on-farm testing in the Philippines was reported, and the baseline survey results presented. During the workshop, retooling of the extension workers on the NuMaSS version 2.0 was done. The software was found to be user friendly and easily learned for extension workers' use. Part of this activity was to enable extension workers and researchers to identify parts of the modules that needed improvement so the NuMaSS software could be adapted to local conditions. Some of the suggestions were to:

1. Include the K module for nutrient constraint;
2. Include diseases in the agronomic constraint;
3. Include pictures and description of indicator plants preferably at various stages found locally.

A further suggestion for consideration is the multiple planting seasons commonly found in tropical regions. For example, in the Philippines, farmers plant crops in two distinct seasons. This variable is not taken into consideration in the NuMaSS software. Fertilizer rates normally vary in the wet and dry season such that rate applications are lower in the wet season than in the dry season because of less solar radiation and more cloudiness.

Latin America

Although project activities target collaboration with national agricultural research service staff, participation of their extension and agri-business counterparts is encouraged. The intent is to collectively identify within each target region methodology to facilitate the transfer and use of NuMaSS information beyond users with immediate access to the computer software. Milestone events include a survey of collaborators goals for local software adoption in 2004, follow-up surveys in 2005 and 2007, and production/release of auxiliary tools, as needed, from 2004 to 2007.

As collaborators gain confidence in the ability to adjust NuMaSS local performance, through their ongoing field and laboratory tests, the types of auxiliary tools needed to enhance local use of the software knowledge will become more apparent.

As mentioned earlier in this progress report, collaborators with common interests include the CIAT-MIS consortia in Central America; potato production systems in Bolivia, Costa Rica and Ecuador; the use of chlorophyll meters (an auxiliary tool) with N recommendations for sorghum and maize in Mexico and Panama; nutrient management for upland rice production systems in Brazil and Panama. Because network-wide workshops are cost-prohibitive, collective dialogue among these common interest subgroups can be achieved through a network-wide information exchange. This exchange would be established through various conduits: a) distribution of these annual reports, b) summary presentations and discussions of annual report findings during site visits and c) e-mail correspondence.

Dissemination of results at the local level occurs through various formats. EMBRAPA-CPATU continues to provide annual field day tours of activities at the Terra Alta Experiment Station and on-farm trials at Tracuateua to extension, agri-business and farmers. Farmers, extensionists, students and agricultural finance officers attending the field day in 2003 at Mr. Dutra's farm totaled 150. About 100 individuals attended a similar field day at the Terra Alta Experiment Station. Thereafter, Dr. Cravo and Mr. Dutra were invited to prepare technical coefficients, at the request of the regional bank (Banco da Amazonia), for use in loans to the area's farmers. On June 7, 2003 Dr. Cravo provided an interview for the 'Agro Amazonia' program on 'Record' TV. The impact in the Tracuateua region was readily evident during this year's site visit; farmers had shifted from an annual production system with a single crop of cowpea with modest fertilizer P inputs to cowpea rotations with upland rice and maize and integrated management of lime, N and P inputs. Timing of nutrient inputs, plant populations, varieties and levels of lime and fertilizer were very similar to the "best" combinations used in the on-farm experiments. Also in 2003 and using the trials at Mr. Dutra's farm, training was provided on cowpea production options for extension agents in 28 surrounding counties. Due to the limited farmer-service capacity of the existing labs at EMBRAPA-CPATU, many farmers have depended on soil analyses and recommendations from labs in Southern Brazil. Results from ongoing trials, eventually, will provide evidence as to whether nutrient recommendations based on research in the Cerrados region are applicable or not to this humid tropical region.

A field day was also held at the Toralapa Experiment Station in Bolivia, where local farmers and extension staff toured the N and P trials with potato. Collaborators in the CIAT-MIS consortia include university, research and extension organizations. Thus, NuMaSS-related activities are both disseminated to farmers and used in formal education programs.

TRADE-OFF ANALYSIS

Project: The Tradeoff Analysis Project Phase 2: Scaling Up and Technology Transfer to Address Poverty, Food Security and Sustainability of the Agro-Environment

In Phase 1 of the Tradeoffs Project developed a policy decision support system based on tradeoff analysis of agricultural production systems, and applied that system to two watersheds in Ecuador and Peru. The first phase emphasized the development of the Tradeoff Analysis (TOA) method, and analytical tools to implement it (data, models and software for their integration). A significant product of the first phase was the Tradeoff Analysis Model, computer software that integrates disciplinary data into standard geo-referenced formats, and provides a modular capability to link existing disciplinary simulation models to support the TOA method.

For Phase 2 of the project, we proposed to (i) further develop and refine the existing TOA method and TOA Model software through applications with collaborating institutions in the Andes, West Africa and East Africa, (ii) develop methods to scale-up the analysis possible with the TOA method from single agro-ecozones (e.g., watershed scale) to larger regional scales and (iii) develop protocols and materials to transfer TOA method and TOA Model software to existing and future user groups. Applications of the TOA method will involve a wide range of stakeholders, including farmer organizations in the study sites, agricultural research organizations and local and national governmental and non-governmental organizations involved with agricultural development.

Refinement of the TOA Model

A major goal of the Tradeoff Project for Phase 2 was to further develop and test the TOA approach and tools through new applications with collaborating institutions. The strategy was to develop collaborations in Phase 2 based in and managed by the collaborating institutions.

Under this strategy, the Tradeoffs Project would provide training and technical support for new applications but would not provide operational funding. However, it was also recognized that demonstration applications would be needed to convince potential collaborators that the approach and tools would be useful to them. Therefore, in West Africa an initial application using available data was prepared for the Senegal peanut basin and was used for the Dakar workshop, described below. Likewise, a preliminary application in Kenya was developed for the Nairobi workshop to be held in September 2004 (see following section).

In the case of Peru, an in-depth case study was carried out by the Tradeoffs project in Phase 1, and that study was expected to be used as the illustrative example on which further collaborations with governmental and non-governmental organization could be build. The strategy appears to have been successful where an external funding source was available to support the institution's buy-in to the use of TOA tools in East Africa, and in West Africa and Peru, though here most of the operational funds continue to come from the Tradeoffs Project budget.

Our experience thus far indicates that institutions would like to adopt TOA and similar high-level analytical tools, but it is rare for national institutions to have the personnel and resources sufficient to support adoption and use of these tools without externally funded projects.

Development of a West African Research and Training Program

A major objective for Phase 2 is to develop a Tradeoffs project presence in West Africa. Bocar Diagana leads this component of the project. The following major activities were carried out:

- A one-week training workshop was held at the Ecole Nationale d 'Economie Applique (National School of Applied Economics) in Dakar in November 2003. Scientists from Senegal, Ghana and Mali participated. The training materials developed for the workshop and the workshop products can be viewed on-line at the project web site (www.tradeoffs.montana.edu). A key product of the workshop was a work plan for a TOA application by each team that participated.
- As part of the Dakar workshop, a preliminary analysis of technical and economic potential for soil carbon sequestration was carried out, in collaboration with ENEA and the Peanut CRSP. The results of this analysis were presented at the February 2004 workshop held in Bamako. This

preliminary analysis shows that there is some potential for farmers to participate in carbon trading. However, more data are needed about the technical and economic feasibility of key management practices that would increase soil carbon.
- Additional data are being collected in Senegal to strengthen the preliminary analysis of soil carbon sequestration potential carried out in 2003. These are: 1) the implementation of a farm-level survey to collect additional data for the Senegal carbon analysis because the preliminary analysis used for the Dakar workshop was based on data collected by ENEA in 2001; 2) the collection of more detailed soils data to establish a relationship between carbon stocks and land use history in Nioro; 3) a study of fertilizer markets conducted in collaboration with ENEA and the Peanut CRSP to have better data on institutional and policy factors affecting fertilizer use; and 4) in collaboration with ISRA scientists, assembling data on the costs and technical feasibility of practices that sequester carbon for further analysis of soil carbon sequestration potential.
- Based on the Dakar workshop, an agreement was reached with scientists from Ghana (SARI), and with Jim Jones (SM CRSP) to collect additional economic data in order to carry out a TOA analysis of soil carbon sequestration in northern Ghana where the SM CRSP Carbon project is already working with SARI to collect biophysical data.

Development of an East Africa Research and Training Program

Another major objective for Phase 2 is to develop a Tradeoffs project presence in East Africa. In September 2002, TOA team members (Antle, Crissman, Diagana, Stoorvogel) met with potential collaborators (ICRAF, ICIPIE, KARI) in Nairobi and at Egerton University. Verbal agreements were made to pursue collaborations with ICRAF and KARI, and draft proposals for collaboration were prepared, as reported in the previous annual report. The Dutch Ecoregional Fund agreed to fund further applications of the TOA methods in East Africa under Stoorvogel's direction. Gibson Guvheya was hired in September 2003 to coordinate the East Africa activities. Key accomplishments in PY2 include:

- The first work co-funded by the Ecoregional Fund and the SM CRSP was the analysis of the sustainability of the production system in the Machakos region discussed below. This application was implemented successfully using the data from the Nutrient Monitoring (NUTMON) research program based at Wageningen (www.nutmon.nl). The following resulted: 1) a set of procedures for adapting the NUTMON data for TOA analysis was developed and documented, which will facilitate use of TOA in other NUTMON applications; and 2) the NUTMON nutrient balance model was incorporated into the TOA modeling framework.
- Plans for a one-week East Africa TOA training workshop were finalized. The workshop will be held at ILRI September 6-10, 2004 and the Machakos TOA application will be used. Participants will include research teams from ICRAF, Egerton University (Livestock/Pond Dynamics CRSP Njoro watershed study), KARI, and the NUTMON project in Uganda.
- Plans for collaboration with ICRAF were finalized. The TOA team will support the use of TOA modeling tools to assess carbon sequestration potential in the Lake Victoria region of Western Kenya. This research is part of a GEF-funded project based at ICRAF.
- Plans for collaboration with the Njoro watershed project (Egerton/Livestock/Pond Dynamics CRSPS) were finalized. Sian Mooney (U. Wyoming, Ag. Economics) will lead the TOA application. An MOU, joint work plan and budget were developed.
- The TOA team met with John Lynam (Rockefeller Foundation, Nairobi). Lynam agreed to consider a proposal to fund a TOA application by the Nutrient Monitoring project in Uganda (also funded by Rockefeller). The Uganda team has been invited to participate in the Nairobi training workshop.
- Reinier Ellenkamp is undertaking soil survey work in Machakos. His masters thesis is expected to be completed September 2004.
- A key component of the East Africa program was the hiring and training of an economist post-graduate researcher to lead the economic component of the Tradeoffs Project activities in the region and to coordinate activities in the region. Crissman in Nairobi is hiring an economist with an MS degree to meet the project needs, and a post-graduate researcher working for the project (Valdivia) who has a high degree of experience with the TOA Model will provide technical support to the collaborating project teams adopting TOA in East Africa.

Machakos, Kenya Case Study

Development of a Whole-farm Approach to TOA Analysis for Mixed Crop-Livestock System

Previous applications of the TOA modeling system used the farmer's field as the basic unit of analysis, principally because this was appropriate for the applications and data available. Nevertheless, it was recognized by the TOA team that this posed a potentially significant limitation for future applications where mixed crop-livestock systems would predominate. Using data from the Nutrient Monitoring project in Machakos, Kenya, the TOA team developed a whole-farm model that incorporates both crop and livestock. This whole-farm approach will be the basis for the generic TOA model framework that will be used in most future applications with collaborating institutions.

Development of Poverty and Food Security Indicators for Use in TOA Analysis

A major advantage of the whole-farm modeling approach is that it allows economic returns from crop and livestock to be aggregated to the farm household level and combined with off-farm income. Using these variables, it is then possible to construct indicators of income per household member. Because the TOA modeling approach is a statistical approach designed to represent the population in a region, these data can be translated into measures of poverty incidence and food security, i.e., proportion of households with per-person income below a poverty threshold, and proportion of households with per-person calorie availability below a food security threshold. This analysis was implemented for the Machakos study in Kenya. Results were consistent with the poverty incidence estimated in a recent study by ILRI. With the TOA modeling system, it is possible to then assess the potential impact of technology or policy interventions on poverty, food security, and sustainability of the production system.

To illustrate we present results of our preliminary analysis in Machakos, Kenya (Figures 1 and 2). We simulated tradeoff curves for three scenarios by varying the price of maize (the principal staple commodity) from 75 percent below the base value to 100 percent above the base. The first scenario is the base technology; the second scenario is constructed by increasing the productivity of organic fertilizers and frequency of use by 50 percent (manure and composted materials); the third is constructed by assuming

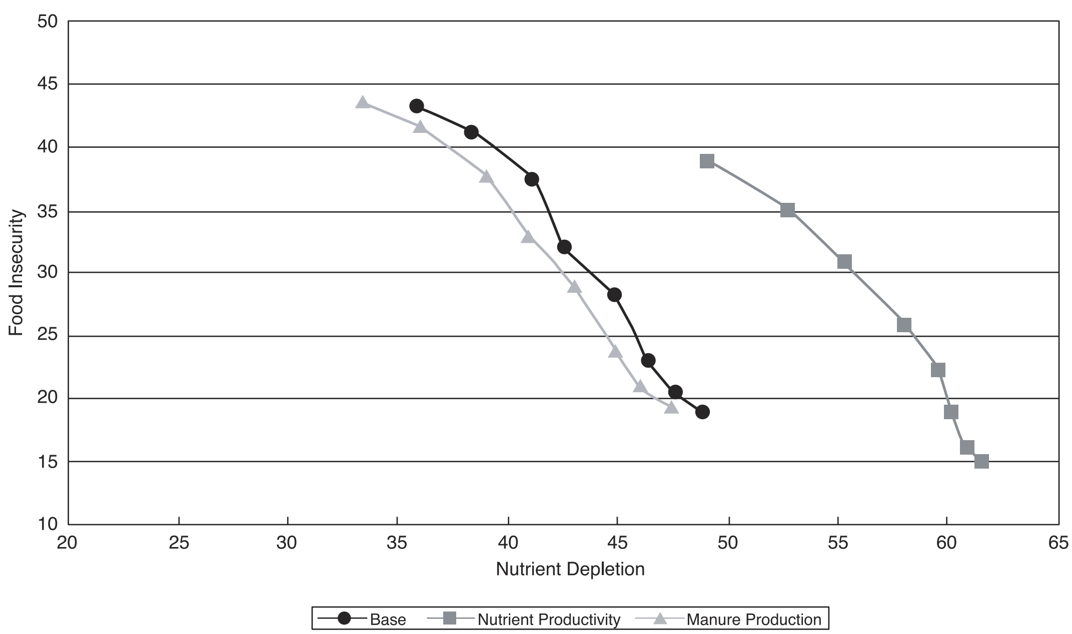

Figure 1. Tradeoffs between Nutrient Depletion and Food Insecurity in Machakos, Kenya, under the base scenario, with increased productivity of organic fertilizer, and with increased manure production (tradeoff is generated by varying maize price from 75 percent below the base to 100 percent above the base).

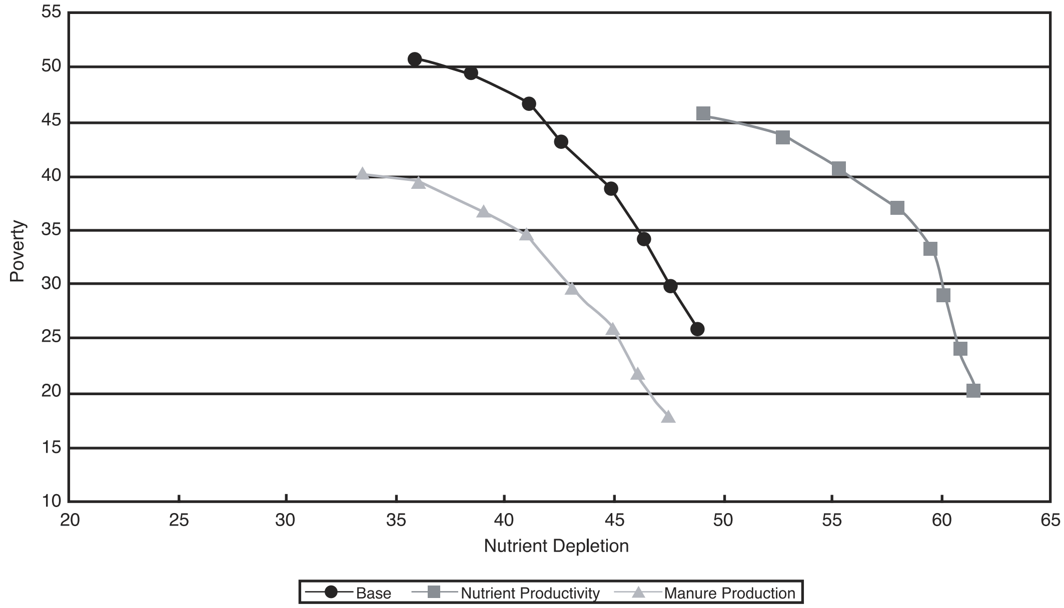

Figure 2. Tradeoffs between Nutrient Depletion and Poverty in Machakos, Kenya, under the base scenario, with increased productivity of organic fertilizer, and with increased manure production (tradeoff is generated by varying maize price from 75 percent below the base to 100 percent above the base).

manure production increases by 100 percent. Figure 1 shows that at base prices and technology, about 32 percent of the households are food insecure, and that soil nitrogen loss rates average about 43 kg/ha, indicating that there is a net outflow of nutrients from the system on average (the base point is the fourth point on the curve counting from the left, with maize prices increasing from left to right).

The nutrient productivity scenario somewhat reduces food insecurity while it significantly increases nutrient depletion. This latter effect is explained by the effect of nutrient productivity increasing the intensity of crop production. The manure production scenario shifts the curve in the opposite direction, but is not much different from the base scenario. All three scenarios show that there is a substantial effect of the maize price on food security and nutrient depletion, with food insecurity declining by over 40 percent as the maize price doubles (base scenario), but with nutrient depletion increasing by about 20 percent. Thus, the analysis provides clear evidence of a strong tradeoff between system intensification through price changes and the long-term sustainability of the system with a static technology.

Figure 2 shows the same scenario analysis for the tradeoff between poverty and nutrient depletion. In this case the fertilizer productivity scenario shifts the curve in a manner similar to Figure 1, whereas now the manure scenario substantially shifts the tradeoff curve in a favorable direction, reducing both nutrient depletion and poverty. Thus, whereas the fertilizer efficiency increase intensifies the system and thus results in a reduction in poverty and food insecurity, this improvement comes at the cost of greater nutrient depletion if more nutrients are not available. In contrast, the increased availability of manure (which could come from increased efficiency of manure and crop residue management, or from an external source) favorably impacts poverty, food security, and sustainability of the system.

Northern Peru: A Case Study of the Sustainability of Terraced Production Systems

Several activities were undertaken in Phase 2 based on research conducted in the Cajamarca region of northern Peru during Phase 1. This work will be completed during PY3, but the activities of PY2 were as follows:

- ***Tradeoff analysis of terracing and related technologies.*** Field data on soil properties of terraced and unterraced fields were collected to complete the DSSAT-based analysis of terracing and related technologies. These data are reported in van den Broek, Stoorvogel and Yanggen (2004). A journal paper on the methodological issues involved in using DSSAT models to simulate productivity in terraced fields will be prepared in PY3.

- ***Analysis of carbon sequestration potential.*** A preliminary analysis was conducted and a report prepared (see Antle et al., 2003). However, additional data were needed to support the analysis of agroforestry in terraced systems. Fieldwork is currently underway and will be completed in Fall 2004. Subsequently the economic analysis will be completed and submitted for publication.
- ***Impacts of climate change in terraced systems.*** IPCC climate scenarios are being used to assess impacts of climate change. The analysis is in process and a report will be written up in PY3 for publication.

Incorporation of the CENTURY and DSSAT/CENTURY Models Into the TOA Model Software

Both CENTURY and DSSAT/CENTURY model interfaces are now available in the TOA Model software. The DSSAT/CENTURY model is being used for the carbon analysis in Peru and Senegal. The CENTURY interface will be used in the applications being carried out for CASMGS. Updated TOA documentation for these interfaces will be prepared in PY3.

Development of a New Version of the TOA Model Software that Incorporates Dynamic Feedbacks Between Biophysical and Economic Models

Basic research on this theme was conducted in PY1 and PY2. A new version of the TOA software is being developed that will allow feedbacks between disciplinary models to be incorporated into the simulation structure. This work is being done with collaboration from CASMGS investigators. The next generation of TOA software will incorporate a method for simulating system dynamics in conjunction with the DSSAT/Century model and dynamic economic models.

Development of Livestock Models that Can Be Utilized in the TOA Model System

Roberto Quiroz (CIP Lima) is leading efforts to develop and test the usefulness of livestock models for use in the TOA model system. Research in PY2 incorporated a pasture growth model into an existing dairy production model, and tested the sensitivity of the models to feed inputs. This model will be available for use with the TOA Model software by the end of PY2. It will link with the farm-household version of the TOA Model described above that incorporates mixed crop-livestock systems.

Adapting the WEPP Erosion Model to Simulate the Impacts of Terracing on Erosion

Consuelo Romero (National Ag University, Lima) is completing work on the WEPP application in northern Peru in PY2 to further test the ability of the WEPP model to simulate the impacts of terracing on erosion by modifying soil properties and slope parameters.

Process-Based Interpolation Methods for Weather Data

Within the TOA project we are developing methods to disaggregate existing general soil surveys using digital soil mapping and to interpolate weather data. Guillermo Baigorria developed process-based interpolation techniques for daily weather data in terms of minimum and maximum temperature, solar radiation and rainfall. In addition, the values of the interpolation methods are evaluated for environmental process models, crop growth simulation models, digital soil mapping and tradeoff analysis.

Scale-up the TOA Method Analysis From Single Agro-ecozones to Larger Regional Scales

A previous investigation of fractal methods by Robert Quiroz (CIP Lima) and collaborators were assessed for their use in estimating moments of net returns distributions used in economic models. Baigorria is investigating methods to scale biophysical input data for use in environmental process models used in TOA. Antle and collaborators are completing research on two non-CRSP projects where scaling of integrated assessment models is being investigated. The results of these projects will be utilized to develop a strategy for scaling-up TOA analysis. One of the key conclusions of this work to date is that use of aggregated data results in a significant bias in some analyses. Another key advance is the development of minimum-data methods for application of the economic simulation models used in TOA. This minimum-data approach utilizes secondary data such as agricultural census data, together with other available data, to estimate net returns distributions. This approach appears to hold more promise for scaling up TOA analysis than the use of aggregate data. This minimum data approach will be utilized and further tests in the application being implemented in Panama, and if successful will become a standard part of the TOA modeling approach to be used where more detailed data are not available.

A proposal to leverage resources for a follow-up phase of the Ecosalud Health Project focused on scaling up and scaling out of the research-intervention methodology of the previous phase is planned. Scaling up refers to expanding geographic coverage of pesticide activities to a representative cross-section of Andean regions within Ecuador; whereas scaling out refers to the broadening of the research focus to include nutrition as a second key health outcome related to agricultural production. A "bridge funding" proposal has been funded by IDRC and the final proposal has been submitted and is pending review by IDRC.

Develop Protocols and Materials to Transfer the TOA Method and TOA Model Software to Existing and Future User Groups

The TOA model, sample programs and workshop materials can be downloaded from www.tradeoffs.nl. These materials formed the basis for the Senegal workshop and will be used in the Kenyan workshop. Based on the Dakar experience, these materials will be updated for the Nairobi workshop. At that point we plan to develop a new, standardized version of documentation that can be used for future training activities.

A large number of research projects have made use or are using the NUTMON toolbox for monitoring tropical farming systems. Although NUTMON provides detailed information about these systems, it does not allow for a regional analysis of possible policy interventions. At the moment, we observe a general trend that NUTMON studies are followed up by on-farm participatory research (e.g., through farmer field schools). The NUTMON-tradeoff interface allows for a new way of analyzing the NUTMON data at the regional level currently illustrated for Machakos. Four different projects are interested in the application of the TOA methodology. Linkages with the NUTMON projects are a way to greatly expand the general applicability of the TOA method and software and also to develop further collaborations in the East Africa region and elsewhere in the world where the NUTMON methodology has been applied.

Through our Phase 2 experiences developing new collaborations, we have established a process for transferring the TOA method and tools. The process of institutionalization includes the following steps;

1) Informing project staff;
2) Project training through workshops;
3) Formalization of the process to incorporate TOA;
4) Execution of TOA by project staff with backstopping of TOA-team; and
5) A second workshop to bring the different projects together and jointly share experiences and solve problems.

RICE-WHEAT SYSTEMS

Project: Enhancing Technology Adoption for the Rice-Wheat Cropping System of the Indo-Gangetic Plains

The rice-wheat cropping system is one of the world's major food production systems. It occupies 20 million ha and provides staples for over one billion people. Half of the land area in this system is found in the Indo-Gangetic plains (IGP) regions of Pakistan, India, Nepal and Bangladesh. The remaining half is in China. With deep alluvial soils and widespread access to irrigation, agriculture in the IGP is not the risky venture that it is in many developing countries. Nevertheless, the rice-wheat system is clearly under stress. Declining yields in long-term experiments, stagnating and possibly declining productivity of rice in NW India and declining factor productivity indicate that the sustainability of the rice-wheat system is questionable.

The overall goal of the project is to enhance technology adoption in the rice-wheat cropping systems of South Asia. Essential elements in our program to meet this goal and to monitor adoption and access impact are:

- Selection of effective technologies that address major constraints to crop productivity;
- A non-linear technology transfer model with feedback loops;
- A GIS framework to address spatial dependence and for program documentation;
- A collaboration with technology transfer partners who work at national and international scales;
- Development of information transfer materials to aid training activities;
- Documentation of technology impacts and technology adoption outcomes;
- National scale analyses of technology adoption impacts to support policy decision making; and
- Strategic research on key technologies and combinations of technologies.

Our specific objectives are to (i) develop methods to accelerate technology transfer of soil management products and practices, (ii) develop methods to scale up technology adoption from participatory scales to national and regional scales, (iii) develop methodologies that provide farmers, government agencies and policy makers with information needed to design policies that encourage the adoption of production practices that are compatible with the long-term conservation of agricultural resources and to (iv) continue development of key technologies.

The general model that we are following is shown in Figure 3. We collaborate with partners who transfer technologies to farmers using their own technology adoption methodologies. We provide information materials and organize technical backstopping from NARES, Cornell and CIMMYT. We study the adoption process to learn about:

- successful (and unsuccessful) features of technology adoption methodologies;
- farmer reactions to the technology, including constraints to adoption; and
- the impact of adoption of the technology.

We feed back information generated during the technology adoption process to modify the technology or the adoption methodology as appropriate.

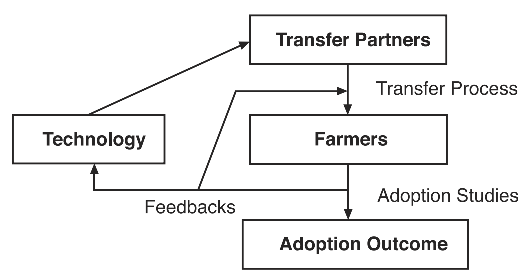

Figure 3. Model of Technology Adoption Program.

The technology transfer partners whom we have selected are international NGOs and national research and extension systems (NARES). Researchers in Bangladesh and Nepal routinely function in a transition role between research and extension. The international NGOs we collaborate with are CARE in Nepal and Bangladesh, and the Bangladesh Rural Advancement Committee (BRAC). These institutions have large "footprints" and they leverage local capacity by creating a network of smaller, local NGOs. This strategy immediately brings the potential to scale up technology transfer. The international NGO's are, in general, also strengthening their linkages to the NARES so that an improved system for technology transfer is evolving.

New partners added in Bangladesh during PY7 include the NGO Rangpur-Dinajpur Rural Service (RDRS), which focuses on females, BARI-Horticulture and East- West Seeds Ltd. In Nepal, we have developed an interaction with the University of Bangor (Wales), which has several DFID funded programs and works through local NGOs, FORWARD and LiBIRD, and the extension system. We have also broadened interactions with extension to the national level in both Bangladesh and Nepal. These expanded activities in Bangladesh (through NW Crop Diversification project) are in the planning or early implementation stages.

In Phase 1 of this SM CRSP, we concentrated on diagnosis of technical and socio-economic constraints to crop productivity, research to better understand constraints and identification/development of soil management practices to improve system output, resource quality and sustainability of the agriculture. This work was done primarily in Bangladesh and Nepal.

For this project year of Phase 2, our focus has been on training and supporting technology transfer with partners, together with evaluation of technology impact and farmer appraisal of the technologies.

Technology adoption activities are underway for the following technologies:
- Healthy seedlings of rice and winter vegetables through use of solarized seedbeds
- System of Rice Intensification (SRI) in combination with healthy seedlings
- Micronutrient enriched seeds; also in combination with healthy seedlings of rice
- Permanent raised beds
- Surface seeding of wheat
- Liming program for Bangladesh

Develop Methods to Accelerate Technology Transfer of Soil Management Products and Practices and Scale Up Technology Adoption From Local to National and Regional Scales

Healthy Seedling Production for Rice and Vegetables

Collaborating partners were CARE, Bangladesh and Nepal; BRAC; and DAE, Bangladesh Nepal. CARE routinely does household wellbeing (based on real property, income, education and social aspects) and gender role analyses as part of their farmer field school (FFS) activities. The analyses show that women and men contribute about equally to rice production with women mostly responsible for the rice nursery and transplanting, while men do most of the land preparation, irrigation and pesticide application. Other activities are shared. Most of the farmers in CARE programs are in the lowest well being category. The BRAC contract seed growers are male, have larger land holdings and are wealthier than the farmers targeted by CARE. The DAE farmers were also male but had smaller land holdings than the BRAC farmers.

Training workshops on the soil solarization technology were held in both Bangladesh and Nepal and local language handouts (3,000) were prepared for farmers. These have been modified based on feedback from partners and farmers. A flipchart that is designed to convey the technology to illiterate farmers has also been developed from the handout.

Rice

Farmers routinely observed that solarization of rice seedbeds gave larger and greener seedlings (almost guaranteed by the N released during and following solarization) that, more importantly, had healthier and larger root systems.

The mean rice yield from 163 monitored FFS/ farm sites in Bangladesh and Nepal was 4.46 t/ha for healthy seedlings compared to 3.87 t/ha for normal seedlings. This represents an average yield increase of 0.59 t/ha or 17 percent, with the range from 0-67 percent. As might be expected, the percentage gain in yield was greatest when yields without solarization were low and the number of galls on seedlings was high. There were also locational differences, most notably the lack of response in Gazipur District, Bangladesh, although previous research had shown good responses there. These results suggest that there is an opportunity to use surveys of farmer seedbeds to target the technology to farms or regions where the impact will be greatest. Variability in nematode presence is being further investigated through a June-July, 2004 survey of root galling in farmer rice nurseries in the eastern half of the Nepal terai.

Fifteen farmers in the CARE, Nepal FFS combined the healthy seedling technology with the SRI production method. Rice yields were consistently increased by both technologies. Mean yields were increased 14-19 percent by use of healthy seedlings and 30-33 percent by use of SRI. The mean yield for the combination of technologies was 6.5 t/a compared to 4.3

t/ha for farmer practice, an increase of 2.2 t/ha or 51 percent. The farmers used a HYV obtained from the NARC breeding program in place of their own seed, which was of poor quality.

Farmer evaluations of the performance of healthy seedlings revealed the following:

Nursery:
- Greater seedling emergence
- Healthy seedlings are taller, greener and have a thicker stem
- Less weed and pest problems in solarized-soil nursery

Main Production Field:
- Quicker establishment of healthy seedlings in main field
- Stronger plants with more tillers from healthy seedlings
- Only need to plant 2 seedlings/hill compared to usual 4/hill (fits well with SRI)
- Less disease (sheath blight and brown spot) and pest (stem borer) on plants from healthy seedlings and less need to spray for pests; ranged from no spray to reduce from 2 to 1 spray (attempts to get quantification of disease and pest incidence were unsuccessful)

Vegetables

Our initial intent was that farmers re-use the solarized rice seedbed for production of vegetable seedlings. This was designed into the program with the BRAC contract seed growers, but most of the CARE rice farmers chose different sites for vegetable seedbeds as they are usually in different locations than the rice seedbeds. Farmers' again observed better seedling emergence and more vigorous seedling growth with solarized seedbeds. Survival and growth of transplants in the main field was also much better with seedlings from the solarized seedbeds, despite the fact that the aerobic environment favors infection with pathogens and parasitic nematodes. Clearly the stronger root system and increased vigor of the healthy seedlings gave them a greater capacity to withstand soil borne biological stresses. Yield increases for a variety of vegetables ranged from 8 to 93 percent, and again varied by location suggesting that the technology can be geographically targeted.

Healthy Seedling Workshop

A two-day workshop to share information and experiences with use of healthy seedlings for rice and vegetables and to discuss the future of the technology was held at the RDRS education facility in Rangpur, Bangladesh in March 2004. All partners plus potential new partners (RDRS and HKI) attended the meeting. Partners were generally positive about the technology noting that it is simple, inexpensive and appropriate, especially for small farmers.

Suggestions for improvement/application of the technology were:
- Reduce seeding rate in rice seedbed as get better seedling emergence and vigor
- Plant only 2 rice seedlings per hill; this would double the area that can be planted from a seedbed (from 20:1 to 40:1 or 250m^2/ha)
- Use high and medium-high lands with irrigation for seedbeds and avoid low lands
- Encourage fertilizer dealers and others to stock quality polyethylene plastic sheet
- Evaluate dry versus wet seedbed for rice seedling production
- Test farmer knowledge of technology as an indicator of information transfer
- Identify target groups, diagnostic tools and indicators to aid scaling up

Except for CARE, Nepal and RDRS, little interest was expressed in coupling healthy seedlings with the SRI method of rice production. Discussions about follow up assessments of farmer adoption of the technology indicated that more attention needs to be given to this topic. Proposed expansion of the healthy seedling project was received favorably but with varying degrees of caution. CARE was the most eager to expand and BRAC was the most conservative, still regarding this as a pilot project. On the other hand BRAC has already used the technology to increase seed production of several vegetables on one of their farms (data not available) and indicated that they would adopt the technology on all eight of their own farms. One-day training workshops involving old and new partners were held in Nepal on May 4, 2004 and in Bangladesh on June 24, 2004.

Micronutrient Enriched Seed of Rice and Wheat

Thirteen farmers agreed to a trial production program for micronutrient-enriched seeds of rice and wheat by soil application of micronutrient fertilizers (Zn, Cu, Mo). This was begun with monsoon season (T. Aman) rice in 2003. Farmers used their own rice variety (mostly Shorna seed) and had adjacent plots of control

($200 \ m^2$) and treated ($400 \ m^2$) areas. Two small plots of variety BR32 grown from micronutrient enriched seed (on control area) or non-enriched seed (on micronutrient treated area) were included to provide a standard variety across all farms. Addition of micronutrients to soil increased the mean rice yield from farmer seed by 0.26 t/ha (7 percent). The mean rice yield from the micronutrient enriched seed of BR32 was increased by 0.62 t/ha (20 percent) compared to control seed grown in micronutrient treated soil, indicating that use of enriched seed is more effective than supplying micronutrients to soil; a result that we have previously reported in research settings. Unfortunately, soil fertilization with micronutrients did not increase rice grain concentration of Zn or Cu, but did achieve a 2x increase with Mo. This result is consistent with PhD research carried out by Sarah Johnson, who has shown that the availability of Zn decreases quickly when soils are flooded. We currently believe that this is due to precipitation of a mixed Fe/Zn sulfide and this would likely also hold for Cu.

Farmers used the same land for production of micronutrient enriched wheat seed (data not yet available). Our previous research has shown that soil fertilization is almost as effective as foliar sprays at increasing the concentration of micronutrients (Zn, Cu and Mo) in wheat grain. Farmers will compare crop production with the enriched and non-enriched seed that they produce.

Bed Planting

Three groups of farmers (26 total) from Rajshahi and Natore districts, Bangladesh were recruited to "adopt" raised bed planting in a triple crop rotation of wheat, mung bean and rice. DAE organized two groups and CARE organized one. Illias Hossain (BARI, Rajshai) was program leader and BARI and CIMMYT provided technical support. The farmers used a power tiller with a bed former/seed drill attachment. The farmer groups provided the power tiller and our project loaned each group a bed former/seed drill. Farmers agreed to compare the bed practice with their conventional practice on the flat. Sites were selected to include a range in soil texture. A one-day training that involved discussion of the raised bed system and practical training was held at BARI, Rajshahi Research Station in October 2003. All farmers and collaborators participated and the total attendance was 45. Although this was the farmers' first experience with beds, they were quite successful in getting good stand establishment with wheat. Wheat grown on beds generally had higher yields than that on the flat (see Table 4). Mean yields were increased by 17, 14 and 8 percent for Duary, Santospur and Durgapur, respectively. Across all sites, the mean yield increased by 13 percent (3.61 vs. 3.20 t/ha).

Table 4. Mean yields of wheat from beds and conventional practice.

Location	n	Yield (t/ha)		Increase
		Bed	Flat	%
Duary	15	3.68	3.17	17.2
Santospur	5	3.50	3.21	13.9
Durgapur	6	3.53	3.27	7.9
Combined	26	3.61	3.20	12.8

A survey of the 26 farm families (138 people: 47 percent male and 53 percent female) in the three study areas was carried out after wheat harvest in 2004. Key results from the survey were:

- Increased time for sowing on beds was observed by 62 percent of respondents. This was also recorded as a two-fold increase in land preparation time for the beds (3 hours) over the conventional (1.5 hours) practice.
- All farmers observed savings in irrigation with beds compared to conventional practice, which was associated with the amount of water used for each irrigation, rather than differences in the number of irrigations.
- Three of the farmers expressed an interest in buying a bed former. However all would also have to buy a Dongfang tractor.
- Seventy-eight percent of the farmers were not willing to buy a bed former because they had no power tiller and wanted to evaluate the technology over a longer period of time (3 years demonstration to farmers).
- Impressions of bed planting for wheat were uniformly positive. All recognized the benefits of beds for improving crop establishment, saving seed, irrigation and producing higher yields. All farmers were willing to continue with mung bean and then rice.

Surface Seeding of Wheat—Survey Results

The survey of surface seeding was delayed until early 2003 when a comprehensive survey was carried out in all districts in the terai of Nepal where the technology was know to have been used. The survey was carried out under the leadership of J. Tripathi (NARC, Bhairahawa) and involved 19 professionals.

The National Wheat Research Program of the Nepal Agricultural Research Council (NARC) initiated development of Surface Seeding (SS) technology for wheat cultivation in 1990 in collaboration with CIMMYT/IRRI. The technology involves surface broadcasting of cow dung coated wheat seed either prior to or after rice harvest onto soils with excess soil moisture for conventional plowing and land preparation.

Surface seeding is a low cost technology since land preparation costs are eliminated and competition for time, land and power is reduced at a time when rice harvesting and planting of winter crops overlap. It also targets small, resource poor farmers with no bullocks or tractors who cannot afford to hire tillage services. Despite these perceived benefits, SS technology has not been widely adopted. A survey was undertaken in early summer 2003 in the six districts in Nepal where surface seeding was practiced in order to obtain a comprehensive understanding of the constraints to adoption of this technology. The districts surveyed were Kapilbastu, Rupandehi, Nawalparasi, Parsa, Bara and Dhanusha. The survey had two parts. The first part is not discussed here. The second part was collection of information on the SS wheat practices that farmers have used and the problems they faced in adopting the technology. A total of 139 farmers responded completely to the survey questionnaire and attended group discussions with the survey team.

Farmer Evaluation of SS Technology

Excess soil moisture, reduced cost and timely planting of wheat were the most common reasons for adopting SS wheat. A majority of the farmers (77 percent) adopted this technology for 1-3 years but adoption was recorded up to a maximum of 8 years. The relay seeding approach was preferred by a majority of farmers, although full (11 percent) or partial (35 percent) lodging of the rice crop was a limiting factor to this practice.

A majority of the farmers discontinued SS wheat after one or more years because of low yields due to insufficient soil moisture, weeds, poor plant stand, waterlogging or uprooting and lodging problems. Less profit and high risk were the two major socio-economic issues to the farmers. Most farmers appreciated the elimination of the cost of cultivation and they generally had a positive opinion of SS despite having significant problems with the technology.

Farmers who adopted the SS technology seem to understand the theoretical aspects but indicated practical difficulties in implementing the technology, especially where a judgment call was needed (e.g., recognizing appropriate soil moisture for planting).

Conclusions and Recommendations of Survey Team

Adoption of the SS technology is very limited. Farmers clearly need more comprehensive knowledge and skills to adapt the technology to varying field and environmental conditions and technology recommendations need to be improved to cover a wide range of conditions.

Provide Information to Support the Adoption of Soil Management Practices Compatible with the Long-term Conservation of Agricultural Resources

More than half of the soils in Bangladesh are acidic but no formal liming program exists at the farmer level, nor are lime recommendations made. Our previous research has shown that yields of both rice and wheat are increased about 25 percent by liming, i.e., from 4 to 5 t/ha (see 2000-01 and 2001-02 reports). We are also concerned with interactions between liming and micronutrient availability since deficiencies of Zn, B and Mo are common and usually uncorrected. Liming could exacerbate deficiencies with Zn and B but increase the availability of Mo, which would be especially important for legumes. Liming at 2 t/ha did not show any adverse effects on crop yields but we saw a slight yield reduction at 4 t/ha.

Good quality dolomitic limestone (“dolochun”) imported from Bhutan is available in Bangladesh.

In this project year we planned to utilize NuMaSS to develop lime recommendations for wheat, maize and grain legumes, but a lack of exchangeable Al data for Bangladesh soils proved to be a constraint to using NuMaSS. We developed a two pronged approach to enable the use of NuMaSS: (a) use of data from surrounding Indian states to provide a preliminary guide for lime requirements in Bangladesh, and (b) collection and analysis of representative acid soils from Bangladesh.

Soil samples were collected from 27 classes and are currently being analyzed for pH, texture, exchangeable Al and ECEC. NuMaSS will then be used to develop lime recommendations.

Two lime response trials with maize were established in the far north of Bangladesh (Patgram, Lalmonirhat district) in collaboration with Doyel, BARI and CIMMYT. The lime rates were chosen to evaluate responses at low inputs (farmers' request) and also to possibly induce Zn deficiency, although Zn is included in the nutrient input recommendations that the farmers agreed to follow. A good response to lime was seen at one farm where 2 and 4 t lime/ha increased yield by 2.4 t/ha or 44 percent. Yields at the second farm were much lower and declined with lime additions above 2 t/ha and plants showed Zn deficiency symptoms, especially at the higher lime rates and it is possible the crop was not managed according to recommendations.

To help local measurement of soil pH, we adapted a Cornell soil pH test kit for use in Bangladesh. We provided 100 kits plus dyes, and training to Md. Bodruzzaman at the WRC, Nashipur so that he could replenish solutions.

Continue Development of Key Technologies

Combination of Healthy Seedlings with Micronutrient Enriched Seed

A replicated plot experiment with BR32 was carried out at the Wheat Research Center and single plot experiments with the different treatment combinations were carried out on two farms to evaluate the impact of combining healthy seedlings with micronutrient-enriched seed. The combination of healthy seedlings and micronutrient enriched seed showed only a small additional benefit over the individual technologies, which suggests that they address the same constraint, namely root health, and appear to be about equally effective at doing so. We know from our earlier research that micronutrient enriched wheat seed improves seedling emergence and root health but have not directly studied this with rice. If further work substantiates our conclusion, we have two quite different technologies that farmers can use to address root health in rice. Fertilization of the nursery soil with micronutrients could also be a worthwhile strategy, as this should increase the zinc content of the seedling (nurseries are generally not flooded) with potential subsequent improvement in root health and Zn supply after transplanting to the paddy.

Impacts of Soil Solarization on Soil Microbial Communities

Steven Culman (MS degree student) is using a mixture of conventional and molecular methods to evaluate the impact of soil solarization on soil microbial communities. He has followed soil bacterial, fungal and nematode populations over one rice-wheat cycle and has returned to Cornell to complete analysis of extracted DNA. Preliminary, results of plating from soils and plant roots are:

- Solarized soils had significantly higher fungal and bacterial CFUs (colony forming units)/gram of soil than non-solarized soils. The difference was greatest immediately following solarization.
- Fungal rhizosphere communities appear to be different between solarized and nonsolarized soils.
- Solarized soils exhibited significantly less total and parasitic plant nematodes than nonsolarized soils.

CARBON SEQUESTRATION

Project: Measuring and Assessing Soil Carbon Sequestration by Agricultural Systems in Developing Countries

With the cultivation of lands for agriculture, declines in soil organic matter (SOM) have become widespread and well established. The consequences of this trend are profound for the resource-poor, developing world where SOM plays an important role in nutrient supply, water-holding capacity and aggregation and tilth of soils. The degradation of soil that results from losses of SOM compromises food security through negative impacts on crop productivity and agricultural sustainability. In large parts of the developing world, insufficient productivity of agricultural land is a prime constraint for satisfying the most basic human need of all: adequate nutrition.

The present international interest in carbon sequestration to offset anthropogenic emissions of carbon dioxide offers an excellent opportunity to support a course of action for rebuilding soil carbon stocks with attendant multiple benefits to the environment and agricultural productivity and sustainability. This program area of the SM CRSP focuses on two regions of the world: West Africa and the Indo-Gangetic Plains (IGP) region of South Asia. Both of these regions can be characterized as SOM challenged, but where technologies exist to rebuild SOM. The major driver of soil degradation in West Africa is poor utilization of limited resources, while it is deliberate destruction of soil aggregates by puddling for rice in South Asia.

The program has two groups: the universities of Hawaii and Florida focus on West Africa and Cornell University focuses on South Asia. Both groups have the same objectives and achieving them is in the same general way. Some specifics will differ as appropriate to the constraints and opportunities in each region. Several points of interaction are identified and meetings between the PIs and key collaborators are planned for exchange of information and methodologies as the program progresses.

Increasing the amount of carbon in soils could help counter the rising atmospheric CO_2 concentration as well as reduce soil degradation and improve crop productivity in many areas of the world. Participation in carbon markets could provide farmers in developing countries the incentives they need to improve land management, though carbon traders need assurances that contract levels of carbon are being achieved. Thus, methods are needed to monitor and verify soil carbon changes over time and space to determine whether target levels of carbon storage are being met. Because measurement of soil carbon changes over the large areas needed to sequester contract amounts of carbon is not possible, other approaches are necessary. A major goal of the University of Florida component of the SM CRSP Carbon Sequestration project is the development and evaluation of an integrated approach in which biophysical models are combined with soil sampling and remote sensing to achieve reliable and verifiable estimates of soil carbon over time and space. Although there are uncertainties associated with data and models, reliability in estimates is realized by using observations to adjust inputs and model parameters for target areas in Mali and Ghana.

The University of Hawaii component of this Carbon project monitors the following soil parameters: soil water profiles (wetting front, water content), crop growth, biomass and grain yield and soil carbon content at sites characterized in terms of topography, mapping waterways, roads and trees, measurement of initial soil physical and chemical properties, as well as rainfall amounts at sites were characterized in terms of topography, mapping waterways, roads and trees, measurement of initial soil physical and chemical properties, as well as rainfall amounts.

West Africa

Methods to Measure Gains and Losses of Soil Organic C Over Time in Spatially Variable Soils

Carbon Sequestration of the Soil in Different Farming Systems

In a collaborative effort between two SM CRSP projects in Senegal (Soil Carbon Sequestration and Tradeoff Analysis), a study area corresponding to the Nioro area that measures roughly 30 x 45 km was selected. Major soil units were obtained from available 1:500 000 soil maps and additional field observations. The relations between soils units and the landscape are well described. In fact, the soil differences were determined by the occurrence of ironstone (difference in soil depth), rivers and depressions (difference in chemistry and texture). The soils that are not near to streams, depressions or shallow ironstone belong to one major group: Sols ferrugineux tropicaux/Lixisols. Within this group differences are small. According to Pieri (1969) those Lixisols cover about 71 percent of the area, Leptosols 10 percent and Ferralsols 4 percent, leaving 14 percent for other soil types. The land is mostly used for agriculture. On average, farmer households possess about 2,5 hectares of land, distributed over 6 parcels. Crops are grown on the glacis, the colluvo-alluvial terraces, the internal zones of the plateaus and the bas-fond areas. Peanuts are rotated with millet, sorghum or maize, depending on increasing moisture status of the location under consideration. It was also noted that shallow soils near the rocky plateaus are now used for agriculture; in other words, the fallow system has almost disappeared. Taking into account soil types and land use system as mentioned above soil carbon samplings were performed. In February 2004, focus was made on organic matter dynamics and impact of land management practices on soil C. For this purpose, three broad categories were identified:

- Crop rotation;
- Nutrient and crop residue management;
- Soil-water conservation with *ados/courbes de niveau* or ACN technology.

Disaggregating between the categories below gives the full realm of situational possibilities that can be encountered in the Nioro study area:

1. Crop rotation (two systems account for 90 percent of the crop rotation);
    - continuous millet: compound fields
    - millet / peanut: bush fields.
2. Nutrient management;
    - organic matter management
    - crop residue incorporation
    a. mineral fertilizer
    b. mineral and organic fertilizer
    c. none of the above.
3. Soil/water conservation;
    a. with ados/ACN
    b. manure, household wastes
    c. without ados/CAN.

Each real situation in the field will be a combination of the three factors above. Geospatial soil sampling were undertaken in four locations within the study zone (3 village farmers fields and across the BaoBolon rivers (Gambia river tributary). About 100 soil samples along representative transects of soil management practices were collected and analyzed for pH, N, C, texture, bulk density and CEC. Soil C estimates from these samples along with survey data analyses to depict the corresponding land use systems will come out soon from the Abibou Niang's MS. Thesis, Wageningen University. In order to simulate the long term changes in soil organic matter under different land uses, the CENTURY model will be used. Modeling is currently used to help predict and understand future changes in soil organic carbon (SOC) due to different land management practices. The final goal is to identify appropriate practices within areas with a large potential of increased SOC sequestration.

Use of the Ensemble Kalman Filter (EnKF)

The University of Florida developed a framework, using Ensemble Kalman Filter (EnKF) techniques, to combine model predictions with measured soil C for increasing the reliability of measured soil C changes over time for a single field (Jones et al., 2004). This framework was extended to include multiple fields that may have correlated soil C and other variables and may also have different initial conditions and management. Different models have been used in this approach. Its use was demonstrated in a rotational grazing pasture in Mali using a soil C model with two state variables and in 12 fields in Ghana using the DSSAT-CENTURY model.

Using EnKF to Assimilate Soil C Measurements with Model Predictions

Since this is a new application of EnKF, the University of Florida is attempting to understand its characteristics relative to geospatial analysis, which has been an important part of the overall project in West Africa. The following points summarize some of our findings:

- In an EnKF, every point must be included in the analysis if estimates of system states are needed at those points. Measurements may only be available at a fraction of those points. But, the covariance matrix structure provides information for estimating states at points that were not measured, similar to kriging techniques using geostatistics.
- In the EnKF, the covariance matrix is explicitly defined for all combinations of points, even if measurements are not made at all of the points in the EnKF.
- In the EnKF, a stochastic spatio-temporal model describes the evolution of system states and of the variances and covariances over time and space. When measurements are made (at a point in time), they are used to update system states, variances, and covariances for all points over space (those

measured as well as those not measured). Even if measurements are not made in a particular year, for example, the EnKF provides estimates of systems states and their uncertainties.
- One difficulty in implanting EnKF for this type of problem is the necessity of having reliable initial estimates of all system states (at both measured and non measured points) and the corresponding initial covariance matrix. The use of georeferenced spatial sampling and geostatistical analysis methods is probably the best way to estimate these initial conditions.
- If there is little correlation among system states over space, the power of the EnKF is limited and the design of an appropriate sampling scheme is very important. Rotating fields sampled reduces uncertainty when there is little correlation among fields.
- One could implement the EnKF by measuring and modeling soil C at points or by measuring and modeling average soil C in fields. The landscape in most agricultural settings is composed of patches of different land use and management practices, which cause discontinuities in soil C over space. Because field management is superimposed over spatial variability of soil properties, assumptions that soil C varies smoothly over space and is stationary are questionable. Nevertheless, it may be possible to decompose the landscape into different land use and management types and treat soil C as a pseudo continuous variable over space for spatial analysis purposes, avoiding dissimilar land units. Data collected over large areas with sufficient sampling intensity to quantify spatial variability at short and long distances (Walter et al., 2003) are needed to evaluate advantages and disadvantages of each approach.

Remote Sensing Progress

Progress was made this year relative to the integrated protocol for measuring soil carbon (C) changes and to the predictive tools for evaluating options for soil C sequestration. In Mali, ground truth information was collected on about 450 fields near one study site (Omarobougou), and at some of those sites, leaf area and vegetative biomass data were collected. Different analysis approaches were evaluated for classifying land use, crops, and whether fields have ridge tillage or not. An expert classifier, in which principal component analysis was used, improved accuracy relative to supervised and unsupervised classification in most cases. Accuracy for classifying cotton was around 75 percent but lower for maize and millet (around 65 percent) and lowest for sorghum (around 50 percent) using the data that we have. Work will continue in Florida and in Mali on ways to increase accuracy. We have purchased a CropScan instrument, which has the same remote sensing image bands as the Quickbird satellite, to obtain data over more conditions to support this effort.

Preliminary efforts to visually identify ridge tillage fields using the high-resolution images indicated that 87 percent of the fields that were classified as ridge tillage fields were correct (sample size of 47 fields).

If crop residue is returned to the soil as a practice to increase soil C, reliable estimates of vegetative biomass are needed. Data collected in Omarobougou, Mali were used to determine the reliability of remote sensing to estimate biomass using two different approaches. An Artificial Neural Network (ANN) method was developed and compared with the use of NDVI. We found that the ANN was considerably more accurate in predicting vegetative biomass for cotton, millet, and maize, but not for sorghum. More data will be collected in the next year to determine why estimates for sorghum were not reliable and to evaluate this approach for all of the crops and native fallow. The Crop Scan instrument will be used to collect data in the two sites in Ghana in 2004.

Adapting the DSSAT Crop Models for West African Conditions

For application of a crop model to a new environment it is important that the model be calibrated for the new conditions (soil type, weather, crop cultivars, etc.). African low input systems differ in many aspects from the systems for which the DSSAT model originally was developed. The models can be adapted if one has access to good data sets, based on field experiments. A lot of effort has been put in obtaining such data from people in- and outside the project.

In Ghana, progress was made on adapting the maize and peanut models in DSSAT v4 to simulate the Ghana candidate cropping systems for increasing soil C sequestration. Experiments were conducted for three years on research stations in Wa and Nyankpala to study the effect of different N fertilizers and crop rotations. Generic tropical maize variety coefficients were used to simulate these experiments along with weather, soil, and management data. The model simulated response to N reasonable well. Model comparisons for peanut were based on research conducted in Ghana under the Peanut CRSP project. Generally, the peanut model predicts peanut growth and yield well, but only if foliar disease is taken into account. The investigators on the Peanut CRSP project showed that Cercospera leaf spot disease is wide spread and is the major reason for low yields in this area of Ghana.

In Mali, we initiated contact with researchers who have data on cotton and plan to work with them to assemble the data and evaluate this new model in DSSAT. Traore and others made progress in Mali on improving the sorghum model for better predicting the varieties grown in West Africa, which are highly photoperiod sensitive and have low harvest index.

Evaluating/Improving the DSSAT-CENTURY Model

The simulation work for cropping systems in West Africa will be done with the DSSAT model, which in its latest version—released in June 2004—has a new soil organic matter (SOM)/residue module that is based on the well-known CENTURY model (Parton et al., 1987). It is this new model combination DSSAT-CENTURY (Gijsman et al., 2002) that created the possibility for applying it for carbon sequestration estimates in West Africa. This model now contains models for maize, peanut, sorghum, millet, and cotton, and will thus be used in our studies. However, modifications to some processes in the model may be needed to adequately simulate differences between conventional and ridge tillage.

The module that simulates water runoff in the released version of DSSAT v4 may not be able to adequately simulate differences between conventional and ridge tillage. Thus, research is being conducted to evaluate the current model and to improve it as needed to make sure that the model adequately describes this important difference. Soil water vs. depth and time data were collected in a cotton ridge tillage field in Mali to improve the relationships in the model for predicting runoff. The flow and soil water data and the mechanistic model will be used to evaluate and improve the crop model for simulating water balance in different management systems in Mali and in West Africa. We also purchased two FloDar instruments to allow us to directly measure runoff from the fields in Mali during the 2004 season to better quantify runoff and evaluate the models.

The net amount of carbon accruing to the soil is the difference between additions and losses. Additions are mainly from plant residues while the major loss is by residue decomposition and mineralization of soil organic matter. In soils, one may distinguish between two forms of organic carbon (i) the easily decomposable (from fresh residue additions) and (ii) the slowly decomposable fraction. The latter is the major contributor to carbon sequestration or storage, which offer long-term soil regeneration. Soil moisture has a major influence on rate of decomposition and mineralization.

An experiment was initiated in Ghana to measure rates of organic matter decomposition under different soil water potentials for testing and improving the DSSAT-CENTURY soil C predictions under different crop, weather, and management practices in the soils of western Africa.

In many soils in West Africa, phosphorus—and not nitrogen—is the primary limiting element for crop growth. In the released version, the DSSAT-CENTURY model only deals with nitrogen. However, during the last year, we integrated a soil P model into DSSAT v4, building on earlier work by Gijsman et al. (1996) and Daroub et al. (2003), following the lines set out by Bostick et al. (2002). Plans are to have this implemented for the five major crops being considered in our part of this project.

Modeling of Factors Affecting Soil C

Senegal

Climatic and soil input data for the PARCHED-THIRST model were developed for a site in Senegal. The data will be used in simulations that investigate ridge-tillage impacts on field water balance and biomass accumulation. The methods and procedures developed for Senegal will be used as prototypes for applications of the PARCHED-THIRST model in Mali, The Gambia, and Cabo Verde, which was selected as the main simulation tool for this purpose. Much of the fieldwork investigating soil moisture and possible elevation dependency of soil carbon was completed this past year. An experimental design comparing ridge-tillage to conventional management was implemented at two sites in Mali. Soil moisture was measured at each of these sites using the Diviner® soil moisture probe. Preliminary results indicate that this is a significant increase in soil moisture (and subsequent surface runoff reduction) in the fields with ridge-tillage. These preliminary results were presented at the NASA/USAID Regional Workshop in Bamako, Feb. 26-28, 2004.

A climate input data set was developed using observed data collected in the peanut basin of Senegal. The climatic historical input was tested using the PARCHED-THIRST model and was found to be error free. The historical input was then used to develop a statistical parameter data set for the site in Senegal. This statistical parameter set is used by the climate generator, which is a part of PARCHED-THIRST, to stochastically generate climatic time-series for extended periods. The statistical parameters estimated functioned properly in the weather generator and several time-series using different "seeds" for the random number generator were generated and tested with the model. All functioned properly. The ability to generate several independent climatic time-series will be used in future application of the PARCHED-THIRST model to evaluate management alternatives for the peanut basin in Senegal. We also developed soil parameter files for fields in Senegal where the PARCHED-THIRST model is to be applied.

Mali

Soil-water monitoring experiment was implemented in two fields in Mali. Assistance provided by IER personnel and Richard Kablan was essential to this implementation. IER personnel collected data from the multiple tubes at each of the two locations over the past rainy season and the results were very encouraging. Procedures were developed in collaboration with University of Hawaii colleagues to process the data with visualization methods to summarize the vast amount of data that was collected, and these results were reported at the NASA/USAID regional meeting in February of 2004 in Bamako, Mali. Outcomes from the soil water experiment encouraged buy-in from USDA-ARS scientists, who were collaborators on the NASA/USAID project with SM CRSP, to develop a groundwater-monitoring component.

Elevation data was recorded using an auto-level during February-March 2004 for previous and new sample locations in Mali, referenced to DGPS locations of the samples that were collected by IER/Mali personnel. Spatial analysis of the soil carbon and elevation data is currently underway by Virginia Tech and University of Hawaii personnel. Also, samples were collected in Malian fields to estimate erosion using Cesium-153 isotope analysis.

Methods to Assess the Potential for Soil C Sequestration

Ridge Tillage Technology

The improvements in drainage and reductions in runoff demonstrate that the ACN (***ados en courbes de niveau***) practice would be very useful in efforts to increase carbon sequestration in agricultural systems. Rainfall is often the limiting element in crop productions systems in semi-arid regions, such as the Sahel region of West Africa. Increasing the water available for crops will reduce the occurrences of agricultural droughts (short periods during the growing season when the crop experience water stress). The impact of the increased water availability related to the ACN practice will ultimately be evaluated based on crop yields and biomass improvements.

Senegal

The storage of carbon (C) in the soil plant residue or manure through amendment or increased biomass production in cultivated land while improving and sustaining agricultural production is one way of reducing atmospheric C and consequently mitigating the greenhouse effect. In the drought-prone, yet highly erodible Sudan-Sahelian zone of West Africa, ridge tillage across the slope not only can help curtail water loss through runoff but is also a means of protecting organic matter amendments for improved crop water and nutrient uptake. This study assessed the effect of locally adapted ridge tillage (*ados en courbes de niveau-ACN*) combined with a bedding operation on soil water availability, soil organic matter content and crop yield for peanut and sorghum based cropping systems of Senegal. Six on-farm trials, three each for peanut and sorghum were established in 2003 in the Nioro area. In each farmer's field, two 0,75 ha plots were established adjacent to each other and one of them subjected to the ridge treatment while the other acted as a control. The sites were characterized in terms of topography, mapping waterways, roads and trees, measurement of initial soil physical and chemical properties, as well as rainfall amounts. Monitored parameters include soil water profiles (wetting front, water content), crop growth, biomass and grain yield, and soil carbon content.

Preliminary results indicate that early in the growing season, ridge tillage promotes a rapid downward movement of the wetting front and permits greater topsoil water content right after a rainfall event. This proves to be an appropriate way of reducing rainwater loss through runoff. As for crop maturation date, peanut is positively affected by tillage as opposed to sorghum for which root damage during the bedding operation induces a delay of growth and flowering. Overall, positive effects on total biomass and grain yield were observed for both crops. The improved biomass production is a basis for increased potential for crop residue application, thus for an increased soil carbon content.

Mali

Results of this year indicate that the ACN technology appears to increase soil organic C, in some cases 10 to 15 percent per year. Considering that this is an increase from a base of 0.2 or 0.3% soil C, the impact on other soil properties such as exchange capacity and water holding capacity is major. The ACN technology reduces runoff from 70 percent to 30 or 40 percent resulting in a major reduction of soil erosion and increasing water content deep in the soil profile as well as increasing the deep drainage and increased restoration of groundwater supplies. A so-far-unmeasured impact of the increased soil water storage is the impact on the trees, usually shea butter trees, in the fields, that not only increases shea butter yields, but may also increases soil C. Studies by IER scientists show that shea butter trees contribute substantial amounts of C as a result of their growth and habit of shedding large amounts of leaves.

At this time the NGO, ProNatura, has agreed to participate with the SM CRSP C program to prepare a proposal for submission to the BioCarbon Fund of the World Bank as well as to the Millennium Challenge Accounts through the IER/Mali and eventually through the government of Mali. A ProNatura scientist will participate in a survey of a region that has been proposed for the C trading project South East of Bamako Mali.

The Gambia

One of the objectives for the C project in The Gambia was to elaborate protocols to estimate the C status of cropping systems for selected parts of the country. The key technology that was used in the country was ridge-tillage, a technology borrowed from Mali. After a thorough literature consultation, initial experiments were placed on selected sites with farmers' active involvement. This was to avoid risk, considering the large size of the experimental plot size.

After two years of successful tillage technology study, over 150 collaborating farmers were invited to a conducted day learning and observing on station research for measuring and assessing soil carbon sequestration by agricultural system in ground /cereal rotation systems. The first year results indicate a positive output between tillage and minimum fertilizer level. One observation is that the ACN technology does not seem to be as effective in increasing crop yields in The Gambia as in Mali. It is not clear why that is occurring, but we suspect that there may be a maximum rainfall, above which the technology does not bring such large benefits. We also suspect that the technology gives greatest benefits where soil infiltration is very low. We propose making measurements of drainage and infiltration in Mali, Senegal, and The Gambia to test this hypothesis in 2004-2005.

The field water balance calculations using the soil moisture measurements quantify the positive impacts the ACN practice has on drainage and runoff. Soil moisture during the growing season of 2003, at two locations in Mali, was measured using a capacitance-based device (Diviner 2000) at multiple locations within fields where ACN was implemented and fields using conventional practices. The tubes in the ACN fields generally had greater drainage and lower runoff than the tubes that were in the fields without ACN. The runoff from the fields without ACN ranged from 60 to 69 percent of the rainfall during the growing season. The runoff from the ACN field ranged from 22 to 62 percent of the rainfall. The amount of drainage within the ACN field is related to the distance from the upslope permanent ridge (Ado). The tubes closer to the up slope Ado had lower drainage and higher runoff. This increase in drainage is the result of water moving from up slope areas and collecting at the down slope Ado. The heterogeneity of water retention between the Ados highlights an aspect of the ACN where improvements may be needed.

Estimating Soil C Using Geostatistics and GIS (excerpts from Delisle et al. 2004)

We have estimated soil organic carbon (SOC) for five farms in Mali by classical and geospatial methods. Soil organic C is quite low, approximately 0.3% in the 0-20 cm depth and 0.25% in the 20-40 cm depth. For the classical method we have given confidence intervals, but the intervals are quite wide and the method is questionable since the data were not collected randomly and the samples are for the most part, not independent. Geostatistical analysis indicated strong spatial dependence among samples, nearly 100 percent dependence of the soil C. Given the lack of independence between samples, the geospatial method may be preferred over the classical method but may also be preferred where 1) the sample mean overestimates C due to a skewed distribution, or 2) where kriging allows prediction of C for sub-regions of a farm such as individual fields. In addition, geospatial tools such as block kriging should be explored for their potential to decrease the level of uncertainty in our estimates.

In order to provide numerical information, over time, regarding the effect of the permanent ridges on C sequestration, we may wish to delineate (using a

GPS) the boundaries of "ridge-till" versus "non-ridge-till" regions within farms. Carbon for these delineated regions may then be calculated by the geospatial method to calculate the C for fields within farms. This will allow the change in C over time to be monitored for ridge-till versus nonridge-till regions.

Experiments for Studying Soil C Sequestration Potential

Field experiments are being conducted at three sites to compare their potential value relative to soil C sequestration. Management systems vary across the different sites.

Mali

In Mali, the basic soil management strategy is ridge tillage, to increase water availability, combined with different options for managing crops and soil fertility. The work in Mali is led by M. Doumbia, Abou Berthe and other IER researchers and by Russ Yost of the University of Hawaii. UF has one student who is collecting data in Mali to develop capabilities to simulate ridge tillage vs. conventional tillage systems, focusing on runoff, soil water simulations and on crop growth and yield. Last year, data were collected on soil water at different depths over the cropping season under cotton. This year, soil water data will be collected again, but we will also collect runoff rates from conventional and ridge tillage fields using two volumetric flow meters (FloDar, based on sonar and radar sensors).

Ghana

In northeastern Ghana (near Wa), five experiments were conducted in 2003. Three experiments were on-station and two were on farms. These experiments were:

- On-station evaluation of effects of cropping systems and residue management on crop yield and soil organic carbon;
- On-station evaluation of response of maize to nitrogen and phosphorus fertilizer;
- On-station evaluation of effects of cultivation on changes in soil organic carbon content;
- On-farm evaluation of effects of peanut-maize rotation and application of fertilizer on yield and soil organic carbon;
- On-farm evaluation of effects of mucuna-maize rotation on maize yield and soil organic carbon content.

In Kpeve, a long-term agronomic experiment was initiated as part of this project in May 2003. A field, which was in fallow for two years and in cassava before that, was prepared by incorporating the native vegetation that had grown in the field for the last two years. The field was divided into 28 plots to evaluate the effects of 7 different crop and residue management treatments, with maize as the main crop being grown.

South Asia

Our objectives in South Asia are to i) develop practical methods to measure gains and losses of soil organic C over time in spatially variable soils and ii) apply methods to assess the potential for carbon sequestration for selected sites. Our activities this year focused on:

1. Development of soil organic carbon-texture relationships for cultivated and native soils;
2. Determination of soil organic carbon stocks in a number of our tillage and residue management experiments in Nepal;
3. Initiation of two experiments on soil carbon and crop residue dynamics using $_{13}$C tracer techniques; and
4. A preliminary assessment of the maximum potential for C sequestration in soils of Rupandehi district, Nepal.

Soil C-Texture/Mineralogy Relationships

C Measurement Issues

In our 2002-03 report, problems with carbon measurement by combustion in soils that contained carbonates were discussed, as was the lack of agreement between combustion and Walkely-Black (WB) methods for measuring SOC. Because of the presence of carbonates total soil carbon was consistently higher than total SOC (Figure 4, left panel). After removing carbonates, SOC by combustion and WB methods compared reasonably well (r 2 = 0.78) and the regression was close to the 1:1 line (Figure 4, right panel). Outliers represented 5 percent of the samples, which is probably adequate for C trading purposes.

A second set of 105 samples collected from our tillage and crop establishment experiment was analyzed by combustion at Cornell (carbonate removed) and by the soils laboratory at NARC, Khumaltar. NARC used the Mebius modification to the WB procedure and the results were in good agreement (r 2 = 0.89) (Figure 5). Despite longer processing time, the Mebius modification of WB appears to be a better analytical method than the standard WB method.

The reasons for pursuing these analytical issues are that 1) Laboratories in developing countries need to demonstrate the capacity to measure SOC with precision and accuracy if they are to contribute to potential C trading opportunities; and 2) NARC has a data set of SOC and soil texture for almost 400 samples collected on a km^2 grid from Rupandehi district. We wish to use this data set to assess C sequestration potential and to study errors in assessment at different scales. We are not yet confident in the SOC values, which has limited our ability to undertake these activities.

Soil Carbon-Texture Relationships

The variability in the SOC/texture relationship is quite high—a range of ~ 1% OC (or about 20 tC/ha) for silt + clay contents greater than 50 percent. This variability may reflect differences in manure use, years under cultivation, tillage, sampling depth or length of time that soils are flooded.

Data from more than 250 surface soil samples (0-15 or 0-20 cm) from rice-wheat areas in Bangladesh and Nepal were used to establish a mean and a minimum soil organic carbon content as a function of soil texture (silt + clay).

It is clear from these data that we need additional data to define the SOC texture relationship for uncultivated soils in S. Asia with confidence. An additional 36 samples of uncultivated soils have been collected from across the eastern terai region of Nepal and are currently being analyzed. Sites for further collections have been identified in Bangladesh.

It should be emphasized that all of the SOC-texture relationships show very low intercepts, indicating that significant amounts of OC will not accumulate in soils in these environments without the protective effects of interactions with mineral surfaces (as provided by silt/clay) and the formation of aggregates.

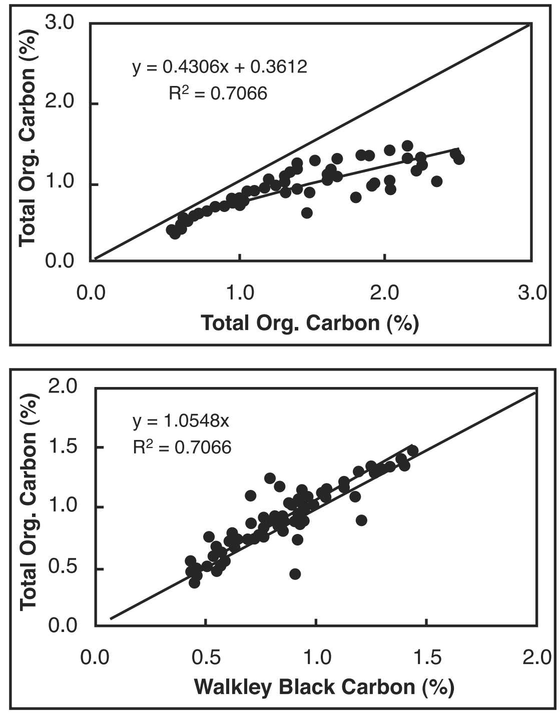

Figure 4. Effect of carbonate removal on C determination by dry combustion (left) and relationship between dry combustion and Walkely-Black measurements of SOC (right).

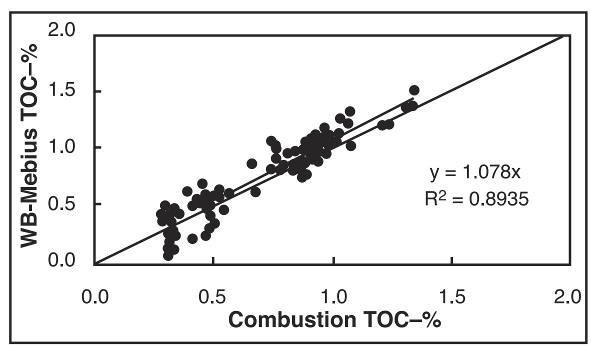

Figure 5. Comparison of SOC measured by modified Walkely-Black (Mebius) at NARC, Nepal and by combustion at Cornell University.

Characterization of Organic C Gains from Sequestration Practices

Effects of Tillage and Residue Management on Carbon Stocks

Tillage and residue management practices at Bhairahawa and Rampur significantly altered soil carbon stocks in two of three experiments analyzed. One experiment showed an annual increase of 0.375 tC/ha over a seven-year period when puddling of soil for rice was stopped. Another experiment showed that carbon retention from a mixture of wheat and rice straw additions was 10 percent over a seven year period with an annual gain of 0.21 tC/ha.

In all of these experiments there was no detectable change in SOC contents below a depth of 20 cm, indicating that sampling to a depth of 30 cm is adequate for assessment of changes in SOC stocks. While accuracy in determination of SOC is required, errors in bulk density measurements are, in our opinion, more of a constraint to assessment of SOC stocks.

Effects of Tillage and Crop Residue Inputs on SOC Dynamics using $_{13}C$ Labeled Materials

Two experiments with $_{13}C$ tracers were initiated. One investigates the relative importance of root and top inputs to soil organic carbon content under conventional tillage and zero tillage. The other will determine the relative decomposition rates of wheat and rice straws for use in modeling C accumulation rates from straw additions.

The first experiment is a study of the dynamics of root and top carbon decomposition patterns in soil (and relative contributions to soil organic C) using in-field $_{13}C$ pulse labeling of rice and wheat, under conventional tillage and zero tillage

The second $_{13}C$ experiment is within the crop residue management experiment at NARC, Bhairahawa and its purpose is to determine decomposition rates for rice and wheat straws, from a one-time application, in order to model SOC accumulation from residue returns to soil.

Methods to Assess the Potential for Carbon Sequestration

Our general approach to this objective for a given farmer site is to couple information on soil texture and current SOC content with knowledge of how SOC changes with adoption of carbon sequestration practices within a broader geographic analyses using GIS. We believe that it is useful to characterize the maximum potential C sequestration as well as the achievable C sequestration with different C sequestration practices and adoption scenarios. We hypothesize that for a particular soil texture, the difference between SOC under native vegetation (uncultivated) and a current cultivated site represents the maximum potential for C sequestration.

The Rupandehi district in Nepal was selected as a test site, because both point and categorized data are available for texture and carbon. Since we are still resolving analytical problems with the point carbon data, we used the point texture data from the district and the texture vs SOC regression for cultivated South Asia rice-wheat soils to generate SOC contents for cultivated soils in the district. Similarly, generalized texture data (based on survey and landform features were used to generate cultivated SOC contents at a more generalized scale.

Potential SOC sequestration for Rupandehi district (115,000 ha) was found to vary between 1.7 x 10^6 tC to 6.4 x 10^6 tC. The difference in potential SOC sequestration between the point texture data and the generalized texture data was only about 20 percent, suggesting that detailed texture data may not be necessary for this kind of analysis. This is pertinent since most texture data sets for developing countries are of the generalized type.

BIOTECHNOLOGY

Project: Assessing the Effects of Bt Crops and Insecticides on Arbuscular Mycorrhizal Fungi and Plant Residue Carbon Turnover and Fate in Soil

Project: Genetic Characterization of Adaptive Root Traits in the Common Bean

Assessment of Bt Gene Project

This is a new project, selected from among four proposals and awarded a subgrant by the SM CRSP. The pre-award activities reported here were supported by funds leveraged from Cornell University.

Field studies have already been established in New York (corn), China (rice), and Colombia (cotton). Preplant soil samples have been collected in the corn trial and pre-plant and anthesis samples in the cotton trials; DNA is being extracted from the pre-plant samples. Protocols for the measurement of glomalin as an indicator of the abundance of AMF (arbuscular mycorrhizal fungi) and a molecular method for determining their community structure have been successfully tested at Cornell University. A likely design has been identified for the construction of $^{13}CO_2$ pulse-labeling chambers.

The enormous progress made in developing and disseminating insect-resistant Bt crop varieties is exciting from the perspective of increasing productivity and decreasing environmental and human health hazards posed by the insecticides normally used to contain pest damage. However, concerns regarding the use of this technology have been expressed, among the foremost of which is its potential impact on non-target organisms. Much of the scientific literature in this area has focused on non-target arthropods. To date, there have been few assessments to determine if this technology poses any risks to the biomass and diversity of microorganisms in the soil. Further, there is no clear understanding whether potential variations in the dynamics of carbon allocation and in field rates of residue decomposition between transgenic and non-transgenic plants have implications for carbon sequestration in soil.

We propose to determine the effect of Bt corn, cotton, and rice on soil organisms—with an emphasis on symbiotic associations between plant roots and arbuscular mycorrhizal fungi (AMF) known as vesicular arbuscular mycorrhizae (VAM) and on soil arthropods important in the primary decomposition of crop residue. We will also compare the rates of decomposition and fate of Bt vs. non-Bt residue and evaluate the potential for increasing carbon sequestration in soil using Bt crops. The crops have been chosen so that we can evaluate effects on soil organisms under both aerobic and anaerobic circumstances: Bt corn and cotton are grown in aerobic soil while Bt rice is grown in primarily anaerobic soil conditions.

Our objectives are to: (i) assess the effects of Bt corn, cotton, and rice on the abundance and diversity of AM fungi and compare them to non-Bt isolines grown with insecticide applications in field trials, (ii) provide an assessment of the abundance and community structure of soil detritivore arthropod populations in field trials of Bt corn, cotton, and rice, and (iii). determine residue decomposition rates, carbon allocation within plants, and fate of residue carbon in soil for Bt corn, cotton, and rice under field conditions.

Assessing the Effects of Bt Corn, Cotton and Rice on the Abundance and Diversity of AMF and Comparing them to Non-Bt Isolines Grown with Insecticide Applications in Field Trials

Corn

A field trial was established at the Musgrave Experimental Farm in Aurora, New York in May, consisting of five replications of the following treatments in randomized complete block design (RCBD): transgenic Bt corn resistant to the corn rootworm (CRW), the non-Bt isoline with a pre-emergent treatment of the insecticide tefluthrin applied to control the rootworm, and the non-Bt isoline without insecticide. These plots are in a field with low rootworm pressure; one replication each of the treatments was also established and sampled in three fields with high rootworm populations. Two composite soil samples consisting of 10 sub-samples across a transect of each plot were collected at planting (pre-plant) to a depth of about 15 cm using soil corers, to obtain a baseline measure of VAM in the plots.

DNA from the pre-plant soil samples is being extracted using kits [Q-Biogene/Bio101 FastDNA SpinKit (for soil)]. Following extraction, DNA from arbuscular mycorrhizae will be targeted for amplification by nested PCR (polymerase chain reaction) using first the ITS5/ITS4 primer pair, which is expected to amplify a number of non-arbuscular mycorrhizal fungi in addition to arbuscular mycorrhizal fungi (AMF). Amplicons from this PCR will be subjected to re-amplification using terminally labeled AMF-specific primers SSU-Glom1 and LSU-Glom. Restriction endonucleases will be used to cut the amplicons, and the terminal fragments analyzed by terminal restriction fragment length polymorphism analysis (TRFLP) to assess the effect of treatment on AMF communities.

A protocol to estimate abundance of AMF by measuring glomalin has been tested with pre-plant samples.

Rice

Three replicates of Bt rice (KMD1) and two non-Bt varieties (Xiushui 11 and Jia-dao 935) were transplanted in RCBD into 2.3 m x 8 m plots at the experiment farm on the Hua-jia-chi campus of Zhejiang University, Hangzhou, China in June. Half of each plot was treated with insecticide. A composite rhizosphere soil and root sample consisting of four sub-samples across a transect of each plot will be collected at the seedling, booting, heading and maturing stages.

DNA from the pre-plant soil samples will be extracted and DNA from arbuscular mycorrhizae targeted for amplification by nested PCR as described above. Amplicons from this PCR will be separated by denaturing gradient gel electrophoresis (DGGE) to obtain a community fingerprint and assess the effect of treatment on mycorrhizal community.

Cotton

A field trial with Bt (Bollgard® technology; variety NuCont 33B expressing Cry1Ac toxin) and non-Bt cotton (variety DP 5415) was established in April at the experimental station CORPOICA (Colombian Corporation of Agronomy Research) in Palmira (Valle), Colombia. The experimental plots measure 225 m^2 (15 m x 15 m) in RCBD. Each of 4 blocks has 6 treatments (plots) for a total of 24 plots under evaluation. The treatments are a combination of the two cotton varieties above with three insecticide application regimes as follows: (a) use of insecticides to control non-target pests (i.e. non-lepidopteran pests), (b) application of conventional insecticides as normally applied in the region, and (c) application of pesticides that contain Bt as normally applied in the region. Composite pre-plant soil samples were collected in April, consisting of 9 sub-samples taken across a transect in each plot. A soil corer approximately 3 cm in diameter was used to take samples to a depth of about 10 cm. An anthesis soil sample was also collected in a similar manner in June, but consisted of rhizosphere soil (within-row), bulk soil (between-row) and roots samples. Soil samples for molecular analysis were stored at -80° C, while those to be used for estimation of mycorrhizal abundance by glomalin measurements and spore counts were stored at 4° C. DNA from the pre-plant soil samples is being extracted using kits [Q-Biogene/Bio101 FastDNA SpinKit (for soil)]; subsequent treatment will be the same as described for Bt corn. Baseline measurements of AMF spores have been conducted using wet-sieving.

Providing an Assessment of the Abundance and Community Structure of Soil Detritivore Arthropod Populations in Field Trials of Bt Corn, Cotton and Rice

Research towards the fulfillment of this objective is ongoing for corn and cotton, and will begin in rice after heading. Pitfall traps are being sampled throughout the season in the corn and cotton experiments, and the Berlese funnel technique will be employed on soil samples in all experiments to assess the abundance and community structure of soil detritivore arthropods.

Determining Residue Decomposition Rates, Carbon Allocation Within Plants and the Fate of Residue Carbon in Soil

Work is ongoing to finalize a design for $^{13}CO_2$ pulse-labeling chambers that will be used in greenhouse studies to create labeled Bt and non-Bt corn. Labeled plant samples will then be subjected to mass spectrometry to determine if Bt and non-Bt plants differ in carbon allocation patterns. Most likely each chamber will be constructed of clear ethyl-vinyl alcohol (EVA) sheeting attached to a plexiglass bottom and PVC pipe frame with holes drilled into it for gas dispersion into the chamber. The frame will be connected to the $^{13}CO_2$ supply cylinder via a regulator, and a fan will be used to facilitate gas circulation within the chamber. An infrared gas analyzer (IRGA) will be used to track $^{13}CO_2$ concentration in the chamber. Labeled corn root and stalk material will be weighed and buried in litterbags after harvest until April 2005, when they will be disinterred and weighed to determine relative residue decomposition rates and the fate of Bt and non-Bt corn residues in soil. Unlabeled materials will be used to assess cotton and rice residue decomposition rates.

Genetic Characterization Project

Accessibility to water and phosphorus has been identified as a major constraint in agricultural settings around the world. Phosphorus deficiency can limit yields in about 90 percent of cultivated soils and water deficits during critical developmental growth stages can have significant detrimental effects on productivity. Soil and water management strategies have been devised to overcome these problems, and the complexity of these solutions depends directly on the complexity of the local settings. Suitable fertilization practices as well as technologically advanced irrigation systems can be used to ameliorate these problems, but their implementation is not always economically feasible, especially in low input agricultural systems. The complexities and challenges of soil management strategies and practices can be reduced with cultivars adapted to marginal edaphic conditions.

The first step in the development of such cultivars is the identification of adaptive root traits that can change the outcome of plant-soil interactions under sub-optimal conditions, and of the genes that controls these traits. Dense soils can restrict root growth and limit access to water. Genetic variation for the ability of roots to penetrate dense soil is a trait that has been found in rice and cotton (Klueva et al., 2000; Price et al., 2000), and genes that control this character have been tagged with molecular markers in rice (Price et al., 2000). Reverse genetics strategies, and gene expression analyses in *Arabidopsis* are beginning to uncover genes that control root growth and development (Bao et al., 2001; Gaedeke et al., 2001).

The paucity of information on the inheritance of root characters is due to the intrinsic difficulties of obtaining reliable measurements. Nevertheless, root size and morphology have been determined using indirect methods. These include measurements of the electrical capacitance of roots (Kendall et al., 1982), the use of proximal root diameter as predictor of total root size for fractal branching models (Spek and vanNoordwijk, 1994), and fractal geometry (Nielsen et al., 1998). In contrast to these methods that are laborious, destructive, and not necessarily accurate, magnetic resonance imaging (MRI) is a technique that offers a great number of advantages for measuring roots non-destructively.

The advent of molecular marker technology has led to the construction of comprehensive genetic linkage maps in many crop species (Phillips and Vasil, 2001). Markers from these maps facilitate localization and tagging of agriculturally important characters. Examples of monogenic trait tagging abound in the literature, and tagging of disease resistance genes is the most typical applications. This approach has been extended to the analysis of quantitative trait loci (QTLs).

Justification

The common bean represents a major protein source for over half a billion people in Africa and Latin America (Pachico, 1989). A significant proportion of common beans in LDCs are grown in low input agricultural systems. Under these conditions, farmers need to cope with an array of overwhelming constraints, including those related to soil management. These constraints can be overcome, of course, by increasing inputs, although a more realistic and efficient approach is to develop crops adapted to marginal agricultural conditions. For instance, according to Flor and Thung (1989), most of the world’s bean-producing regions face serious mineral nutrition problems because they lie in acid soil zones. Common bean cultivars with efficient root systems, for mineral or water uptake, are likely to have a significant impact in marginal soils. While beans represent a major source of proteins in the developing world, interest in beans is increasing in the U.S. due to its high fiber content and hypocholesterolemic properties (Costa et al., 1994).

The work we are proposing below is in line with the USAID strategic objectives aimed at developing products that overcome soil-management constraints in different agricultural settings. Identification and molecular tagging of genes that control root growth and morphology will facilitate the development of cultivars suitable for specific soil conditions. For instance, breeding cultivars that have a strong basal root system in the top soil capable of efficiently extracting P.

This project will combine two technologies not commonly used in the study of roots: magnetic resonance imaging (MRI) and quantitative trait loci (QTL) analysis with molecular markers. The implementation of this combined approach will be immediately applicable to other crops at two levels. First, implementing MRI technology for characterizing root growth and developmental parameters in the common bean will facilitate the application of this technique to other crops. Second, the genetic information generated in this project can potentially benefit other legumes such as soybeans, cowpeas and mung bean, peas, chickpeas, lentils and faba beans. For instance, genes controlling seed size were detected in orthologous chromosome regions in cowpea and mung bean (Fatokun et al., 1992). Thus, genes that control root traits of interest in common bean could potentially be detected in syntenic chromosome segments in not only cowpea and mung bean, but in soybean, alfalfa and others. Furthermore, some synteny has been detected between some legumes and *Arabidopsis* (Lee et al., 2001; Yan et al., 2003). This observation implies that results from this work could potentially be applied to non-legume species.

Objectives

The long term objective of this proposal is to reduce the constraints of soil management via the development of cultivars with root systems suitable for specific soil environments. The specific objectives are:

1. To establish magnetic resonance imaging (MRI) as a reliable non-destructive procedure to measure root growth and to characterize root morphology in the common bean, *Phaseolus vulgaris*.
2. To survey *Phaseolus vulgaris* accessions from Andean and Mesoamerican origin, and assess the extent of genetic variation in root morphology, size and growth rate.
3. To identify and map, via QTL analysis with molecular markers, genes that control root characteristics in the common bean using a recombinant inbred (RI) family. This RI family (F_{10}) was generated between the Andean breeding line 'Calima' and the Mesoamerican land race 'Jamapa.'
4. To add the genetic information to the existing DSSAT drybean crop-soil model to predict the impact of using genetically improved cultivars in specific soil environments.

Accomplishments to Date

The project postponed its start to PY7. Key to the program is the recruitment of a suitable graduate researcher familiar with the MRI and QTL methodologies. During the past year, field data on shoot growth of a recombinant inbred family were collected and will be useful in analyzing shoot to root ratios.

FIELD SUPPORT TO MISSIONS

Project: Timor-Leste Agricultural Rehabilitation, Economic Growth and Natural Resource Management

Project: Improving Maize Productivity in the Planalto Area of Angola

Timor-Leste Project

The purpose of the Timor-Leste Agricultural Rehabilitation, Economic Growth and Natural Resource Management project is to strengthen the human and institutional capacity of the Ministry of Agriculture, Forestry and Fisheries (MAFF).

The goal of the project is to enable the Ministry's research and extension staff to continue to assist the nation's agricultural sector beyond the life of the project. To reach this goal, the project has three objectives.

Objective 1. Increase agricultural productivity and food security.
Objective 2. Diversify and intensify crop production to generate new income and employment opportunities.
Objective 3. Improve watershed productivity and sustainability through the adoption of sound natural resource management practice.

To enable the MAFF to achieve these objectives, the project will train the Ministry's research and extension staff to apply modern biophysical and socio-economic methods to produce, process and market farm and forest products for local and international markets. In order to produce quick results, the project will focus its efforts in the Seical watershed and work with rural communities situated at low, medium and high elevations to increase agricultural productivity across a range of agro-climatic zones. The lessons learned in the watershed will be the basis for transferring successful technologies to similar agro-climate zones in the nation's 26 watersheds.

A key and primary aim of this project is to enable MAFF in the years ahead to transform the existing subsistence farming system into a market driven economy. For this to occur, subsistence farmers must be full partners in the process of change. One of the critical tasks of the project will be to ensure full and willing participation of farmers in the project.

This field support activity was implemented as part of Modification No. 12 to the core grant in July 2003.

Progress in 2003-2004

Project activities were initiated in September 2003 with the posting of a country coordinator. At the recommendation of the Minister of MAFF, the principal location targeted for this project was the Seical watershed in the agricultural district of Baucau. Specifically, three sub-districts were identified: Venilale at the highest elevation, Gariuai/Fatumaca at the mid-elevation and Seical near sea level. A training session on soil testing was introduced to MAFF staff from 10 of the 13 agricultural districts in September. Using outputs from the soil test kits, a set of fertilizer-maize trials were established in November 2003 at the 3 locations in the upper and mid-elevation sites on farmers' fields. These trials were designed to serve as demonstrations plots for both MAFF and the communities. Maize is not planted in Seical and was not included in this series of trials.

Participatory Rural Appraisal (PRA)

A PRA, participatory rural appraisal, was conducted in January 2004 by University of Hawaii faculty and MAFF staff involving community members in the Venilale and Gariuai (Fatumaca and Buburaga) sub districts. Outcomes of the PRA subsequently guided the implementation of project activities relative to Objective 1 on increasing productivity and food security and Objective 2 on increasing opportunities for income generation.

From the PRA, we learned the major constraint to improving both production and income was an invasive weed, ***chromolaena orodata***. The areal extent of this weed made it prohibitive, both physically and economically, to implement an eradication program with herbicides. Bio-control was being considered by MAFF in association with their colleagues from Australia and will potentially help not only communities in the Baucau district but in all 13 agricultural districts in the country.

To utilize information gathered from the PRA, an experiment was designed to include farmer inputs and involve them in applying their skills, interests and intuitive knowledge of the land and climate as participants in a broad scale (a watershed scale) "land use" trial. Interested farmers were posed with the question "what would you do to and how would you increase your household income?" Responses reflected the need to diversify. After growing either or both rice and maize for food security reasons, most farmers, if not all, designated vegetables, poultry, livestock and fish as "money makers." Participating farmers indicated the primary purpose of the land use trial was to "make money." Each of the farm sites was geo-referenced. Furthermore, each of the farm sites included a vegetable garden in which chromolaena was used as a green manure. Chromolaena, it was learned, is a nitrogen accumulator. When an area was cleared of this weed, it was then used for income generation activities.

Four weather stations were installed along a transect from sea level (Seical) to the upper elevations (Venilale) to assess the effect environment has on the outcome of this trial.

A factor which might also benefit the various farm groups is that of the Ricardian principles of comparative advantage, whereby if these farm groups produce goods at a lower cost than another country and if that country produces a different set of goods at a lower cost than these groups, then each could trade their own relatively cheaper goods for the others relatively cheaper goods and both gain from the trade.

At the end of the first year, 10 of the first 11 farm groups were reported to have had income from their trials.

Natural Resource Management

As with Objectives 1 and 2, activities implemented under Objective 3 were outcomes from the PRA. We found that people needed forage trees for livestock and firewood trees, and that there was an active forestry nursery but without a working outreach program. When the local foresters asked for more nursery training, several workshops were presented on agro-forestry nurseries and produced tree seedlings for forage and other uses. In December, our group planted out demonstration agro-forestry projects and held a series of workshops on the use of multipurpose trees for forage, including one on how to use electrical fencing to control livestock grazing. Our program also fostered what appears to be unprecedented community involvement with the MAFF forestry program, so that seedlings that the MAFF produce are planted and taken care of by farmers who want them. The MAFF nursery in Baucau and those of CCT (Coffee Cooperative Timor) produced seedlings of *Leucaena leucocephala* to be planted at sites of the land use trial, where they were established as live fences to protect vegetable crops from livestock.

Angola Project

One objective of USAID/Angola is to stimulate the agriculture sector to serve as a source of food security, income and quality of life for rural Angolans by increasing agricultural productivity and competitiveness on the domestic, regional and world markets. To increase agricultural productivity, the SM CRSP together with World Vision, Ministry of Agriculture and CDRA and CLUSA partners, intend to overcome low maize yields in the Planalto region by introducing site-specific nutrient management for small farmers using a participatory learning approach. This approach seeks to assist farmers and farmer organizations, both directly and through local scientists, to diagnose and identify nutrient responsive production systems and to determine their fertilizer requirements for maize production.

Building the capacity of farmers for sustainable agriculture development will result in an improved development of the economy, society and environment. A scientific and cost-effective basis for increasing maize production is to ensure that the right nutrients are applied to the right crop at the right time and in the right amounts. A site-specific nutrient management approach, developed by the SM CRSP Project and its collaborators, provides a way to do this by the following step-wise structure: 1) Diagnosis, 2) Prescription, 3) Economic analysis, and 4) Empowering the farmer/grower with this information. This approach has been validated in Thailand, the Philippines and Mali, West Africa.

The farmer-empowering technology includes training farmer leaders to use soil test kits so they can "diagnose" nutrient responsive situations in their fields, farms or even problem sections of their fields. Extension personnel learn to use simplified decision-aids to interpret and convert soil test kit values into amounts of specific fertilizers to economically solve the diagnosed problem.

Objective

Enable Angolan scientists to diagnose nutrient deficiencies and prescribe fertilizers to empower farmers to improve maize and potato productivity in Huambo and other Planalto provinces.

Activities

Soil samples were collected from selected sites in the ProPlanalto region following the initial site-specific nutrient management-training workshop conducted in Huambo in August 2004. The workshop was organized in partnership with World Vision, CLUSA and CDRA. The soil samples provide baseline characterization of soils in the ProPlanalto and are important input data for diagnosing, predicting and estimating economic viability of fertilization of maize and potato crops. Angolan scientists acquired skills in using and interpreting outputs from soil test kits for nutrient diagnosis, in concepts of site-specific nutrient management and diagnostic results from soils that may be used for subsequent demonstration plots.

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Nepal Agricultural Research Council (NARC)
G.S. Giri
S.M. Maskey
R. Munamkarmy
S.P. Pandey
T. Pokharel
S. Rai
G. Sah
K. Sah
R.P. Sapkota
K. Scherchand
J. Tripathi
J. Tuladhar

University of Bangor
K.D. Joshi

Nicaragua
International Center for Tropical Agriculture Center (CIAT)
Pedro P. Orosco

National Institute for Agricultural Technology (INTA)
Elbenes Vega

Central American University (UCA)
Celia Gutiérrez

National Agrarian University (UNA-Nicaragua)
Domingo Reyes

Campesino University (UNICAM)
Elvis Pérez

Panama
Panama Agricultural Research Institute (IDIAP)
Roman Gordon
Benjamin Name
Jose Villareal

Philippines
Cagayan Valley Integrated Area Research Center (CVIARC)
Qurino Asuncion

Department of Agriculture Local Government Unit
Bonifacio Macarubbo
Jovito Gerona

Leyte State University
Angela Almendras
Racquel Serohijos

Philippines Rice Research Institute
Madonna Casimero
Rona Dollentas
Rudolfo Escabarte
Josephina Lasquite
Alice Mataia
Remelyn Relado

Visayas State University
Angela Almiendras

Senegal

Institut Sénégalais de Recherches Agricoles (ISRA)
M. Khouma
M. Ndiaye
M. Séne

The Netherlands

Wageningen University and Research Center
Jetse Stoorvogel

Thailand

Dept. of Agriculture
Santi Thirporn

Dept. of Ag. Ext (DOAE)
A. Charoensaksiri

Kasetsart University
Tasnee Attanandana

Dept. of Land Development (DLD)
Buri Bunyasompobphan
S. Kongton
T. Vearasilp

United States

Cornell University
G. Abawi
C. Adhikari (NARC/Cornell-Nepal Country Coordinator)
M. Devare
J. Duxbury
S. DeGloria
M. Latham
J. Lauren
D. Lee
S. Riha
J. Thies
N. Uphoff

Montana State University
John Antle
Bocar Diagana

North Carolina State University
Deanna Osmond
Jot Smyth
M. Wagger
J. White

Texas A&M University
F. Hons
H. Shahandeh

Understanding Systems, Inc.
Will Branch

University of Florida
Kenneth J. Boote
Samir Daroub
Arjan J. Gijsman
James W. Jones
Johannes Scholberg

University of Hawaii
Harry Ako
Robert Alexander
Richard Bowen
Andre du Toit
Carin du Toit
Kent Fleming
Michael Forman
J.B. Friday
Cathy Chan-Halbrendt
Nguyen Hue
Richard Kablan
Hu Li
Clark Liu
Harold McArthur
Luciano Minerbi
Richard Ogoshi
Robert Paull
John Powley
Fernando Sousa
Gordon Tsuji
Goro Uehara
Russell Yost

Virginia Tech University
K. Brannan

USDA Plant, Soil & Nutr. Lab
R. Welch ((Ithaca)

International Agricultural Research Centers (IARC)

CIMMYT

E. Duveiller (Nepal)
R.K. Gupta (RWC-India)
P. Hobbs (Nepal & Cornell Univ.)
D. Hodson (Mexico)
S. Justice (Nepal)
C. Meisner (Bangladesh & Cornell Univ.)
G.M. Panaullah (Bangladesh)
M.A. Razzaque (Bangladesh)

CIP

Charles Crissman (Kenya)
Roberto Quiroz (Lima)
David Yanggen (Lima)

ICRISAT

Pierre C. Sibiry Traore (Mali)

ILRI

Ernesto Gonzalez-Estrada
Philip Thornton

Private Sector

CY Associates
J. Gaunt (Cornell Univ.)

Doyel Agro Industrial Ltd.
Md. M. Haque (Bangladesh)

East-West Seeds
M.G. Hossain (Bangladesh)

TRAINING

Degree Programs

Name	Home Country	Gender	Degree
Cornell			
Steven Culman	USA	M	MS
Sanjay Gami	Nepal	M	PhD
Sarah Johnson	USA	F	PhD
Anne-Marie Mayer	England	F	PhD
Andrew McDonald	USA	M	PhD
Ramesh Pokharel	Nepal	M	PhD
Florida			
Valerie Walen	USA	F	PhD
Welch Bostick	USA	M	PhD
Jawoo Koo	S. Korea	M	PhD
IAAS Rampur			
Gopal Bhatta	Nepal	M	MS
Jagadish Kuinkel	Nepal	M	MS
Janma Gairhe	Nepal	M	MS
Montana			
Kara Gray	USA	F	MS
Universidad Nacional Agraria			
Denis Arica	Peru	M	MS
Renzo Barron	Peru	M	BS
University of Hawaii			
Hamidou Konare	Mali	M	PhD
Ricardo Maria	Mozambique	M	MS
Antonio Querido	Cabo Verde	M	PhD
Aminata Sidibé-Diarra	Mali	F	PhD
Wageningen University			
Guillermo Baigorria	The Netherlands	M	PhD
Reinier Ellenkamp	The Netherlands	M	MS
Abibou Niang	The Netherlands	M	MS
Cecilia Romero	The Netherlands	F	PhD
Alejandra Mora Vallejo	The Netherlands	F	PhD

Non-Degree Programs

Name	Home Country	Gender
Cornell		
Md. Bodruzzaman	Bangladesh	M
Montana State University		
Bocar Diagana	West Africa	M
Gibson Guvheya	Nairobi	M
Roberto Valdivia	USA	M
University of Hawaii		
Golden Jubilee	Thailand	F
Sukunya Yampracha	Thailand	F
Weena Wilnonk	Thailand	F

Workshops

Workshop	Location	Date	No. Attended
Rice-Wheat	North Bengal Institute Bangladesh	March 2004	24
Rice-Wheat	USA	June 2003	11
Carbon	El Bata, Mexico	December 2003	2
Carbon Sequestration	Bamako, Mali	March 2004	25
NuMaSS	Argentina	July 2003	8
Field Support	Timor Leste	January 2004	29
		February 2004	9
		May/June 2004	58
		July 2004	61
		August 2004	38
		September 2004	22
TOA	Nairobi, Kenya	November 2003	20
	Dakar, Senegal	September 2004	18

PROJECT MANAGEMENT

Management Entity (ME)

The University of Hawaii serves as the Management Entity for the Soil Management CRSP. Dr. Goro Uehara serves as Director and Dr. Gordon Y. Tsuji serves as Deputy Director. As the Management Entity, the University of Hawaii administers grant funds received from the Agency for International Development under Grant No. AID/LAG-G-00-97-00002-00. The Management Entity is responsible for the overall implementation of the research program and for coordination of project activities under seven sub-agreements with participating institutions and two direct projects at the University of Hawaii. Principal investigators prepare annual work plans and budgets associated with each of their respective project objectives and submit them to the Management Entity for transmittal to the Technical Committee for review and evaluation.

The Management Entity reports on the overall progress of program activities and represents the SM CRSP in negotiations with AID and in meetings and teleconferencing of the CRSP Council. The CRSP Council consists of directors of the nine different CRSPs that are administratively managed by both the Office of Agriculture and the Office of Natural Resource Management in the Bureau for Economic Growth, Agriculture and Trade (EGAT) of USAID. In 2003, the SM CRSP and two other CRSPs (IPM and SANREM) were moved from the Office of Agriculture and became part of the Land Resources Management (LRM) Team in the Office of Natural Resource Management (NRM).

Additionally, the Management Entity represents the interest of the SM CRSP in responding to requests for technical support and/or participation in forums received from the LRM/NRM team and from USAID missions. Field support activities with USAID missions in East Timor and Angola were implemented in response to such requests.

Operationally, the office of the Management Entity is in the Department of Tropical Plant and Soil Sciences in the College of Tropical Agriculture and Human Resources at the University of Hawaii.

Administratively, the Management Entity utilizes the services of the Research Corporation of the University of Hawaii (RCUH) to implement and manage its sub-agreements with participating institutions. The RCUH is a non-profit organization established by the State Legislature in 1965 to support “off-shore” research and training programs of the University of Hawaii. The University of Hawaii has oversight responsibilities of the RCUH.

The CRSP Guidelines established in 1975 by the Board for International Food and Agricultural Development (BIFAD) for USAID and federal regulations serves as a guide to manage the SM CRSP by the Management Entity. A revised version of the Guidelines was distributed in August 2000. Those guidelines direct each of the CRSP programs to establish a Technical Committee, a Board of Directors, and an External Evaluation Panel. The office of the Management Entity is responsible for administrative and logistical support to members of these “bodies.” A description of the role and composition of each follows.

Participating Entities

Board of Directors (BOD)

The CRSP Guidelines states: “The Board consists of representatives or all of the participating institutions and may include individuals from other organizations and host country institutions. The AID Program Officer and the ME Director serve as ex-officio members. The institution, which serves as the ME, will have a permanent member on the Board. Board members are selected by their participating institutions on the basis of their administrative responsibilities and relevant expertise. They should not be chosen solely to represent their respective institutions or projects, but to function in the objective interest of the CRSP. The Board operates under a defined charter to deal with policy issues, to review and pass on plans and proposed budgets, to assess progress, and to advise the ME on these and other matters. While the ME institution has the authority to make final decisions relative to program assignments, budget allocations and authorizations, the ME must, in the collaborative spirit, carefully consider the advice and guidance of the Board and other CRSP advisory groups. Any departure form the Board’s recommendations should be justified, recorded in minutes of the meeting, and reported in writing by the ME.”

The Board of Directors had their annual meeting in October 30, 2004 in Seattle. John Havlin of North Carolina State was re-elected to serve as Chair of the Board with Ramesh Reddy as Vice-chair. As Board

Chair, Havlin participated in the annual meeting of the principal investigators and members of Technical Committee in Bamako, Mali from July 12 to 16, 2004.

Members and officers of the Board of Directors include:

- Dr. John Havlin, North Carolina State University, Chair
- Dr. Andrew Hashimoto, University of Hawaii
- Dr. Thomas McCoy, Montana State University
- Dr. Ramesh K. Reddy, University of Florida, Vice-chair
- Dr. Philip Thornton, ILRI, Nairobi, Kenya

Minutes of meeting are available by accessing the SM CRSP web site at the following URL, http://tpss.hawaii.edu/sm-crsp. http://agrss.sherman.hawaii.edu/sm-crsp

Technical Committee (TC)

The CRSP Guidelines states: "The Technical Committee is established with membership drawn primarily from principal scientists engaged in CRSP activities, known as principal investigators (PIs), and host country scientists involved in CRSP or IARC activities. The ME Director and the AID Program Officer serve as ex-officio members. The TC meets from time to time to review work plans and budgets, program performance, to propose modifications in the technical approach to achieve program objectives, and to recommend allocation of funds. The TC reports its findings in writing to the ME who will share them with the BOD."

The meeting of the Technical Committee was held in Bamako, Mali at the Plaza Hotel in from July 12 to 16, 2004 to review annual reports for PY7 and work plans and budgets for project year eight (PY8). Russell Yost of the University of Hawaii stepped down as a member of the TC and was replaced by James W. Jones of the University of Florida.

Members of the Technical Committee include the following:

- Dr. E.B. (Ron) Knapp, Retired, CIAT, Chair
- Dr. Thomas Walker, Michigan State University, Maputo, Mozambique
- Dr. John Antle, Montana State
- Dr. James W. Jones, University of Florida

Dr. Charles Sloger of AID/EGAT/NRM/LRM, who serves as the SM CRSP's Cognizant Technical Officer (CTO) and Drs. Goro Uehara and Gordon Tsuji of the ME, participated in the meeting. Dr. Sloger reported that the budget for PY8 totaled \$2.8M compared to the \$3.5M (\$2.9M + \$600K) in PY6 and \$3.0M (\$2.4 + \$600K from PY6) in PY7.

Each PI made oral presentations of annual reports and work plans to members of the TC before noon and met with the TC in the afternoon of the same day to discuss each project's progress and their work plans.

External Evaluation Panel (EEP)

The CRSP Guidelines states: "The EEP is established with membership drawn from the scientific community to evaluate the status, funding progress, plans, and prospects of the CRSP and to make recommendations thereon. In accordance with the CRSP guidelines, the panel shall consist of an adequate number of scientists to represent the major disciplines involved in the CRSP, normally no more than five members. This number will vary with program size and cost-effectiveness. The term of office shall be long-term to retain program memory. A five-year term is recommended for the initial panel and subsequently rotated off on a staggered time base. Provisions should be made for replacements for low attendance, for resignations or for other reasons. In instances where a minor discipline is not represented on the EEP, the Chairman may request the assistance of an external consultant from the ME."

"Panel members will be internationally recognized scientists and selected for their in-depth knowledge of a research discipline of the CRSP and experience in systems research and/or research administration. International research experience and knowledge of problems and conditions in developing countries of some members are essential. The members are selected so that collectively they will cover the disciplinary range of the CRSP, including socioeconomic components that can influence research and technology adoption. Panel members should be drawn from the United States (some with experience in agricultural research and knowledge of the Land Grant University system) and the international community and should include at least one scientist from a developing host country. Availability to devote considerable time to EEP activities is an important criterion for membership."

The EEP did not meet in PY7. During the meeting of the Board of Directors in Seattle in October 2004, the Board prepared a recommendation to USAID to utilize external members of the TC and BOD plus one or two other experts to serve the functions of the EEP.

As this report goes to print, no response was received from USAID.

USAID/CTO

At the end of the PY 7 on September 30, 2004, Charles Sloger was replaced as the SM CRSP's CTO. David Hess, Director of AID/EGAT/NRM, and Jeff Brokaw, Team Leader for the LRM, advised the SM CRSP that both Mike McGahuey, Jr. and Carrie Stokes would be our new CTOs.

CRSP Council

Principal communication links among the CRSP programs are established through the CRSP Council. Directors of nine CRSPs constitute membership of the CRSP Council. Current chair of the Council is Dr. Irv Widders, Director of the Bean Cowpea CRSP at the Michigan State University with Dr. John Yohe of the INTSORMIL CRSP at the University of Nebraska serving as Vice-Chair. Members of the Council are as follows.

Director	***CRSP***	***Institution***
Michael Carter	BASIS	Wisconsin
Irv Widders	Bean and Cowpea	Michigan State
Tag Demment	Global Livestock	California, Davis
John Yohe	INTSORMIL	Nebraska
"Short" Heinrichs	IPM	Virginia Tech
Tim Williams	Peanut	Georgia
Hillary Egna	Pond Dynamics	Oregon State
Carlos Perez	SANREM	Georgia
Goro Uehara	Soil Management	Hawaii

The CRSP Council serves as a communication link among the nine CRSPs and as a conduit for information flow to and from USAID and other organizations such as NASULGC (National Association of Universities and Land Grant Colleges). Communication involves either teleconferencing, e-mail correspondence through the Internet, and meetings as necessary, typically on an annual basis. The INTSORMIL staff at the University of Nebraska created a web site for the CRSP programs. The URL for the site is http://www.ianr.unl.edu/crsps/.

FINANCIAL SUMMARY AND EXPENDITURE REPORT

Financial Summary

Modifications or "mod" to the Grant are the incremental awards to the core budget. Mod#11 added $2.4M to the core budget and $600,000 for field support from the mission in Dili, Timor-Leste. Mod#12 was an additional award of $1.8M for an additional 18 months for field support from the USAID mission in Dili, East Timor and Mod#13 was an award of $140,000 for field support from the USAID mission in Luanda, Angola. The combination of the $2.4M in Mod#11 plus the $600,000 from Mod#10 resulted in the PY7 annual budget of $3M compared to the $2.9M for PY6.

Table 5 is a cumulative list of modifications to the grant with award totals and dates of the incremental awards.

Expenditure Report

Tables 6a, 6b and 6c list the cumulative annual expenditure report, cost sharing and allocation of funds from the ME to each participating institution and project, respectively. This report also includes the final expenditure report from Texas A&M that is associated with the budget for PY5. An additional column in Table 6a is listed for field support (FS) activities in Timor-Leste and in Angola. Dr. Goro Uehara is the PI for the former and Russell Yost is the PI for the latter.

Note the expense report totals for both Cornell (CU) and Hawaii (UH) reflect the combined expenditures of two projects at each institution.

Table 5. Incremental funding awards to the SM CRSP for the period covering February 11, 1997 to September 30, 2004.

Award	PY	Amount	Period
Initial Grant	1	$2,467,975	Feb 11, 1997–Sept 30, 1997
Mod # 1	1 & 2	$1,131,025	Oct 01, 1997–Apr 30, 1998
Mod # 2	2	$2,500,000	May 01, 1998–Apr 30, 1999
Mod # 2[a]	2	$200,000	May 01, 1998–Apr 30, 1999
Mod # 3[b]	2	$1,000,000	May 01, 1999–Jul 31, 1999
Mod # 4	3	$2,500,000	May 01, 1999–Apr 30, 2000
Mod # 5[c]	3	$200,000	May 01, 1999–Apr 30, 2000
Mod # 6	4	$2,500,000	May 01, 2000–Apr 30, 2001
Mod # 6[c]	4	$100,000	May 01, 2000–Apr 30, 2001
Mod # 6[d]	4	$200,000	May 01, 2000–Apr 30, 2001
Mod # 7	5	$2,146,428	May 01, 2002–Feb 10, 2002
Mod # 8	5	N/A	Feb. 11, 2002–Sept 30, 2002
Mod # 9	6	$636,188	July 25, 2002–Oct 25, 2002
Mod # 10	6	$2,123,505	Oct 25, 2002–Sept 30, 2003
Mod # 10[e]	6	$140,307	Oct 25, 2002–Sept 30, 2003
Mod # 10[f]	6	$600,000	Oct 25, 2002–Sept 30, 2003
Mod #11	7	$3,000,000	Oct 1, 2003–Sept 30, 2004
Mod #12[g]	7	$1,800,000	Oct 1, 2003–Sept 30, 2004
Mod # 13[h]	7	$140,000	Oct 1, 2003–Sept 30, 2004

Notes: Superscripts a, b and c refer to field support funds received by the SM CRSP from the Office of Disaster Relief, the AID mission in Bangladesh, and the AID mission in Ethiopia, respectively. Superscript d and e refer to supplement funding to the core budget from AID for impact assessments and Biotechnology respectively. Superscript f refers to supplemental funding to the SM CRSP core budget for the following year. Superscript g and h refer to field support funds received by the SM CRSP from the AID mission in Timor-Leste and Angola respectively.

Table 6. Financial summary statement ($'000) of expenditure, cost sharing and funding for PY 7 (Oct 1, 2003 to Sept 30, 2004) from vouchers received.

a. Summary of Expenditures reported during PY 7 (Oct 1, 2003 to Sept 30, 2004)

Institution	MSU	NCSU	CU	TAMU	NifTAL	UFL	UH	FS	ME	Total
	501	174	509	102	0	196	554		514	2,550
								784 (*Timor-Leste*)		784
								23 (*Angola*)		23
Total	501	174	509	102	0	196	554	807	514	3,357

b. Cost Sharing for PY 7 (Oct 1, 2003 to Sept 30, 2004)

Institution	MSU	NCSU	CU	TAMU	NifTAL	UFL	UH	ME	Total
Total	91	28	208	0	0	15	118 (*UH*)	N/A	459
							64 (*Timor-Leste*)		64
	91	28	208	0	0	15	182		523

c. Summary of Cumulative Core Funding (February 11, 1997 to September 30, 2004)

Institution	MSU	NCSU	CU	TAMU	NifTAL	UFL	UH	ME	Total
Mod #2	194	1,000	483	361	190	58	0	214	2,500
	0	0	0	0	0	168	0	32	200[a]
Mod #3	39	173	604	57	36	0	0	61	1,000[b]
Mod #4	142	765	773	293	143	0	0	384	2,500
Mod #5	0	0	0	0	0	0	0	200	200[c]
Mod #6	176	876	523	276	173	95	0	380	2,499
Mod #6[d]	0	0	0	0	0	0	0	200	200[d]
Mod #7	138	784	470	200	140	74	0	34	2,146
Mod #8	0	0	0	0	0	0	0	0	0
Mod #9	130	63	141	0	0	71	145	87	637
Mod #10	423	188	474	0	0	219	486	334	2,124
Mod #10[e]	0	0	0	0	0	0	0	140	140[e]
Mod #10[f]	0	0	0	0	0	0	0	600	600[f]
Mod #11	553	250	712	0	0	350	1,222	503	3,590
Mod #12[g]	0	0	0	0	0	0	1,800	0	1,800[g]
Mod #13[h]	0	0	0	0	0	0	140	0	140[h]

Notes: Superscripts a, b and c refer to field support funds received by the SM CRSP from the Office of Disaster Relief, the AID mission in Bangladesh, and the AID mission in Ethiopia, respectively. Superscripts d and e refer to supplement funding to the core budget from AID for impact assessments and Biotechnology respectively. Superscript f refers to supplemental plus field support funding to the SM CRSP core budget for the following year. Superscripts g and h refer to field support funds received by the SM CRSP from the AID mission in Timor-Leste (East Timor) and Angola respectively.

FIELD SUPPORT, COST SHARING AND LEVERAGING

Field Support

Field support is also referred to as "buy-ins." These are additional activities undertaken by the SM CRSP at the request of a USAID field mission. Funds to support these additional activities are provided by the mission to the ME institution through the Office of Procurement (OP), now the Office of Acquisition and Accounting (OAA). In PY7, the mission in Dili, Timor-Leste extended the initial 6-month sub-grant to 24 months and the mission in Luanda, Angola reached agreement for a one year sub-grant award. Interestingly, both are lusaphone or Portuguese speaking countries. Timor-Leste has two national languages, Portuguese and Tetun.

Timor-Leste

The action plan for the first six-month program was extended by 18 months for a two-year program. Total funding provided by the mission was $2.4 million for the 24 months. The project entitled "Timor-Leste Agricultural Rehabilitation, Economic Growth and Natural Resources Management" involved the recruitment of two full-time staff members to be posted in-country and involved the conduct of a participatory rural appraisal to guide project researchers in the conduct of activities to increase productivity, improve household incomes and preserve and sustain their forest resources in the Seical watershed, Baucau Agricultural District.

Project startup was hindered early on by administrative hurdles in personnel recruitment and in transferring funds to non-U.S. affiliated banks in Timor-Leste. With the assistance of OAA, most of these hurdles were overcome over the first year.

The project's URL, http://tpss.hawaii.edu/tl, serves as the information source on this activity.

Angola

Field support from the mission in Angola evolved after the participation of Angolan scientists in a workshop on site-specific nutrient management held in Mozambique from March 22 to 26, 2003. Ricardo Maria, a MS candidate at the University of Hawaii from Mozambique, organized the workshop. Mr. Maria received support through a scholarship provided by the INTSORMIL CRSP via USAID/Maputo. The workshop in Maputo was conducted in Portuguese by the host institution, INIA, and Russell Yost, PI for NuMaSS activities in Africa.

Charles Sloger, CTO for the SM CRSP, Yost and Ken Lyvers of the USAID mission in Luanda were instrumental in facilitating this field support activity for 12 months at a cost of $140,000.

Cost Sharing

Table 6b lists the cost sharing contributions from each of the participating U.S. institutions involved with the Soil Management CRSP. The total reflects the 25 percent matching requirement specified in the CRSP Guidelines (1975, 1999) of the modified total direct costs (MTDC). The following costs are exempt from cost sharing:

1. Funds to operate the ME.
2. Funds committed under terms of a formal CRSP host country subagreement, including facilities, host country personnel services, and equipment and commodity purchases by a participating U.S. institution for use by a host country entity or by the U.S. institution in a host country.
3. Costs for training participants as defined in ADS 253. Provisions for such training normally would be made in the formal sub-agreements.
4. Hospital and medical costs of U.S. personnel of the CRSP while serving overseas.

Matching may include in-kind support such as facilities and utilities to salaries/wages and fringe benefits costs.

Leveraging

Leveraging refers to unanticipated technical and material support provided to the project by host country and partner organizations. In this respect, leveraging is an indicator of acceptance of project goals and objectives. Leveraging is reported in terms of costs of human, fiscal and material resources from collaborating and cooperating institutions, organizations, agencies, and individuals. Values related to these costs are best estimates reported by principal investigators and their collaborators and are reported as equivalent U.S. costs in the list below by projects.

Project	Leveraged funds (est)	Subtotals
Carbon Sequestration		
NASA and SANREM CRSP	250,000	
IER, Mali	50,000	
ICRISAT, Mali	25,000	
NARI, The Gambia	25,000	
SARI, Ghana	50,000	
University of Ghana	15,000	
INERA, Burkina Faso	10,000	
BARI, Bangladesh	25,000	
BRRI, Bangladesh	25,000	
NARC, Nepal	25,000	
IAAS, Nepal	25,000	500,000
NuMaSS		
Kasetsart University	50,000	
Philippine Rice Research Institute	50,000	
IER, Mali	50,000	
NARI, The Gambia	25,000	
INIDA, Cape Verde	25,000	
INIA, Mozambique	15,000	
International Rice Research Institute (IRRI)	25,000	
ISRA, Senegal	50,000	
UCR, Costa Rica	50,000	
PROINPA, Bolivia	25,000	
CIAT-MIS	25,000	
INIFAP, Mexico	50,000	440,000
Trade-off Analysis		
International Potato Center (CIP)	50,000	
Wageningen Agricultural University (WAU)	42,000	
ISRA, Senegal	10,000	
Ecole Nationale d'Economie Applique	5,000	
Ecoregional Fund (ISNAR)		
Panama	50,000	
Kenya	120,000	
Sahel Agr Research Institute	5,000	
Consortium for Agr Mitigation of GHG	10,000	292,000
Rice-Wheat		
CIMMYT, Bangladesh	50,000	
IFAD, Cornell	50,000	
NARC, Nepal	25,000	
BARI, Bangladesh	50,000	
BRRI, Bangladesh	25,000	
CARE, Bangladesh & Nepal	25,000	
BRAC, Bangladesh	15,000	
RDRS, Bangladesh	10,000	
LiBird, Nepal	15,000	
FORWARD, Nepal	15,000	280,000
Biotech		
CIAT	15,000	
Zhejiang University	15,000	30,000
Field Support		
Timor-Leste		
MAFF	50,000	
GTZ	5,000	
Villages in Baucau Agricultural District	31,000	86,000
Angola		
World Vision	25,000	
CLUSA	25,000	
CRDA	25,000	75,000
TOTAL		1,703,000

PUBLICATIONS, PRESENTATIONS AND REPORTS

Publications and Books

Antle, J.M. and B. Diagana. 2003. Creating Incentives for the Adoption of Sustainable Agricultural Practices in Developing Countries: The Role of Soil Carbon Sequestration. Paper prepared for the American Agricultural Economics Association Annual Meetings, Montreal, Quebec, July 27-30. American Journal of Agricultural Economics 85(5):1178-1184.

Attanandana, T. and R.S. Yost. 2003. A site-specific nutrient management approach for maize-Thailand. Better Crops International. Vol. 17, No. 1 (3-7), May 2003. Potash and Phosphate Institute/Potash and Phosphate Institute of Canada.

Bao, Y.Q., B. Kost, N.H. Chua. 2001. Reduced expression of alpha-tubulin genes in *Arabidopsis thaliana* specifically affects root growth and morphology, root hair development and root gravitropism. Plant J. 28, 145-157.

Bostick, W.M., J. Koo, V.K. Walen and G. Hoogenboom. 2004. A web-based data exchange system for crop model applications. Agron. J. 96-853-856.

Bostick, W.M., S.H. Daroub, J.T. Ritchie, and J.W. Jones. 2002. A modular approach to modeling phosphorous in cropping systems. ASA meeting Poster. ASA Annual Meeting, Indianapolis, IN.

Costa, N.M.B., A.G. Low, A.F. Walker, R.W. Owen, H.N. Englyst. 1994. Effect of baked beans (*Phaseolus vulgaris*) on steroid metabolism and non-starch polysaccharide output of hypocholesterolemic pigs with or without an ileorectal anastomosis. Br J Nutr. 71, 871-886.

Duxbury, J.M., J.G. Lauren, M.H. Devare, A.S.M.H.M. Talukdar, M.A. Sufian, A. Shaheed, M.I. Hossain, K.R. Dahal, J. Tripathi, G.S. Giri and C. A. Meisner. 2004. Opportunities and constraints for reduced tillage practices in the rice-wheat cropping system. pp. 121-131. *In:* R. Lal, P.R. Hobbs, N. Uphoff, D.O. Hansen (eds.). Sustainable Agriculture and the International Rice-Wheat System. Marcel Dekker, Inc. New York.

Duxbury, J.M. Climate change, carbon dynamics and world food security workshop at the Ohio State University, June 10-1, 2003, Columbus, OH. *In press*.

Fatokun, C.A., D.I. Menancio-Hautea, D. Danesh, N.D. Young. 1992. Evidence for orthologous seed weight genes in cowpea and mung bean based on RFLP mapping. Genetics 132, 841-846.

Flor, C.A., M. Thung. 1989. Nutritional disorders, pp 571-604. *In:* Bean Production Problems in the Tropics, H.F. Schwartz and M.A. Pastor-Corrales (eds.). CIAT Press, Cali, Colombia.

Gaedeke, N., M. Klein, U. Kolukisaoglu, C. Forestier, A. Muller, M. Ansorge, D. Becker, Y. Mamnun, K. Kuchler, B. Schulz, B. Mueller-Roeber, E. Martinoia. 2001. The *Arabidopsis thaliana* ABC transporter AtMRP5 controls root development & stomata movement. EMBO J 20, 1875-87.

Gijsman, A. J., Hoogenboom, G., Parton, W.J., and Kerridge, P.C. 2002. Modifying DSSAT crop models for low-input agricultural systems using a soil organic matter-residue model from CENTURY. Agron. J. 94:462-474.

Gijsman A.J., Oberson A., Tiessen H. and Friesen D.K. 1996 Limited applicability of the CENTURY model to highly weathered tropical soils. Agronomy Journal 88: 894-903.

Jones, J.W., W.D. Graham, D. Wallach, W.M. Bostick and J. Koo. 2004. Estimating soil carbon levels using an Ensemble Kalman Filter. Trans ASAE 47(1):331-339.

Jones, J.W., V. Walen, M. Doumbia and A.J. Gijsman. Soil carbon sequestration: understanding and predicting responses to soil, climate and management. In Carbon Sequestration Book, R. Lal (ed.). *In press*.

Kamprath, E.J. and T.J. Smyth. 2004. Liming of soils. *In:* D. Hillel (ed.) Encyclopedia of Soils in the Environment. Elsevier Sci., Oxford, UK. *In press*.

Kendall WA, GA Pederson, RR Hill. 1982. Root size estimates of red-clover and alfalfa based on electrical capacitance and root diameter measurements. Grass Forage Sci. 37, 253-256.

Klueva, N.Y., R.C. Joshi, C.P. Joshi, D.B. Wester, R.E. Zartman, R.G. Cantrell, H.T. Nguyen. 2000. Genetic variability and molecular responses of root penetration in cotton. Plant Sci. 155, 41- 47.

Lee, J.M., D. Grant, C.E. Vallejos, R.C. Shoemaker. 2001. Genome organization in dicots. II. Arabidopsis as a 'bridging species' to resolve genome evolution events among legumes. Theor. Appl. Genet. 103, 765-773.

Nielsen, K.L., C.R. Miller, D. Beck, J.P. Lynch. 1998. Fractal geometry of root systems: Field observations of contrasting genotypes of common bean (*Phaseolus vulgaris* L.) grown under different phosphorus regimes. Plant Soil 206, 181-190.

Pachico, D. 1989. Trends in world common bean production, pp. 1-8. *In:* Bean Production Problems in the Tropics, H. F. Schwartz and M. A. Pastor-Corrales (eds.). CIAT Press, Cali, Colombia.

Parton, W.J., J. W. B. Stewart, and C.V. Cole. 1988. Dynamics of C, N, P and S in grassland soils: a model. Biogeochemistry 5:109-131.

Phillips, R.L., I.K. Vasil. 2001. DNA-based Markers in Plants, 2nd edition. Kluwer Academic Publishers, Dordrecht, eds,

Price, A.H., K.A. Steele, B.J. Moore, P.B. Barraclough, L.J. Clark. 2000. A combined RFLP and AFLP linkage map of upland rice (*Oryza sativa* L.) used to identify QTLs for root-penetration ability. Theor. Appl. Genet. 100, 49-56.

Sidibé, Aminata, R. Yost, M.D. Doumbia, Tasnee Attanandana, Adama Bagayoko, A.B. Kouyate, R. Kablan and X. Wang. 2003. A proposed algorithm for estimating the amounts of rock P needed to meet crop phosphorus requirements in West African Soils. Communications in Soil Science and Plant Anal. 35:385-397.

Stoorvogel, J.J., J.M. Angle, C.C. Crissman and W. Bowen. 2004. The Tradeoff Analysis Model: Integrated Bio-Physical and Economic Modeling of Agricultural Production Systems. Agricultural Systems 80:43-66.

Stoorvogel, J.J., J.M. Antle and C.C. Crissman. 2004. Trade-off analysis in the Northern Andes to study the dynamics in agricultural land use. Journal of Environmental Management. *In press*.

Van den Broek, J., Stoorvogel, J.J, Yanggen, D., 2004 The effects of terracing on soil properties: A Case study for the Peruvian Andes. CIP Working paper, submitted.

Yan, H., J. Mudge, D.J. Kim, R.C. Shoemaker, D.R. Cook, N.D. Young. 2003. Estimates of conserved microsynteny among the genomes of *Glycine max*, *Medicago truncatula* and *Arabidopsis*. Theor. Appl. Genet. 106, 1256-1265

Presentations and Reports

Antle, J.M., J.J. Stoorvogel, R.O. Valdivia and D. Yanggen. Assessing the Economic Potential for Soil Carbon Sequestration: Terraces and Agroforestry in the Peruvian Andes. Working Paper, September 2003.

Badini, O., C. Stockle, A. Kodio, J.W. Jones and M. Keita. 2004. Analyzing Potential Increases in Productivity and Soil Carbon Using Rotational Grazing. Proceedings of Regional Scientific Workshop on Land Management for Carbon Sequestration. February 2004, Bamako, Mali. http://www.sanrem.uga.edu/carbon/workshopProgram/index.html.

Berthe, A.A., O.P. Kante, I.S. Mouleye, A. Berthe, M.D. Doumbia, R. Kablan, R.S. Yost and Constance Neely. 2004. Les benifices de l'adoption des courbes a niveau: Une approache d'amelioration de la productivite. Presented at: Regional Scientific Workshop on Land Management for Carbon Sequestration in West Africa. Bamako, Mali.

Bostick, W.M., O. Badini, J.W. Jones, R.S. Yost, C.O. Stockle and A. Kodio. 2004. Ensemble Kalman Filter Simulation of Carbon Dynamics in a Semi-Arid Rotational Grazing System. Presented at the "Regional Scientific Workshop on Land Management for Carbon Sequestration." Bamako, Mali. February 26-27, 2004.

Bostick, W.M., J. Koo, J.W. Jones, A.J. Gijsman, P.S. Traoré and B.V. Bado. 2003. Combining Model Estimates and Measurements Through an Ensemble Kalman Filter to Estimate Carbon Sequestration. ASAE Paper No. 033042. ASAE, St. Joseph, MI 49085. 13 pp.

Brannan, K.M., R. Kablan, R.S. Yost, M.D. Doumbia, A. Yoroté, Y. Toloba, S. Sissoko, and M. Vaksman. 2004. Effect of the "Amenagement en courbes de niveau" on agricultural field water balance in Mali. Presented at: Regional Scientific Workshop on Land Management for Carbon Sequestration in West Africa. Bamako, Mali.

Cravo, M.S., J. Corteletti, O.L. Nogueira, T.J. Smyth and M.M.F. Batista. 2003. Resposta do feijão caupi à fertilizacão mineral e orgânica em Latossolo Amarelo da região nordeste do Pará. XXIX Brazilian Soil Sci. Congress, Ribeirão Preto, São Paulo. CD Rom.

Cravo, M.S., J. Corteletti, O.L. Nogueira, T.J. Smyth and M.M.F. Batista. 2004. Resposta de Culturas Anuais à Adubacão Fosfatada em Latossolo Amarelo de Áreas Degradadas do Nordeste do Pará. FERTBIO—Joint Brazilian Meetings on Soil Fertility, Micorrhizae, Soil Microbiology and Soil Biology, Lages, Santa Catarina. CD Rom.

Delisle, L., S. Traore, A. Ballo, M. Doumbia and R. Yost. 2004. Modeling soil spatial variability for C stocks estimation at the field level. Presented at: Regional Scientific Workshop on Land Management for Carbon Sequestration in West Africa. Bamako, Mali.

Diagana, B., J. Antle, J. Stoorvogel and K. Gray. Economic Potential for Soil Carbon Sequestration in the Nioro Region of Senegal's Peanut Basin. Paper presented at the NASA Regional Scientific Workshop on Land Management for Carbon Sequestration in West Africa, Bamako, Mali on February 26-27, 2004. Invited to be included in a special issue of Agricultural Economics to be published in 2004/2005.

González-Estrada, E., V.K. Walen, J. Naab, P.K. Thornton and M. Herrero. A farm-level analysis of carbon sequestration in Ghana using IMPACT linked to the DSSAT-Century, Household and Ruminant models. Proceedings of Regional Scientific Workshop on Land Management for Carbon Sequestration. February 2004, Bamako, Mali. SANREM CRSP, http://www.sanrem.uga.edu/carbon/workshopProgram/index.html.

Jarju, A.K., B.O. Jobe, F.S. Fatajo, M.N. Faye, Alieu Bittaye, C. Yamoah, R. Kablan and R. Yost. 2004. Ridge Tillage for Carbon Sequestration in the Gambian Cropping Systems. Presented at: Regional Scientific Workshop on Land Management for Carbon Sequestration in West Africa. Bamako, Mali.

Jones, J.W., P.S.C. Traore, J. Koo, W.M. Bostick, M. Doumbia and J. Naab. 2004. A Frame work for Integrating Remote Sensing, *in situ* Sampling, and Biophysical Models for Monitoring Soil Carbon Sequestration. Proceedings of Regional Scientific Workshop on Land Management for Carbon Sequestration. February 2004, Bamako, Mali.

Johnson, S.E., J.M. Duxbury, J.G. Lauren and K. R. Dahal. 2003. Effect of micronutrient seed priming on mineral nutrition of various crops in the rice-wheat system. ASA Annual Meetings. Denver, CO, November 2-6, 2003.

Johnson, S.E. and J.M. Duxbury. 2003. Effect of reduced soil conditions on Zn availability to paddy rice. ASA Annual Meetings. Denver, CO, November 2-6, 2003.

Kablan, R., K. Brannan, R.S. Yost, M.D. Doumbia, A. Yoroté, Y. Toloba, S. Sissoko and M. Vaksman. 2004. Effect of the Amenagement en courbes de niveau on soil moisture storage and crop water use efficiency in Mali. Presented at: Regional Scientific Workshop on Land Management for Carbon Sequestration in West Africa. Bamako, Mali.

Konare, H., N.V. Hue, R.S. Yost, G. McCarty, M. Doumbia, H. Coulibaly and A. Bagayoko. Practical methods of estimating soil organic C in soils of the Sahel, West Africa. Regional Scientific Workshop on Land Management for Carbon Sequestration in West Africa. Bamako, Mali.

Koo, J., W.M. Bostick, J.W. Jones, A.J. Gijsman and J.B. Naab. 2003 Estimating soil carbon in agricultural systems using Ensemble Kalman Filter and DSSAT-CENTURY. ASAE Paper No. 033041. ASAE, St. Joseph, MI. 49085. 13 pp.

Naab, J.B., J. Koo, J.W. Jones and K.J. Boote. 2004. Simulating Cropping Systems in Ghana with DSSAT-CENTURY. Proceedings of Regional Scientific Workshop on Land Management for Carbon Sequestration. February, 2004, Bamako, Mali. http://www.sanrem.uga.edu/carbon/workshopProgram/index.html.

Osmond, D.L., T.J. Smyth, R.S. Yost, D.L. Hoag, W.S. Reid, W. Branch, X. Wang and H. Li. September 2004. Nutrient Management Support System (NuMaSS), v.2.1. Soil Management Collaborative Research Support Program, North Carolina State University, Raleigh, NC.

Padgham, J.L. Management of the rice root-knot nematode (*Meloidogyne graminicola*). http://mulch.mannlib.cornell.edu/rootknot/index.html.

Séne, M., A.N. Badiane, M. Khouma, K. Brannan, R. Kablan and R. Yost. 2004. Effects of Ados en courbes de niveau on soil water conservation, soil carbon content and crop yield in the Peanut basin on the Sudano-Sahelian zone; Senegal. Preliminary results. Presented at: Regional Scientific Workshop on Land Management for Carbon Sequestration in West Africa. Bamako, Mali.

Smyth, T.J. 2003. Seminar on NuMaSS software. PROINPA, Cochabamba, Bolivia, July 18, 2003.

Smyth, T.J. 2003. Nutrient Management Support System (NuMaSS): software development, description and applications. July 21, 2003. National Institute for Agricultural Technology, Pergamino, Argentina.

Smyth, T.J. 2004. Developments in the NuMaSS-Latin America Project. CIAT-MIS Annual Planning Meeting, Matagalpa, Nicaragua, March 3, 2004.

Smyth, T.J. and P.P. Orozco. 2004. Adjusting NuMaSS to Regional Conditions: example with data from an N fertilization trial. CIAT-MIS Annual Planning Meeting, Matagalpa, Nicaragua, March 4, 2004.

Traoré, P.C.S., A. Folliard, M. Vaksmann, C. Porter, M. Kouressy and J.W. Jones. 2004. Enhanced Photoperiod Response Modeling for Improved Biomass Simulation in a Sudanian Carbon Accounting Framework.

Traoré, P.C.S., W.M. Bostick, A. Yoroté, J. Jones and M. Doumbia. 2004. Upscaling Carbon Model Predictions Using Very High Resolution Imagery: Evaluation of Contextual Approaches to Land Cover Classification and Crop Identification. Proceedings of Regional Scientific Workshop on Land Management for Carbon Sequestration. February 2004, Bamako, Mali. http://www.sanrem.uga.edu/carbon/workshop-Program/index.html.

Walen, V.K., J.W. Jones and M.D. Doumbia. 2004. The Effect of Ridge Tillage on Infiltration in a West African Soil. Oral presentation at CSA-SSSA-ASA annual meeting, November 2003, Denver, CO.

Walen, V.K., J.W. Jones and M.D. Doumbia. 2004. Development of a Rainfall-Runoff Partitioning Simulation Model to Study Infiltration in a West African Cropping System Oral Presentation at the Biological Systems Simulation Conference, March 2004, Gainesville, FL.

Walen, V.K., J.W. Jones and M.D. Doumbia. 2004. Development of a Rainfall-Runoff Partitioning Simulation Model to Study Infiltration in a West African Cropping System. Oral presentation to the IFAS Graduate Research Symposium, April 2004. UF, Gainesville, FL.

ACRONYMS

ACN	Aménagements en courbes de niveau; aka, ridge tillage
ATDP	Agro-based Industries & Technology Development Project (USAID Bangladesh)
BADC	Bangladesh Agricultural Development Corporation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BRAC	Bangladesh Rural Advancement Committee
BRRI	Bangladesh Rice Research Institute
CARE	International non-governmental organization
CIAT-MIS	International Tropical Agriculture Center-Integrated Steepland Management
CIMMYT	International Maize and Wheat Improvement Center
CIP	International Potato Center
CSM	Cropping System Model
CO_2	Carbon dioxide
CRSP	Collaborative Research Support Program
CSD	Chinese seed drill
CT	Conventional tillage
CURLA	Regional University Center for the Atlantic Coast
DAE	Department of Agricultural Extension (Bangladesh)
DAP	Diammonium phosphate
DFID	Department for International Development (UK)
DICTA	Agricultural Science and Technology Directorate
DLD	Department of Land Development
DOA	Department of Agriculture
DSR	Direct seeded rice
DSSAT	Decision Support System for Agrotechnology Transfer
DT	Deep tillage
ECEC	Exchangeable cation exchange capacity
EMBRAPA-CPATU	Brazilian Agricultural Research Enterprise-Humid Tropics Research Center
ENEA	Ecole Nationale d'Economie Applique
FFS	Farmer Field School
FAO	Food and Agricultural Organization
FHIA	Honduran Foundation for Agricultural Research
FORWARD	Local non-governmental organization (Nepal)
GIS	Geographic Information Systems
GO-Interfish	CARE rice-fish program in Bangladesh
HKI	Helen Keller International
HYV	High yielding variety
IAAS	Institute for Agriculture and Animal Science (Rampur, Nepal)
IBTA	Bolivian Institute for Agricultural Technology
ICRAF	International Center for Research in Agroforestry
ICRISAT	International Center for Research in the Semi-Arid Tropics
ICTA	Institute for Agricultural Science and Technology
IDIAP	Panama Agricultural Research Institute
IDRC	International Development Research Centre
IER	Institut d' Economie Rurale, Mali
IHCAFE	Honduran Coffee Institute
INIA	Instituto Nacional des Investigacões Agricolas
INIAP	National Agricultural Research Institute
INIFAP	National Forestry and Agricultural Research Institute
INPOFOS	Potash & Phosphate Institute
INTA	National Institute for Agricultural Technology

ISRA	Institut Senegalaise de Recherces de Agricole
ITC	Candelaria Community Technical Institute
KU	Kasetsart University
ILRI	International Livestock Research Institute
IMPACT	Integrated Modeling Platform for Animal-Crop sysTems
INIAP	National Agricultural Research Institute, Ecuador
INIA	National Agricultural Research Program, Peru
IPCC	Intergovernmental Panel on Climate Change
IRRI	International Rice Research Institute
ISRA	Institut Senegalaise de Recherces de Agricole
KARI	Kenya Agricultural Research Institute
KU	Kasetsart University
Li-BIRD	Local Initiatives for Biodiversity and Development
MOU	Memorandum of Understanding
NARC	Nepal Agricultural Research Council
NARES	National Agricultural and Extension Systems
NGO	Non-Governmental Organizations
NO_x,NO,NO_2,N_{20}	Nitrogen oxides
NT	Normal Tillage
NuMaSS	Nutrient Management Support System
NUTMON	Nutrient Monitoring
OC	Organic carbon
P	Phosphorus
PROINPA	Foundation for Andean Products Research and Promotion
RDRS	Rangpur-Dinajpur Rural Service
RT	Ridge tillage
SHABGE	CARE vegetable program in Bangladesh
SM CRSP	Soil Management Collaborative Research Support Program
SOC	Soil organic carbon
SOM	Soil organic matte
SRI	System of Rice Intensification
SS	Surface Seeding
TDR	Time domain reflectometry
TOA	Tradeoff Analysis
TPR	Transplanted rice
TRF	Thailand Research Fund
UCA	Central American University
UCR	University of Costa Rica
UNA-Catacamas	National Agricultural University
UNA-Nicaragua	National Agrarian University
UNICAM	‘Campesino’ University
UNIDERP	Univ. for Development of the State and the ‘Pantanal’ Region
VT	Virginia Polytechnic Institute and State University
WB	Walkely-Black method for carbon determination
WRC	Wheat Research Centre (Bangladesh)
Zamorano	Pan-American School, Honduras
ZT	Zero tillage (surface seeding)