SOIL MANAGEMENT COLLABORATIVE RESEARCH SUPPORT PROGRAM

PROJECT YEAR 6
ANNUAL PROGRESS REPORT

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

2002-2003

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Soil Management C♦R♦S♦P

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EXECUTIVE SUMMARY

As a global program representing a small fraction of on-going international agricultural research, the Soil Management CRSP must choose with care which among three research purposes it employs to achieve its land resource management objectives. The first purpose of research, often referred to as basic research, is to understand processes. The SM CRSP rarely undertakes this type of research and does so only when basic understanding of processes blocks attainment of the second and third purpose of research.

The second purpose of research is to use our understanding of processes to make predictions. This often forgotten and neglected research purpose is the link that connects applied research to basic research.

The third purpose of research, which corresponds to the SM CRSP's major focus, is to enable its customers to use science-based predictions to manage and control outcomes. In short, the three purposes of research are to understand, predict and control. The SM CRSP, as well as this annual report, is about enabling our customers to control outcomes.

To enable large numbers of individuals and groups operating in diverse socioeconomic and biophysical environments to control their own destinies requires each individual or group to make sound decisions. Making good decisions depends first on properly diagnosing a problem and second on reliably predicting the anticipated outcomes of alternative prescriptions.

A case in point is the SM CRSP's Nutrient Management Support System (NuMaSS) project that enables host-country institutions in Africa, Asia and Latin America to replace outdated trial-and-error methods with those of science-based diagnosis and prediction to increase farm profits using fertilizers. The trial-and- error method is analogous to a doctor prescribing medication for an ailment without knowing its cause.

In agrarian societies, enabling farmers to make better agronomic and economic decisions makes sense because they make up the majority of the population. But choices available to farmers are often determined and influenced by policy decisions made by government officials. This aspect of agricultural systems is covered by the TOA project, which utilizes a policy decision support system based on tradeoff analysis of agricultural production systems. First applied in Latin America, the CRSP's TOA is being readied for application in West and East Africa.

A key attribute of NuMaSS, TOA and other SM CRSP products is their ability to operate globally and locally. They are able to operate globally because the knowledge and principles captured, condensed and organized in them apply everywhere. Outcomes that affect the lives of SM CRSP customers, however, are influenced by local, often highly site-specific conditions. Thus, to serve customers living in diverse environments around the world, the CRSP products are designed to couple global knowledge with local data to generate information useful for decision making by our customers.

In Mali, the government is helping farming communities install a soil and water conservation practice. Although this practice significantly and visibly improves farm performance especially in low rainfall years when the risk of food shortages is high, its adoption rate is low because low incomes prevent farm households from paying for the small installation cost. In documenting the benefits of the practice, the SM CRSP has discovered that the practice results in the sequestering of a significant amount of carbon as soil organic matter, which in turn loosens the soils, causing more water to infiltrate into the soils to recharge the ground water and provide a more stable water supply in village wells that often run dry. The Malian government now realizes that the sequestered carbon, if traded to offset CO_2 emitted by industry, can generate new income to help finance the war on poverty. The SM CRSP is working with the Malian and other West African countries to develop a carbon accounting system to enable them to participate in carbon trading should that opportunity arise.

Collaboration with the International Agricultural Research Centers is another important feature of the SM CRSP's effort to reach more customers. In South East Asia, where the green revolution had one of its greatest successes, the performance of high yielding rice varieties has not only reached a plateau but has been declining from unforeseen soils-related factors. By working together with local and international organization, the SM CRSP is adding its knowledge to help sustain the food production in the world's most densely populated region.

Rhizosphere biotechnology is a new field not just for the SM CRSP but also for agricultural science in general. The rhizosphere is hidden from view but much of what we see above ground hinges on what occurs below ground. The role of the SM CRSP in this regard is to ensure that advances in biotechnology are extended to the rhizosphere as well as to ensure that genetic engineering of the above ground parts does not impair the symbiotic relationships that naturally occur in the root zone.

Finally, the SM CRSP continues to partner with USAID Missions to strengthen the human and institutional capacity of developing countries. This is the fastest growing component of the CRSP and will continue to be a high priority area for the years ahead.

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, countries involved, principal investigators and host country institutions are listed in the following Table 1.

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

The demands for assistance in policy- and farm-level decisions on soil nutrient management exceed the human capacity of experts available in most of the developing countries targeted by USAID for "improved food availability, economic growth and conservation of natural resources through agricultural development," leading to bottlenecks in both the access to and transfer of pertinent technologies. Scarcity of experts can be alleviated, however, if the knowledge required is organized in a manner that enhances both the efficiency of country-level experts to assist and the capabilities of less-experienced personnel. 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.

In Phase 2 of this SM CRSP, we intend to enhance the adoption of integrated nutrient management strategies by adapting NuMaSS through a network of ongoing programs in Latin America, Africa 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 their 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.

Latin America Activities

With CIAT and the MIS Consortia in Honduras and Nicaragua, corn yield and soil data from multi-location, on-farm trials with fixed rates of N, P and K in two watersheds are being used to evaluate diagnosis of N and P with NuMaSS.

Collaborators at IDIAP in Panama have established critical soil P and K levels for upland rice and cowpea on Ultisols and have started field trials to evaluate N fertilizer requirements for promising upland rice cultivars. North Carolina State University researchers are working with IDIAP to develop regional diagnostic and recommendation criteria for N levels in corn, based on 15 site-years of existing N fertilization trial data in a region dominated by Alfisols. Results from data on the Alfisols will be used to assess outcomes from trials on Ultisols. Chlorophyll meter readings in the N trials show promising results for future use of this auxiliary tool in diagnosing N deficiency and adjusting existing N fertilization rates for future crops. A series of P fertilization trials with corn were initiated

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

Project Title	Countries Institutions	Principal	Participating 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 Attanaadana, Madonna Cusimero	University of Hawaii Kasetsart University Philippine Rice Research Institute
Adoption of the Nutrient Management Support (NuMaSS) Software Throughout Latin America	Honduras, Ecuador, Brazil, Panama, Mexico	T. Jot Smyth and Deanna L. Osmond	North Carolina State University
Program Area 2. Tradeoff Analysis			
Tradeoff Analysis Project Phase 2: Scaling Up and Technology Transfer to Address Poverty, Food Security and Sustainability of the Agro-Environment	Kenya, Senegal, Peru, Equador	John M. Antle	Montana State University
Program Area 3. Rice–Wheat			
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 Jones and John Duxbury	University of Hawaii University of Florida Cornell University
Program Area 5. Biotechnology			
Genetic Characterization of Adaptive Root Traits in the Common Bean	United States	C. Eduardo Vallejos and James 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

on Alfisols with variable clay contents in Panama to evaluate NuMaSS P recommendations.

Collaborative activities with EMBRAPA involve CPATU in the Amazon and CNPGC in the southwest Cerrados. In the Amazon, a series of long-term field calibration trials were started for N, P, K and lime requirements for multiple improved cultivars of cowpea, upland rice and corn in regions where Oxisols and Ultisols were cleared from rainforest vegetation and cropped for several decades without external nutrient inputs. Additional trials with corn and soybean were planned and will start in January 2004 in regions where degraded pastures are being converted into mechanized crop production. In the southwest Cerrados region, collaborators at CNPGC are evaluating P requirements and acidity tolerance of promising grass and legume forages.

INPOFOS and INIAP in Ecuador and the University of Costa Rica will collectively initiate trials with potato to develop diagnostic and predictive criteria for P in Andisols with variable levels of amorphous Al. Evaluation and adoption of NuMaSS on alkaline and calcareous soils are being conducted in the Tamaulipas province of Mexico via collaborative activities of Texas A&M University with INIFAP. Current nutrient recommendations by NuMaSS, INIFAP and the Texas Agricultural Experiment Station in Weslaco, Texas will be evaluated and compared in irrigated and dryland grain sorghum trials on selected major soil types in the region. Development of a module to enable users to add local soil and crop values to the NuMaSS database is approaching completion. The initial prototype will be tested in conjunction with the extensive soil, crop and climate database that CIAT has assembled for Honduras.

Africa and Southeast Asia Activities

Rock phosphate is of major interest in both Mali and Thailand and there is a similar basic algorithm, but for comparatively very different soils in each country. Issues of potassium sufficiency have been identified as critical in Senegal and are also of great interest in Thailand. These types of issues and activities provide multiple opportunities for collaboration and mutual benefit among the countries participating in this program area.

Several academic degree training activities have been initiated, including the beginning of a graduate program by a Malian scientist, cooperating with IER/Mali, who will be expanding and adapting decision-aid concepts to include rock phosphate and its use in the Sahel. Also, a collaborative relationship was developed with the INSORMIL CRSP to support a graduate student from Mozambique, who will be working on the introduction and testing of NuMaSS and other site-specific nutrient management technologies in his country. A survey of farmers in Northern Ghana was carried out as an example of firstly identifying farmers' needs and requirements before using the NuMaSS technology. The approach was well received by farmers and has yielded important information in adapting the NuMaSS software for Africa.

Studies in Thailand for the first year of Phase 2 were focused on field-testing and improving N predictions using NuMaSS. The Thai decision-aid (Thai corn) was developed initially using a simplification of CERES-Maize N. The simplification was effected by determining climate and soil parameters for each of the major soil series of the maize belt of Thailand. Soil series was then used as an index of minimum datasets that were used to run CERES-Maize N and make predictions of N required. The results of the predictions were tabulated and these results were retrieved from simple tables on handheld computers again indexed by soil series (Attanandana *et al.,* 1999). Thus, soil series identification was a crucial step in the Thai decision-aid for nutrient management. The identification of soil series was also simplified from that used by Soil Taxonomy, by substituting simple observations of soil color, soil texture, calcareous concretions, soil pH, and soil depth (Vearasilp *et al.,* 2003). In Thailand as well as most other countries, fertilizers are added as N, P, and K mixtures and combinations. That NuMaSS does not include a K module limits use and appeal. To address this need an associated project was established with the assistance of Thai co-investigators with support from the Thai Research Fund and the Thai Golden Jubilee Project. This effort is expected to contribute to the adoption of nutrient management decision-aids by providing a comprehensive assessment of N, P, and K requirements for crops. Associated work in other regions under SM CRSP Phase 2, indicate strong K deficiencies (see Senegal section in this program area report).

In Phase 1 of the project, field tests of predictions of the N, P, and lime algorithms used in NuMaSS were initiated and reported in a workshop held in 2002 (Casimero *et al.,* 2003).

For Phase 2, a workshop was held at Leyte State University (LSU) on 6-8 May 2002 aimed at developing the work plan for this phase to coordinate three project sites. It was agreed that the three sites (one for Luzon, Visayas and Mindanao islands) and a total of 30 farmer cooperators would be involved in the on farm trial of the NuMaSS. Participants in the workshop were stakeholders working in upland areas including local and international scientists, extension personnel of local government units and players in the fertilizer industry (the PhilPhos Fertilizer Production Plant). This plant, the largest in SE Asia imports much of its rock phosphate from Togo, Africa. The work plan for each of the sites was outlined. The activities were designed to attain the outputs of the various objectives of the program in the second phase. Aside from identifying the activities to be conducted, the general protocol for the on-farm trial, site selection and identification of farmer cooperators was made. The protocol will guide the researchers from each site in selecting the farms and cooperators and establishing the on-farm trials.

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

Latin America

NuMaSS uses various soil and crop coefficients in diagnosing nutrient constraints and in prescribing remedies. Testing is done to ensure that local crop cultivars and soil conditions are adequately represented by existing coefficients. The milestone event for this project year was the development of a detailed 5-year plan of network activities upon the completion of visits to all sites. Existing data sets, participant interests and some of the ongoing activities for each site will be described in the following sections.

MIS Consortium, Honduras

The Consortium for the Management of Fragile Soils of Central America (MIS) is an inter-institutional organization devoted to the development, adaptation and dissemination of technologies to improve management of fragile soils in Central America. Nineteen institutions (NARS, Universities and Development Projects) in Honduras and Nicaragua participate in the Consortium. Primary support comes from the Soil Water and Nutrient Management Program convened by CIAT. MIS activities are conducted in reference watersheds in both Honduras and Nicaragua. In August 2002, a three-day training workshop on the NuMaSS software was conducted by SM CRSP members held in conjunction with visits by participants to the Tascalapa watershed near Yorito, Honduras and the Calico (San Dionisio) watershed near Matagalpa, Nicaragua. The 20 workshop participants included 15 from Honduras and 5 from Nicaragua, representing 11 institutions. Three major themes were identified and concept notes were developed and submitted to the MIS Executive Committee:

- Incorporation of regional data into the NuMaSS data base,
- Correlation of soil/plant analytical methods and results among the eight laboratories distributed among MIS member-institutions in Honduras and Nicaragua;
- NuMaSS field testing and validation of existing field trial data with software predictions.

A Memorandum of Understanding between CIAT and NCSU, the latter on behalf of SM CRSP, was developed and implemented to cover collaborative activities between this project and MIS. In the last year of Phase 1 (2001-2002), a series of replicated, on-farm NPK trials with corn were conducted in the two watersheds, with five experimental treatments, each replicated three times in 14 m2 plots. Soil samples for the NPK field trials are being analyzed in this project year to test and compare NuMaSS yield predictions in Diagnosis for N and P deficiencies with the yield results for the N and P treatments. Nitrogen uptake data for corn in the control treatments also provide estimates of the native soil N supply. Reviews of field trial data and laboratory survey results will be combined to identify critical knowledge gaps that will need further investigation as part of the effort to adopt NuMaSS to the MIS regional domain.

EMBRAPA, Brazil

Collaborative activities are underway with two of EMBRAPA's national research centers, the Eastern Amazon Research Center (CPATU) in Belem and the Beef Cattle Research Center (CNPGC) in Campo Grande. Initial site visits were made in September, 2002. Seminar presentations on NuMaSS were made to the staff at both centers as well as the Federal Rural University of Amazonia, the Federal University of Para in Belem and the University for State and Pantanal Development in Campo Grande, whose faculty works closely with the CNPGC on soils-related matters.

Activities with CPATU focus on the recuperation of productivity on lands that are locally characterized as having category 2 degradation. These are areas that are predominantly Oxisols and Ultisols, cleared of rainforest vegetation and cultivated for several decades with little or no external nutrient inputs under either shifting cultivation or pastures. Secondary forest regeneration in fallow areas is poor and, in pastures, biomass of invader species exceeds that of the forages. The Tracuateua-Terra Alta region is located east of Belem along the Atlantic Coast. Our collaborative activities focus on nutrient management for cowpea-based cropping systems, which currently exceed over 20,000 ha. Long-term trials, on-farm and on-experiment station, were initiated with farm cooperative support and as part of local grant projects. These trials are designed to evaluate yield responses of one or more cultivars to multiple rates of individual nutrients (P, K, N and lime). The first crop cycle of cowpea was completed in October 2002 and most areas are currently planted to upland rice or corn.

Phosphorus. Significant differences in cowpea yields were noted between fertilizer P and organic inputs, i.e., chicken litter, in trials where broadcast rates of 22, 44, 66 and 88 kg/ha fertilizer P and of 5, 10, 15 and 20 tonnes/ha of chicken litter. Three cowpea varieties were tested for a comparative response to fertilizer P application. When fertilizer P was banded at rates of 0, 22, …, significant differences among varieties were observed. Blanket applications of K and lime were also included in these trials.

Potassium. Response of three cowpea cultivars to K fertilization was evaluated in an on farm trial adjacent to the banded fertilizer P study. Blanket applications of P and lime were also made to all treatments. Similar to the P trial, yields for cultivars Canapu and BR3 were superior to that of cultivar BR2. Yield differences between cultivars are related to their differences in phenology and rainfall distribution during the cropping cycle. Days from emergence to flowering are greater for BR2. The sequence of planting dates for these on-farm experiments was in the order of K followed by P, then lime; overall grain yields for the experiments also declined in the same order as drought stress increased with delays in planting dates.

Liming. A long-term liming experiment was also initiated in the same field adjacent to the experiments with P and K. Treatments were a factorial combination of lime and gypsum rates. Blanket applications of P and K were made to all treatments and the same three cowpea cultivars were evaluated. There was a significant yield response to 1.0 t lime ha^{-1}, when averaged across gypsum treatments and cultivars. Furthermore, there was a significant reduction in yield with 0.5 or 1.0 t gypsum ha^{-1}. Preliminary soil analysis indicates that acidity was not a major constraint for cowpea. The experiment will continue through subsequent crops and will provide indications on soil acidification, potential acidity constraints and residual effects of lime. On-farm and on-experiment station trials are being used to evaluate nutrient requirements and yield responses for corn or selected upland rice cultivars planted in the wet season. Furthermore, N fertilization trials were also initiated. These data in current and future crops will provide a more thorough interpretation of findings on crop yields and in the development of a local database for NuMaSS.

The Paragominas region is located South of Belem along the Belem-Brasilia highway. Currently, the region is being transformed into a major production center for soybean and corn. Farmers are converting pastures into annual crop production systems with both conventional and no-till practices. Due to farmer requests for technical assistance, EMBRAPA-CPATU has established and permanently staffed a research nucleus in Paragominas. There is strong interest in using the NuMaSS software, coupled with soil test analytical services at CPATU, as the primary tool for technical assistance in nutrient management for this region. Testing and adoption of NuMaSS will follow a similar approach to that used in the Tracuateua-Terra Alta region. Long-term trials, both on-farm and on-station, will be established to evaluate promising cultivar and hybrid yield responses to variable rates of lime, K, N and P under crop rotations of corn, soybean and other promising species. Planting of the initial crop for these trials is scheduled for January 2003.

The CNPGC is located near Campo Grande in the ustic *Cerrado* ecosystem. Soils in the region include Alfisols, Quartzipsamments, Ultisols and Oxisols. The Center provides national and regional leadership in forage grass and legume germplasm selection and management technologies for pastures. A pasture management strategy with increased popularity is the periodic rotation between pastures and annual crops. The Center maintains a large, replicated, long-term experiment with Panicum- and Brachiaria-based pastures to evaluate frequencies of pasture-crop rotations and different cropping alternatives. Collaborators at the Center are interested in using NuMaSS as a tool to help devise nutrient management recommendations for the annual crops. CNPGC collaborators are also interested in contributing their information on grass and legume nutrient requirements to the NuMaSS database. One of the current limitations for economic interpretations of pastures in NuMaSS is that it considers forage rather than animal productivity. Hopefully, CNPGC can help us to devise coefficients that will enable economic assessments at least in *Cerrado* ecosystems of animal productivity for nutrient recommendations to pasture systems.

IDIAP, Panama

The Panamanian Agricultural Research Institute (IDIAP) maintains a soil and plant analysis lab in Divisa that serves the public in the surrounding provinces of

Cocle, Veraguas, Herrera and Los Santos. Collaborators in this region of Panama were visited during 23-26 April 2003. The laboratory in Divisa is already using NuMaSS to provide lime recommendations. Their current interests in local adoption of NuMaSS focuses on developing nutrient recommendations for upland rice and corn—two crops for which they have already developed a significant research database.

From trials undertaken in 2000–2002 for upland rice and corn, much nutrient management data were obtained. Use of these site-specific values significantly improved the match between NuMaSS predictions and observed data. These data will be further investigated with collaborators to clarify differences in previous land-use history, rainfall and other site variables. Our intent is to identify proxy variables for sites that would enable the future development of an N database for NuMaSS in this region of Panama.

Africa

Testing and adapting NuMaSS software and concepts in Africa have very different requirements than elsewhere but provide an excellent test of the flexibility and adaptability of information technology. In Asia, our collaborators developed their own software and carry out implementation in their own language and in ways pertinent to local nutrient management issues. In Africa, the attitude differs dramatically in the approaches, the technology and the methods appropriate for implementing the decision-making structure. At the same time there are numerous parallels that have currently led to some mutual activities among collaborators. For example, some of the soil test kit technology developed in Asia seems useful, at least initially, in the collaborating countries in Africa. Rock phosphate is of major interest in both Mali and Thailand, and a similar basic algorithm, but for drastically different soils, is being tested in both countries. Issues of potassium sufficiency have been identified as critical in Senegal while also being of great interest in Thailand.

Senegal

A workshop, initiating the SM CRSP Carbon and NuMaSS projects in West Africa, was held February 17-21 in Bambey, Senegal. The purpose of the workshop was to initiate the SM CRSP Carbon and NuMaSS projects in Africa. A missing element study was carried out to identify possible causes for extremely low yields of sorghum and peanut in a phosphogypsum-rock phosphate study at Nioro, Senegal. Results of the study indicate that potassium was extremely deficient and the most limiting nutrient among N, P, K, Ca, Mg and S, while calcium was the second most limiting nutrient. These results indicate the need for the potassium module that is being developed in Thailand and Mali by collaborators.

Mozambique

A collaborative study with INTSORMIL CRSP was initiated in Mozambique. The primary activity was to provide limited research support of a graduate student who is carrying out NuMaSS project objectives, but whose academic and some research support comes from the USAID mission in Maputo through INTSORMIL. 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 in the dissertation work of Ms. Aminata Sidibé-Diarra at the University of Hawaii. She has completed a laboratory study, published the results and conducted the first of several field studies.

A study has begun under the supervision of Dr. M. Doumbia with funds from IER/Mali on an implementation of the K algorithm that has been proposed for addition to PDSS and the NuMaSS software.

Ghana

A test set of interviews were conducted in the Upper West region in Wa and Nadowli districts to determine the causes of low soil fertility on farmlands and the options farmers and experts reasoned could be used to overcome them. These interviews were the first attempt during Phase 2 to determine the issues that NuMaSS is likely to be able to address and resolve. This activity thus relates to the objective of determining causes and factors that will affect the acceptability of NuMaSS and the NuMaSS approach in Africa.

The direct interviews based on checklist includes some of the following questions:

1. What do you use to increase nutrients in the soil?
2. Do you know of existing technology to increase carbon of your land?
3. What are your suggestions to better address farmers' needs in the use of these technologies?

The survey indicated that the methods farmers use in managing fertility of their fields include:

- Natural bush fallow ranging from 3 to 6 years.
- Crop residue management.

- Crop rotation.
- Application of animal manure.
- Limited use of inorganic fertilizers.

These choices are rational given that the soils in the Wa area are predominantly sandy and moisture retention is often problematic. These technologies were chosen to ensure that organic matter is not depleted in the soil. Farmers are aware of the potential value of inorganic fertilizer but its high cost and unavailability at the right time impedes their widespread use. Some farmers have manure, with which they use to supplement scarce fertilizer during the cropping season. To promote the economic use of fertilizer, we suggest the application of the NuMaSS DSS to 1) determine fertilizer rates under the above management systems and 2) compare statistically the full NuMaSS fertilizer rate with a half and a quarter of the full rate generated by NuMaSS. Farmers' practices will serve as check plots. This approach respects farmers' traditional soil fertility management practices and is likely to enhance efficient use of the limited amount of inorganic fertilizer. The soil test kit could be calibrated with actual laboratory results and used for routine monitoring of soil fertility on farmers' fields. The advantage of the kit is that the results are quick and correction of a nutrient deficiency can be made within a short time span.

Southeast Asia

Thailand

Thailand began a focused initiative in 2000 and 2001 to implement decision-aid approaches to nutrient management. Their resources and our collaborators represent perhaps the highest level, in availability, of superior quality local expertise that can adapt NuMaSS algorithms to their own conditions, needs and language. Our Thai collaborators have previously adapted the Phosphorus Decision Support System (PDSS) algorithms into their decision-aid, called SimCorn, that is available in both desktop and handheld versions. We have previously adapted the PDSS software to include the Bray II extractant, which is widely used in SE Asia and have incorporated both perennial crop and rock phosphate modules in the PDSS software.

Subsequent interest by the Thai group in the PDSS as an alternative to their existing Mitscherlich-Bray approach and its testing and adoption into the SimCorn software has led to further consideration of the algorithms used in NuMaSS. Initial results of testing the PDSS approach to estimating P requirements led to a 50 percent reduction in soil P requirements. Other countries in the project test and use different parts of the NuMaSS decision-aid, while still others, in Africa for example, are not at the point of testing NuMaSS algorithms, but are assessing initial farmer information needs with respect to nutrient management.

For this project year, the work was designed to field test the initial Thai work, which exclusively used the DSSAT software approach to determine N requirements. Results from the 2002 harvest year indicated that all N algorithms as implemented in DSSAT v3, DSSAT v3.5, and NuMaSS needed updating and, in some cases, parameter modification, in order to match field-determined N requirements. Analysis of NuMaSS results in this cropping year suggested that abnormal and unexpected amounts of N were mineralized during the cropping season. This unexplained mineralization is being further studied. The combining of soil test kits with the NuMaSS and DSSAT software seems useful, and the field data show that the soil test kit nitrate test is effective in diagnosing fields that are responsive and non-responsive to the application of N fertilizer. The work in Thailand has provided an example of how to incorporate the use of NuMaSS ideas, concepts and structure into other decision-aids. In addition, our Thai collaborators are presently supporting graduate studies in the development and testing of a potassium (K) algorithm and have now proposed that UH incorporate the K algorithm into the present PDSS system of NuMaSS and are willing to provide the financial support to do so. This illustrates the flexibility of our approach in motivating local scientists to consider and develop their own decision-aid ideas and concepts and adapt the NuMaSS concepts to their own needs. This offers them a chance to expand and develop their expertise in decision-aid development with the expectation that these decision-aids can subsequently be used for other applications both in nutrient management and in other aspects of agriculture and food production.

Philippines

The upland areas comprise the third largest crop production zone in the Philippines, where crops are either planted to a permanent cropping system or to a shifting cultivation system. In both systems, there is a problem of low and unstable productivity and questionable sustainability of the resource base because of erosion, drought, low soil fertility and acid sulfate soils. Under the shifting cultivation system, short duration crops such as rice, corn, root crops and vegetables are planted. In most cases, the cropping system is limited to only one crop planted during the wet season. Farmers have limited knowledge on increasing cropping intensity and sustainable cropping systems.

With the burgeoning Philippine population, the upland areas will soon be in the forefront of producing major commodity crops. These upland areas, however, have a great potential for diversified cropping systems. Once soil acidity and nutrient constraints are solved, more crops can be grown, new cropping strategies are possible, yields can be increased, products and services diversified and the improved vegetation cover would protect and the soil from erosion and minimize off-site transport of nutrients.

In Phase 1, we set up on-farm trials in four provinces. Participatory Rural Assessments (PRAs) were conducted in each sample site to establish benchmark information on the socioeconomic characteristics of the area and to assess the resources of the farming households. Farming problems identified were low yield, lack of capital, low soil fertility, low income, insufficient technology and pests and diseases. When asked to address the problems of low yield and low income, the farmers indicated their receptivity to new technologies by indicating that proper nutrient management plays a major role in the attainment of high yields and ultimately a higher income.

Most soils tested were found to be mainly acidic with a high level of aluminum saturation and a clayey soil texture. The problem of acidity in these soils is associated with deficiencies of nutrients such as nitrogen, phosphorus, potassium, calcium, magnesium and molybdenum as well as toxic amounts of aluminum and manganese (Mn). So far, there is no estimate of how much of these acid soils are specifically aluminum- or Mn-toxic. However, as production expands to the untapped acid upland areas, we can expect to encounter more problems associated with excess Mn. (Bajita-Locke 2003, *PhD dissertation*).

A series of field and greenhouse experiments were conducted to investigate the dynamics of Mn phytotoxicity in soybeans, and to test management options that can alleviate the problem under field conditions. Field experiments were conducted on an Ultisol in northern Philippines while the greenhouse experiment used a manganiferous Oxisol from Oahu, Hawaii. In both greenhouse and field experiments, leaf Mn concentration in soybeans and soil saturated paste Mn were poor indicators of Mn phytotoxicity based on the poor correlation between these test results and plant biomass production or grain yields. Over a range of growth conditions, therefore, plant and soil tests for Mn must be interpreted with caution. Nutrient and environment conditions may greatly modify plant response to excess Mn. Thus, the difficulty of establishing one critical value for soil tests or plant tests that will diagnose Mn phytotoxicity over a range of plant species and growth conditions. The uncertainty of using soil or plant tests to diagnose Mn phytotoxicity becomes a bottleneck to its management. For better diagnosis and management of excess Mn, we needed to study the dynamics of the phytotoxic response. Why and how nutrients as well as the environment affects phytotoxic response to Mn will have profound implications on its diagnosis and management (Bajita-Locke 2003, *PhD dissertation*).

N Predictions Using NuMaSS

Field tests of predictions of the N, P and lime algorithms used in NuMaSS were initiated in the Philippines in Phase 1 of the SM CRSP and reported in a workshop held in 2002 (Casimero *et al.,* 2003). In this project year, studies in Thailand focused on field-testing and improving N predictions using NuMaSS. The Thai decision-aid (Thai corn) was developed initially using a simplification of CERES-Maize N. The simplification was effected by determining climate and soil parameters for each of the major soil series of the maize belt of Thailand, and soil series was then used as an index of minimum datasets that were used to run CERES-Maize N and make N predictions. The results of the predictions were tabulated and these results were retrieved from simple tables on the handheld computers again indexed by soil series (Attanandana *et al.,* 1999).

Soil series identification was a crucial step in the Thai decision-aid for nutrient management by substituting simple observations of soil color, soil texture, calcareous concretions, soil pH, and soil depth (Vearasilp *et al.,* 2003). As described elsewhere, the identification of soil series was also simplified from that used by Soil Taxonomy.[1] The field responses to N obtained in the 2002 cropping season indicate yields ranged from 800 to 1200 kg/rai (equivalent to 5000 to 7500 kg ha^{-1}). In numerous plots, check plot yields were equal to or greater than those where N was applied. This turned out, with one exception, to occur where medium levels of pre-plant nitrate were measured by soil test kits. The exception, where pre-plant nitrate was very low (VL) or low (L), responses to applied N occurred. It was later determined that this farmer's field (Jamlong) had been planted to legume in the previous crop, thus explaining part of the reason for the incorrect diagnosis by the soil test kit. This comparison suggests that the use of the pre-plant nitrate test by the soil test kit was generally quite

[1]Soil Survey Staff. 1999. 2nd edition. Soil taxonomy: a basic system of soil classification for making and interpreting soil surveys. USDA Natural Resources Conservation Service, Handbook 436. U.S. Government Printing Office, Washington, D.C.

useful in detecting N responsive conditions in these two soil series. Unfortunately, these two soil series do not represent many of the maize-producing soils of Central Thailand and further comparisons are being carried out currently.

The responses of maize to applied N were also used to compare N predictions of the DSSAT v3 and v3.5 maize modules and in adapting a simplified version for use in the Thai decision-aid. As discussed elsewhere results from version 3.5 were adapted from those of 3.0 to include the initial nitrate from soil test kits. From the field response comparisons and other data, it was determined that DSSAT v3.5, with adjusted coefficients and assuming 500 kg of residue remained at the beginning of the planting season, gave predictions closest to field-determined N response. Subsequent versions of the Thai decision-aid, Thai corn, will use updated and revised predictions from DSSAT v3.5. This reflects the approach to adjusting and adapting the DSSAT maize module to field-obtained N response curves in earlier versions of Thai maize decision-aid. The field tests of N were used to calibrate and adjust DSSAT versions of the N module and also used to compare and contrast NuMaSS N module predictions. Of note were the overestimates of the N module of NuMaSS in relation to field-obtained response curves. A further analysis of the check yields of the seven on-farm experiments indicates that the check plot yields were much higher than expected. This occurred in spite of the Low to Very Low amounts of soil test kit nitrate. This higher than expected mineralization of the native soil N resulted in higher check plot yields and a much lower field estimates of the N fertilizer requirement than anticipated. As a result, the initial NuMaSS recommendation was an overestimate. The over estimation seems to be related to low estimates of soil mineralization. The initial estimates were 5% and 2% for the Satuk and Pak Chong series, respectively.

During the year, the sites of the on-farm trials as well as the farmer cooperators were agreed upon in Iliagan, Isabela, Philippines. Certain criteria and guidelines were followed in the selection of sites and cooperators. Soil samples were taken from each farmer's field and analyzed. The data were used to diagnose and predict the lime, N and P requirement for each farmer's field.

On-farm experiment results indicate a very significant yield increase in plots applied with NuMaSS recommendations compared with the control, farmer's practice and the regional recommendation. Maize grain yield increased by more than 4.5 t/ha with the application rates based on NuMaSS recommendation compared to the control, 2.2 t/ha over farmer's practice and 1.2 t/ha compared to the regional recommendation. The removal of N from the NuMaSS recommendation resulted in a 2.2 t/ha or 46 percent reduction in yield compared to the yield obtained when N was applied. These results indicate that NuMaSS was able to predict the lime, N and P requirement of maize during the season.

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

Latin America

NuMaSS 2.0 has fourteen extensive databases containing information on crops, soils, fertilizers, manures, legume cover crops and diagnostic probabilities of nutrient deficiencies. Some of the data were collected from publications (e.g., crop yield data table), whereas other data were provided (e.g., soil pedon data table). Specificity of recommended default values by the software depend on how much data there is. In some cases, users may want to either add their local values to existing data tables or create their own data tables. Development of a new module is approaching completion to allow users to customize the following data tables in NuMaSS: crop yield, crop critical level, legume cover crops, manure, fertilizers and soils. Structure of the data base customization ensures that integrity of the software's original decision support system is maintained. Once the module is fully developed and tested, it will be released as a patch file for NuMaSS 2.0, which we anticipate will be small enough for distribution via e-mail.

Africa and Southeast Asia

In Phase 2 of the project, protocols for testing, comparing and adapting nutrient management decision aids to use in increasing the NuMaSS knowledge base and its adoption will be prepared. To do this, farmers in Senegal will use soil test kits and comparison of results between fields will be made. The farmers involved in this survey will attend a training session that deals with the use of these kits, and we anticipate this will take place in this project year and 2004. Also in Senegal, field studies on the optimum rate of phosphogypsum will be made.

In Thailand, as in most other countries, fertilizers are added as N, P, and K mixtures and combinations. NuMaSS does not include a K module, and this has limited its use and interest as a fertilizer prediction system. To address this need, an associated project was established with the assistance of Thai co-investigators using funds from the Thai Research Fund and the Thai Golden Jubilee Project. This effort is expected to contribute to nutrient management decision-aids adoption by providing a comprehensive assessment of N, P, and K requirements for crops. Associated work in other regions under this SM CRSP in Phase 2, indicate strong K deficiencies (see *Senegal* subhead in this report). Also initial soil data from Laos suggest that K is very low in some of the rice soils that are being considered for alternative crops in rice-based systems. Moreover, a rock phosphate module for acid sulfate soils is being developed by an associated project funded also by Thai research funds and the Thai Golden Jubilee program. This rock phosphate algorithm, discussed in the *Africa* section of this report, was developed initially for sandy soils of the Sahel but is now being tested in heavy clay, acid sulfate soils in Thailand. It is expected that the results of the Thai study will also assist in adapting the module to the clayey soils found in the inland valleys of Mali where paddy rice production is gaining major importance in reducing costly imports of rice from neighboring countries.

Adapt NuMaSS Database and Structure to Users and Regions

Latin America

Project activities target collaboration with national agricultural research service staff and encourage participation of their extension and agri-business counterparts. Collectively, these participants can identify and facilitate the transfer and use of NuMaSS-based information beyond those users with immediate access to the computer software. In this project year, initial visits to potential collaborators and their sites were planned and implemented. A comprehensive assessment of collaborators' intended use of the software will be conducted after completion of initial visits to all collaborators at the end of Project Year 1. Participation of extension, agri-business and farmers in the nutrient management decision-making continuum is illustrated, for example, by the *field day* activities that EMBRAPA-CPATU is implementing with their collaborative field trials in the state of Para, Brazil.

Africa & Southeast Asia

In this project year, we will enhance adoption or adaptation of NuMaSS-based knowledge by users in different geographical regions of Africa and Southeast Asia.

The adaptation of the NuMaSS database and structure is of major importance in our work in Africa. Several associated activities are underway that relate to this objective in Thailand as well. Firstly, participatory methods of determining limitations to maize production and the role of nutrient management in those limitations have been carried out. These surveys will parallel those obtained in Phase 1 studies but go further in fostering farmer organizations that facilitate the learning and transfer of farmer and extension officer knowledge and technical information from the Department of Agricultural Extension. These activities have also largely been carried out by associated projects in Thailand, including those by the Thailand Research Fund mentioned before and an FAO site-specific nutrient management project in Thailand. Some of the ideas and approaches used in the Thai studies have been carried out in farmer surveys in northern Ghana.

In Year 2, in Senegal, we will identify farmers' views of nutrient limitations and challenges. In Year 2 and 3, in Mali, we will adapt NuMaSS and PDSS software to include the rock phosphate module.

TRADEOFF ANALYSIS

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

This program area addresses the need in developing countries to generate the farm- and regional-level information demanded by decision makers to assess i) the sustainability of existing technologies, ii) the potential for adoption of economically and environmentally sustainable technologies and iii) the economic and environmental consequences of policy decisions for poverty, food security and sustainability of the agro-environment. In Phase 1 of the Tradeoffs Analysis program area, *a policy decision support system* based on tradeoff analysis of agricultural production systems was developed and applied to two watersheds in Ecuador and Peru. This phase emphasized the development of the Trade-off Analysis (TOA) method and analytical tools to implement it (data, models and software for their integration). A significant product of Phase 1 was the Trade-off 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.

The TOA method was implemented in Ecuador (in collaboration with the national agricultural research program, INIAP) and in Peru (in collaboration with the national soil conservation program, PRONAMACHS, and the national agricultural research program, INIA) to assess tradeoffs associated with pesticide leaching, water and tillage erosion, terracing, agro-forestry, and related soil management technologies. These applications provided the first tests of the TOA method and TOA Model software.

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 TPA Model software to existing and future user groups.

In the second phase of this project, 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.

Development of a West African (WA) Research and Training Program

In this project year, the development of a Trade-offs project presence in West Africa was initiated with the hiring of Bocar Diagana to coordinate the WA programs. Major activities include collaborative agreements with Institute Senegalais de Recherche Agricole (ISRA) in Senegal and a joint agreement with the Peanut CRSP and Ecole Nationale d'Economie Applique (ENEA).

Development of an East Africa Research and Training Program

The objectives of the TOA program in East Africa are to disseminate the TOA method and tools to institutions involved in research and policy decision-making. In this project year, the TOA team members met with potential Kenyan collaborators (ICRAF, ICIPIE, KARI) in Nairobi and at Egerton University in September 2002. Verbal agreements were prepared to invite collaborative work with ICRAF and KARI. Among the first activities of the program will be applications of TOA in two regions of Kenya, one in collaboration with the KARI National Dryland Farming Research Center, and one in collaboration with the World Agroforestry Center (ICRAF). Since the TOA approach is based on the formation of a multidisciplinary team of scientists for implementation of the TOA method, a collaborating project to utilize the TOA approach will need to form a suitable team. Based on the Trade-offs Project PI's assessment, the Egerton project would need to establish an agricultural science component comprised of at least one economist and one soil scientist. Expertise in crop science, animal science, and agroforestry also could be useful.

Because the TOA method is designed to study agricultural production systems such as those observed in the upper Njoro watershed, the focus of the TOA application will be the analysis of this agricultural system and its impacts on water quantity and quality. The TOA analysis would produce information that could be used as inputs into a hydrologic model of the river. However, the TOA modeling tools would not be suitable for analysis of conditions in the lower watershed where urbanization, non-agricultural industry, and other factors are impacting water quality and quantity.

At the project-planning meeting in Lima in November 2002, the TOA team met with CIP leadership and agreed to jointly fund a post-doc economist position to be based in Nairobi to serve as the TOA project coordinator for East Africa.

The Dutch Ecoregional Fund agreed to fund further applications of the TOA methods in East Africa, and the first work funded will be based on the use of the Nutrient Monitoring survey conducted by Wageningen University in Kenya.

Refinement of the TOC Model

The models developed for the analysis of terracing and agroforestry technologies in northern Peru were adapted to be used for a preliminary analysis of the technical and economic potential for soil C sequestration. A draft report presenting the methods and results has been prepared and will be finalized in July 2003. Interfaces for the CENTURY and DSSAT-CENTURY models will be developed so they can be incorporated into the TOA model framework. In addition, new soil samples are being collected that will be used to parameterize the DSSAT-CENTURY model to provide additional data on the technical potential to sequester carbon in this production system. The analysis and data collected will also be coordinated with the soil C sequestration project to test models being developed for Africa and South Asia (see *Carbon Sequestration* program area in this report).

Interfaces for these two models are being developed so that they can be utilized within the TOA model framework. The current version 3.1 of the TOA model software utilizes what can be called a loose coupling of disciplinary models. This loose coupling approach does not allow dynamic feedbacks between disciplinary models. A research paper on this theme was prepared and presented at a conference at Cornell University in May 2003 (Antle and Stoorvogel, 2003). Anew version of the TOA software is being developed that will allow feedbacks between disciplinary models to be incorporated into the simulation structure.

Roberto Quiroz (CIP Lima) is leading efforts to develop and test the usefulness of livestock models for use in the TOA model system. Activities this year include incorporating a pasture growth model into an existing dairy production model, and testing the sensitivity of the models to feed inputs. Consuelo Romero (National Ag University, Lima) is continuing work initiated in Phase 1 that is aiming to utilize the WEPP erosion model within the TOA system to further test the ability of the WEPP model to simulate the impacts of terracing on erosion by modifying soil properties and slope parameters. The WEPP interface to the TOA system was developed in Phase 1.

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

A review of available secondary data in Peru was conducted (Yanggen and Suarez, 2002), and statistical and fractal methods for scaling data were also investigated. The project team will assess these data and methods in August 2003.

A proposal for a follow-up phase of the Ecosalud Health Project was developed. The proposal focused on scaling up and scaling out of the research-intervention methodology of the previous phase and has been submitted to IDRC and is pending review.

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

The continued development and testing of TOA Model training materials and preparation for a training workshop with West African collaborators were undertaken.

A web site for the TOA Model (www.tradeoffs.nl) with on-line training materials was created. These materials are being updated and will be used in a planned one-week training workshop to be held at the Ecole Nationale d'Economie Applique in Dakar, Senegal, November 17-21, 2003. Participants will be from ENEA and ISRA in Senegal, and from collaborating institutions in Ghana and Mali.

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 (Duxbury *et al.,* 2000), stagnating and possibly declining productivity of rice in NW India (Duxbury, 2000) and declining factor productivity (Hobbs and Morris, 1996) indicate that the sustainability of the rice-wheat system is questionable. Neither farmers nor researchers are really sure of the reasons for these alarming trends. Diagnostic research from this project indicates that pressure from soil borne pathogens—or poor biological health—is a major underlying constraint that has received little attention. This fundamental constraint undoubtedly limits the effectiveness of many yield-enhancing technologies such as improved nutrient management and improved crop establishment. Consequently, yields of rice, wheat and many other crops will always be sub-optimal until this major constraint is addressed. We have developed several technologies to assist with this issue, but it remains an area that needs research to characterize biological populations, to better define soil biological health and to learn how to manage soil biology for the benefit of crop production.

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.

Understanding constraints to successful adoption of technologies is not generally considered by scientists. For example, we have worked with soil fertility specialists in

Bangladesh to compare crop yields obtained with general farmer practice to those obtained with regional and soil test based nutrient recommendations. While improved nutrient management showed benefits on all farms, the most striking result of the research was large differences in yields amongst farms with the best nutrient management practice. Understanding and overcoming the reasons for these differences would enhance adoption of nutrient management practices.

For this project year, we began to focus on developing (i) methods to accelerate technology transfer of soil management products and practices, (ii) methods to scale up technology adoption from participatory scales to national and regional scales, (iii) 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 (iv) to continue development of key technologies.

Technology adoption activities in the rice-wheat cropping system were initiated or have been planned for the following technologies:

- Healthy Rice Seedlings (Bangladesh, Nepal; in combination with vegetable production on solarized soils).
- System of Rice Intensification (SRI; in combination with healthy seedlings) (Nepal).
- Micronutrient Enriched Seeds (Bangladesh; also in combination with healthy seedlings of rice and vegetables).
- Permanent Raised Beds (Bangladesh).
- Surface Seeding of Wheat (Nepal).
- Liming (Bangladesh).

Separate adoption programs are being developed for each of the technologies, except that SRI and micronutrient seed enrichment of rice are also being done in conjunction with healthy seedlings. The different technology adoption programs began with the rice crop of 2003 (funding received too late for the wheat 2002-03 crop) and are at various stages of implementation. Most effort has been given to programs on healthy rice seedlings.

Healthy Rice Seedlings, SRI and Production of Vegetables on Solarized Soil

The technology transfer partners whom we have initially selected are international NGO's and national research and extension systems. Researchers in Bangladesh and Nepal routinely function in a transition role between research and extension. The international NGOs we are working with are CARE in Nepal and Bangladesh and the Bangladesh Rural Advancement Committee (BRAC) in Bangladesh. Interactions with Helen Keller International (HKI) have not so far led to development of a collaborative program. The initial programs are at the pilot scale. We have deliberately chosen to work with international NGOs as they have large "institutional footprints" and because they commonly operate by creating a network of smaller, local NGOs. This strategy represents a change from our proposal and immediately scales up our program. We also find that the international NGOs are, in general, also strengthening linkages to national research and extension programs so that an improved system for technology transfer is evolving.

A one page (back to back) color information sheet describing the healthy seedling technology was developed for use in farmer training in Nepal and Bangladesh. It was translated into both Nepali and Bangla using language understandable to farmers. Copies were laminated to increase durability. The value of the handout to farmers will be formally evaluated; preliminary feedback is positive.

During discussions with CARE and BRAC, we emphasized the application of the healthy seedling technology for vegetables as well as rice. We wished to collaborate with HKI because of their community nursery programs for the production of vegetable (and other plant) seedlings. However, producing a healthy vegetable seedling would likely not be beneficial if it is planted into a disease or nematode infested soil. Consequently, we developed a program based on production of healthy rice seedlings followed by use of solarized rice nurseries for vegetable crop production. Use of rice nurseries for "early" vegetable production is a common practice in both Bangladesh and Nepal. We expect this program to be successful, and to provide an entry point for extending the solarization technology to home gardens and to HKI community nurseries.

Currently rice is close to the transplanting stage. The program in Nepal also includes a comparison of SRI and conventional production methods in combination with healthy seedlings.

Micronutrient Enriched Seed

Micronutrient enrichment of seed could be used by commercial seed enterprises to produce 'super seed.' However, it then becomes like hybrid seed in that farmers need to buy seed every year. While we eventually expect to involve the commercial sector, we have chosen to work first with 15 farmers to promote generation of micronutrient enriched seed of rice and wheat in dedicated seed production fields that are fertilized with micronutrients (Zn, Cu and Mo). Supplying micronutrients via seed and use of a dedicated seed production field minimizes the investment in micronutrient fertilizers. Potential problems are the availability and quality of micronutrient fertilizers, and the need to analyze seed to determine that it is enriched with micronutrients.

A second farmer participatory activity is to assess the impact of combining soil solarization and micronutrients on the performance of rice and vegetable seedlings when these are transplanted into non-treated production fields. The approach is to use lead farmers for seedling production who then supply seedlings to other farmers for testing.

Raised Beds

A farmer participatory transfer of permanent bed technology for the rice-wheat-mung bean system has been planned for Bangladesh and will be initiated in PY2.

Two sets of research experiments are also being carried out with raised beds. One experiment compares raised beds with conventional production practices and with SRI under normal and reduced water regimes. This experiment, which was initially carried out in the boro 2001-02 season at two locations (Rajshahi and Joydepur) showed no significant differences between the three production methods, except for spacing in the SRI. The experiment was repeated with some modifications at three locations (Rangpur site added) in the boro 2002-3 season. The modifications include using older seedlings for the SRI (15-17 day versus 10 day in 2001-02) to compensate for slow growth due to cold weather. Seedlings were also planted into flooded soil to provide protection from cold and it is not possible to follow the recommendation for SRI that soil not be flooded during early growth of the crop. Data from the current project year was not yet available at the time of this report.

The second experiment is the comparison of conventional production practices with permanent raised beds for the rice-wheat-mung bean rotation that is being carried out at Rajshahi and Dinajpur. The experiment is in the third rotation cycle, but data is not available for the current project year.

Surface Seeding of Wheat

Surface seeding of wheat is initially targeted for heavy textured soils in Nepal. Our program initially used GIS and survey components to obtain basic information to support a broader technology adoption program. The initial objectives of the GIS analysis, which is being carried out in collaboration with the NARC, Khumaltar GIS unit in Soil Science, are to use satellite imagery to identify (i) areas suitable for surface seeding technology and (ii) the temporal pattern of surface seeding adoption. The suitability activity also utilizes information generated in earlier projects on mapping of rice-fallows by ICRISAT and mapping of land resources (1:50,000 scale) by Kenting Earth Sciences (digitized by ICIMOD).

The survey of farmers is to determine the current status of surface seeding, farmers' evaluation of the technology and reasons for disadoption (which is known to have occurred). The survey was carried out during May 2003 in the central and eastern districts of the terai where surface seeding has been introduced. Results are not yet available.

Liming

A GIS based analysis of the requirements and impacts of a countrywide liming program was initiated for Bangladesh. Planners of national agricultural programs and national policy makers are the targeted groups of this analysis. The project will utilize existing data and maps of soil acidity for Bangladesh coupled with results from the literature and Phase 1 of our CRSP project. The analysis will include: (i) soil pH lime requirement relationships for acid soils in Bangladesh, (ii) residual effects of lime potential for over-liming to induce Zn and B deficiencies, (iii) impacts of liming on crop productivity and national production of rice, wheat and maize, (iv) economic impacts of liming for farm households and the nation annual requirements and geographic distribution pattern for lime sources and (v) supply capacity of the private sector recommendations for implementation of a national scale liming program.

A soil scientist from the WRC, Mr. Md. Bodruzzaman, is currently at Cornell for the months of July and August to develop the science aspects of the analysis and to consider the utility of the NuMaSS decision support system. Economic and GIS analyses will follow.

Effect of Soil Solarization on Soil Biological Communities

A PhD degree student from Nepal and a MS degree student from the US are researching areas relevant to the effects of soil solarization on soil microbial communities. The PhD student, Ramesh Pokharel, is working with *meloidogyne graminicola,* which we have identified as a major problem in the rice-wheat system that can be controlled by soil solarization. The objectives of this research are to characterize the diversity in *meloidogyne graminicola* populations from Nepal and assess rice and wheat germplasm for resistance to selected strains of the nematode.

Research by an MS degree student, Steve Culman, is aimed at gaining a better understanding of the changes in microbiological diversity in the rice-wheat cropping systems of Nepal as a result of soil solarization. Bacterial, fungal and nematode communities will be considered. Bacteria and fungal communities will be analyzed by molecular methods (TRFLP), backed up with traditional methods as necessary. Nematodes will be determined by standard extraction procedures. A field experiment with two nursery treatments (solarized and non-solarized) and two field treatments (solarized and non-solarized) has been established at two sites (NARC station, Khulmaltar, and IAAS, Rampur). Soils (rhizosphere and bulk) will be sampled for biological studies and changes in microbial and nematode community structure will be related to impacts on crop productivity over one cycle of rice and wheat.

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 constraint this program addresses is the “lack of standard procedures to measure gains and losses of carbon (C) sequestered as soil organic matter.” Overcoming this constraint supports U.S.AID’s goal or Strategic Objective of “Improved food availability, economic growth, and conservation of natural resources through agricultural development.” Overcoming this constraint can benefit food production, accelerate economic growth and conserve natural resources in many ways.

The factors involved in the measurement of soil organic carbon (SOC) include chemical determination of soil organic C at a field scale, the extrapolation of field measurements to large areas for policy and carbon trading level analyses and the prediction of longterm trends in soil organic C status.

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. A major goal of this program area 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. A participatory research approach engages researchers, farmers and institutions in host countries in all aspects of the project and aims to facilitate joint learning by investigators, host country researchers and others about management systems that both increase productivity and soil C sequestration.

West Africa

Analysis of Soil C Sequestration Potential

One of the systems of interest is the ridge tillage system (RT, *courbes de niveau*), which has been adopted by hundreds of farmers in central and southern Mali and has shown to significantly increase yields (see Table 2). With RT, the land is tilled in a way that ridges are formed perpendicular to the slope and the crop is planted on top of these ridges. This system strongly reduces rainwater runoff and related soil erosion, and enhances water infiltration. Consequently, water availability to the crop is improved and the loss of the fertile topsoil layer (high organic matter content) is reduced, so the crop has a better rooting environment.

Mali

Measurements of soil C made from samples by M. Doumbia and R. Yost in RT fields in Mali suggest that RT may lead to increases in soil C by up to 0.2 percent over 8-10 years compared to changes in soil C under conventional management (CT) over the same time period (M. Doumbia, personal communication, February 2003). The DSSAT-CENTURY model was used in an exercise to test the hypothesis that RT would lead to increases in soil C by 0.2 percent in the top 20 cm over a ten-year time period. The simulated results showed that RT increased soil C by about 0.13 percent in the top 20 cm over ten years (compared with the 0.2 percent hypothesized). These results are, of course, very preliminary in nature, but appear to be reasonable and give us encouragement. If the models are adapted and used carefully, they should be useful for comparing soil C sequestration potential under different management systems, especially when used to complement and extend experiments that are performed in the field. Much more work remains to be done, however, before such results are credible. It should be noted that the measurements were taken in eight farmers' fields that were identified, measured and soil organic C levels quantified with the collection of some 350 samples. The samples were compared at three laboratories to confirm quality and compare methods. Indications are the existing methods of measuring soil C, specifically the Walkley-Black, is not appropriate for either the current accuracy of measurement or from the environmental point of view. As stated earlier, predictions of C sequestration potential of RT experiments are that an increase from 0.2 to 0.4 percent C will take place in nine to ten years. The implications of this on cation exchange capacity and water holding capacity are likely to be considerable given that this soil has initially about 0.2 to 0.4 percent C. Few water and soil conservation practices, including the RT conservation practice, have been successfully modeled for the purpose of improving and determining the potential scope of the practice.

To estimate 100,000 tonnes of C accretion, from 20,000 to 85,000 hectares zones need to be surveyed and measured. This will obviously require remote sensing technology, which is being evaluated through the assistance of an associated NASA-supported project that also includes IER/Mali and the University of Florida. Scaling up field-scale measurements to regional levels appears to require a combination of remote-sensing and simulation modeling technology. The NASA grant to the University of Georgia supports a joint CRSP (SANREM and Soil Management) effort.

Ghana

A field survey in Northern Ghana indicates that a great deal of burning of residues takes place. Reducing the amount of burning may be an important way to reduce C loss. Quantifying the amount of C lost through burning and through other residue management techniques such as composting needs to be evaluated. The influence of burning on soil C status was a concern not only of scientists in Ghana, but in Mali and Senegal as well.

Table 2. Grain yield (tonnes/ha) with or without the implementation of the courbes de niveau technology (Gigou *et al.,* 1999).

Treatment	No Ridge-Till		Ridge-till	
	Sorghum	Millet	Sorghum	Millet
Control	0.88	1.50	1.48	2.02
Fertilized	1.24	1.86	2.17	2.24
Fertilized + Rock P	1.55	1.76	2.33	2.07
Fertilized + gypsum	1.93	2.00	3.52	2.86

Senegal

In Senegal, experiments were conducted with the following objectives: i) test the effects of improved nutrition, namely the addition of phosphogypsum and the use of NuMaSS for improved nutrient management and biomass production, ii) use native plants such as *Piliostigma reticulata, Guera senegalensis,* and others that grow and stay green during the dry season and observe the effects on C sequestration and iii) initiate and implement selected water and soil conservation techniques, such as the RT in experiments adapted to the vast peanut production basin of Senegal (over a 6.5 million ha region). An RT experiment was established in a peanut farmer's field, Nioro, which is probably the first RT field or experiment attempted in Senegal. If successful, it will represent a major effort in adapting the practice to peanut cropping systems that are the core of southern Senegal's agricultural productivity.

The Gambia

In The Gambia, an RT experiment was initiated at Yundum, and initial samples for soil characterization were taken. The positive interaction observed but not statistically tested in Mali will be tested here. Initial results show that maize responded to fertilization by over four-fold, much as expected. Yields without the addition of NPK were 960 kg ha-1 while yields with the application of 400 kg of NPK fertilizer were 4530 kg ha-1. We expect to test the RT x fertilizer interaction at this site next season. In collaboration with the National Agriculture Research Institute (NARI), we have initiated what is apparently the first water and soil conservation experiments in the country by the implementation of a RT experiment which also is the first replicated experiment on the interaction between the RT practice and improved nutrient management.

Cabo Verde

In Cabo Verde, plans were drafted and approved for a set of experiments with (INIDA) that will be carried out under the SM CRSP C project in the next growing season.

Integrated Protocol for Measuring Gains and Losses of Soil C Under Agricultural Systems

The University of Florida's strategy in West Africa is to develop and document a robust protocol that can be used to i) identify practical options for farming systems that simultaneously increase food productivity, thereby reducing risk of food insecurity, and increase soil carbon stocks in degraded soils and ii) measure and monitor soil carbon sequestration in agricultural systems at scales from fields to areas large enough for C trading. Our approach is to conduct case studies in Sub-Saharan West Africa along a gradient of rainfall, soil types and farming systems and research components of the protocol that are necessary for its development.

Our emphasis this year has been on getting started on multiple aspects of the overall project. Two investigators from Florida traveled to Ghana and Mali to develop a coordinated plan with partners in those countries, to assess the status of data availability for evaluating our crop-soil models and to collect preliminary data for use with our remote sensing component of the project. Also, progress was made on methodologies for measuring and assessing soil carbon by combining field measurements with soil and crop models using an approach called the Ensemble Kalman Filter.

The EnKF Approach

In this project year, a new approach was developed, called the Ensemble Kalman Filter (EnKF), to combine model predictions with measured soil C for more reliable estimates of soil C changes over time for a single field. This framework was also revised to apply the EnKF to the DSSAT-CENTURY model and to assimilate biomass estimates (ultimately from remote sensing) in addition to soil carbon measurements (Figure 1). This new approach is aimed at developing a more reliable soil carbon accounting system and a way to aggregate estimates over space. The ultimate aim is to evaluate the uncertainties associated with using simple and complex models when the goal is to produce aggregate soil C estimates for carbon trading.

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.

Mali

During our trip to Mali, we identified a number of data sets collected by IER, ICRISAT and CIRAD

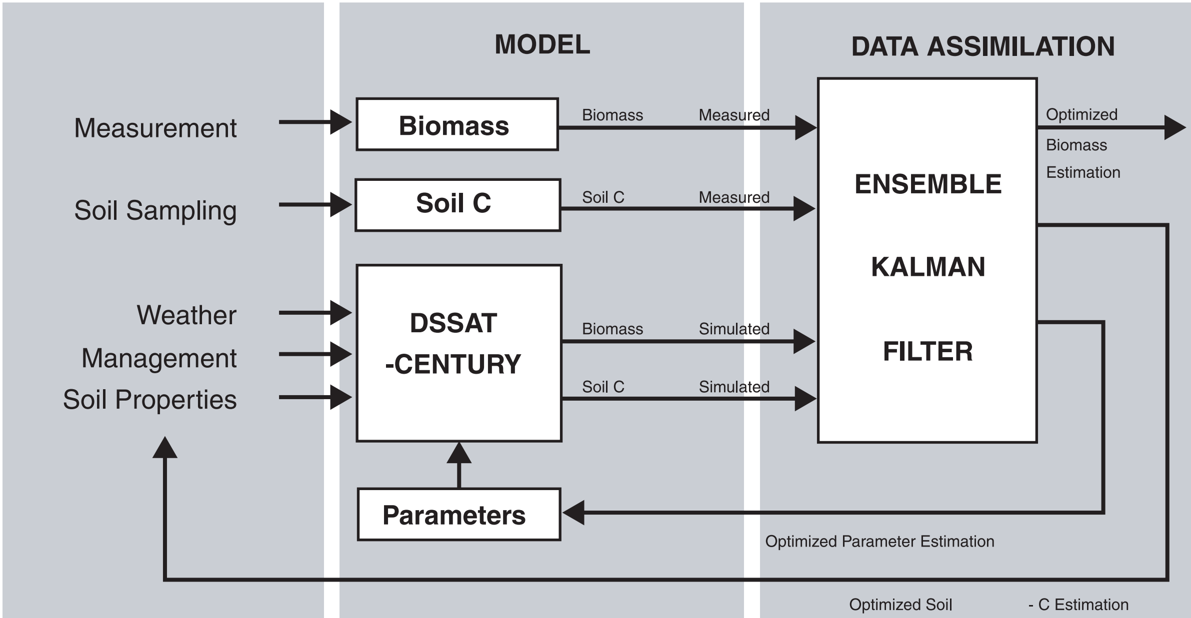

Figure 1. Schematic showing optimal soil C estimates using the EnKF to integrate observed soil C and biomass data with predictions of soil C using the DSSAT-CENTURY model (from Koo *et al.,* 2003).

researchers that would help adapt the models for maize, sorghum and millet and calibrate the model to simulate maize and sorghum data sets in a preliminary effort. Only one data set was available for millet.

The data sets will not allow us to evaluate the ability of the model to simulate soil C changes. Investigators visited a long-term experiment in Burkina Faso managed by Vincent Bado during our trip to Mali. We now have data from Bado's experiment, which has been ongoing for about 10 years, and includes a number of crop rotations, including maize, sorghum cotton and peanut, and also native fallow. Periodically, Bado collects soil C in each plot, which will provide valuable data for evaluating both crop and soil C components for cropping systems and soils very similar to those in Mali and northern Ghana.

Ghana

In Ghana, a similar effort is underway to adapt the maize, peanut, and soybean models in DSSAT v4 to simulate the Ghana candidate cropping systems for increasing soil C sequestration. A number of peanut data sets (more than 10) are available for Northern Ghana, obtained through cooperation with the Peanut CRSP. J. Naab has also assembled three years of maize and soybean data for adapting models for these crops and a student (J. Koo) is currently working with those data.

Two Quickbird images (Omourobougo and Fansirakoura) were obtained to begin studying the potential of using remote sensing in this region to estimate LAI and biomass. If remote sensing estimates of LAI and biomass are reliable, they can be used in the EnKF approach for combining models with measurements to estimate soil C over large areas. Land use, LAI and biomass samples are being collected to develop capabilities for using remote sensing to scale up estimates of soil C over space. Our plans are to extend the EnKF method for use in estimating soil C over large areas in C trading projects. In addition, soil and weather data sets are being assembled for predicting soil C sequestration over large areas. However, little has been done to report at this time.

Data from both Mali and Ghana are being assembled to adapt the DSSAT Cropping System Model (CSM) for simulating growth and yield of major crops (sorghum, millet, maize and cotton) in these countries. This model, contained in the new DSSAT v4 model application package, incorporates the CENTURY soil C and N module developed by Gijsman *et al*. (2002).

Water and Soil Conservation Model

While the UF project is using the crop model, the UH project is using a water and soil conservation model to simulate and improve the performance of soil and crop technologies to sequester C. The water and soil conservation models are also expected to help define the limits and the variation in the amounts of C sequestered by the RT technology given different soils, hydrology and topology. This is underway with the characterization of the water status of RT and when modeled using the Parch-Thirst water and soil simulation model. Even initial assessment of soil C content and variability is an extreme challenge. Initial techniques use soil spatial variability properties of the soils from West Africa as characterized using geospatial techniques recently made available in GIS software, specifically using the Surfer[2] and ArcGIS[3] software. Initial estimates of variability suggest that a rather large number of samples at relatively close spacing will be required. Quantification of soil C and soil C change is the objective of a collaborative study with an ICRISAT scientist and the University of Florida.

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 overall approach to carbon sequestration in soils in based on the following hypotheses or tenets:

- Soil aggregation, which varies with soil texture, is the primary variable controlling soil organic carbon (SOC) levels in tropical soils.
- Soil texture is a good surrogate for total aggregation of soils only in the absence of tillage.
- Tillage causes loss of soil organic matter through destruction of macro-aggregates and microbial mineralization of the *physically protected* soil organic matter pool.
- Micro-aggregates and their associated SOC are stable to tillage, and this *passive or chemically protected* SOC pool represents the minimum level of SOC.

Undisturbed, native forest or grassland soils, where macro-aggregation is at a maximum, define the upper limit for soil organic carbon (SOC). In contrast, SOC in rice-wheat soils of South Asia should be close to the lower limit because puddling of soil for rice has destroyed macro aggregates, leaving only SOC associated with the passive pool in micro-aggregates. The difference between these two limits is physically protected SOC, controlled by tillage. Unfortunately, ***the rotation of flooded (paddy) rice with wheat or any other upland crop leads to the most carbon degraded surface soils in the world*** because of the intense physical destruction of aggregates followed by aerobic conditions that enhance biological decomposition processes.

Soil in a farmer's field may be anywhere between the upper and lower lines depicted in Figure 2; for example it may be a clay soil with the SOC content at point A. By reducing tillage, SOC levels will increase over some time frame to a new equilibrium level, which, for various reasons, will most likely be less than the maximum or saturation carbon content of a soil shown by point B and the upper dashed line. Both the rate of increase in SOC and the new equilibrium SOC level will depend on the particular reduced tillage practice; for example practice M1 gives a different pattern of SOC accumulation and a higher equilibrium level than regime M2. The highest SOC level will, of course, be associated with no tillage. The conceptual model in Figure 2 establishes the boundaries for SOC levels and provides the framework to assess soil carbon sequestration over time at the field scale. Characterization of SOC gains associated with reduced tillage will be done through a mixture of experimental measurement and modeling. Our general vision for quantitative estimation of SOC sequestration at landscape or larger scales is to use GIS spatial analysis with various databases (soil texture, current SOC levels, impacts of reduced tillage practices on SOC dynamics as a function of texture) and scenarios. The probability of adoption of reduced tillage practices will also be considered in order to determine "achievable" C sequestration amounts.

SOC-Texture Relationships

The initial step in our project was to establish the upper and lower limits of the soil texture-SOC relationship for soils of the Indo-Gangetic plains (IGP). To determine the lower limit relationship, SOC and texture data were measured on archived soil samples collected during Phase 1 of the SM CRSP from rice-wheat sites in the Rupandehi district, Nepal-mid-Terai, the Birgunj district, Bangladesh-northwest Bangladesh, and the Chuadanga district, Bangladesh west central Bangladesh. Soil samples (107) obtained from a 1995 CLIMA-NARC legume survey across the Nepal Terai were also used, and we assume that these were from rice-legume rotations as rice is grown throughout the Terai in the monsoon season.

Measured C from the three sites ranged from 0.4 to 3.3 percent and averaged 1.3 percent. The legume survey provided the widest range of soil textures, followed by the Rupandehi data. The Bangladesh soils

[2]© 1997-2004 Golden Software, Inc.
[3]© 1995-2004 Environmental Systems Research Institute, Inc. (ESRI)

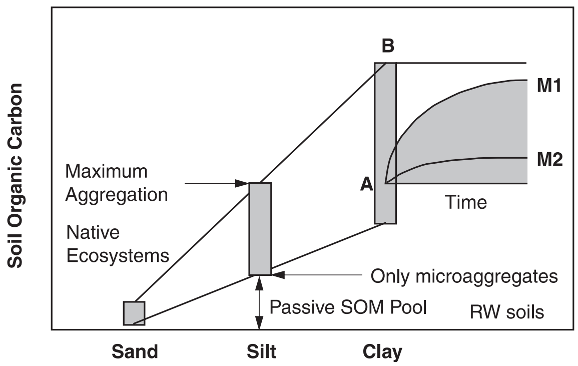

Figure 2. Conceptual model for soil organic carbon.

tended to cluster around the finer textures. There was, however, no relationship between silt+clay content or clay content and soil C. Many of the soil C values were higher than expected (<0.5 to 1%), suggesting that carbonate could be present in these soils, which was later confirmed.

Soil C values from combustion analysis were generally higher than SOC determined by the Walkley-Black method for both the Rupandehi and Bangladesh surveys, which is consistent with carbonate being present in the samples used for combustion. We have persisted with the combustion method because this is widely considered to be the "gold standard" (quote from G. McCarty) for C analysis. However, Walkley-Black is the standard method for SOC analysis in South Asia and most developing countries. A recent study reported by McCarty, Kimble, Reeves and Yost (2002 ASA) indicated that the Walkley-Black method underestimates organic carbon at values less than 1 percent.

Global soil carbon data were also utilized to investigate the soil texture-carbon relationship under native and agricultural land use practices outside the South Asian region, using the WISE Global Soil Profile Database from the International Soil Reference and Information Center (ISRIC). Most of the SOC measurements were made using the Walkley Black method, with some by combustion. Data for soils in tropical latitudes were extracted from the MS Access database file (Batjes, N.H., 2002; http://www.isric.org).

Problems in using the ISRIC database included variable sampling depth, uncertainties in interpretation of the native land use categorization, different analytical methodologies and uncertainty about pre-treatment of soils with acid.

A significant positive relationship was found between silt + clay content and SOC for the wet, native ISRIC sites, but only 22 percent of the variation in SOC was attributed to the silt + clay content. Separating the forest and grassland land use categories changed the relationship only slightly. There was no relationship between soil texture and SOC for agricultural soils in general, but a significant positive relationship was obtained where rice was the crop (n = 13). For rice, 70 percent of the variation in SOC was explained by the silt + clay content. Since the rice data was from SE Asia, we are confident that they were for paddy rice, but may not be for rice in rotation with upland crops.

The data generated by us and taken from the ISRIC global soil database indicate that our conceptual model was reported to be generally correct. However, laboratory methods to determine SOC remain questionable. Issues of methodology need to be addressed in the determination of SOC for carbon sequestration; notably 1) the use of procedures that assure carbonate removal from soils, 2) comparisons of SOC stocks, rather than percentage C in surface soils, so that measurements are made to sufficient depth and 3) the robustness of different methods of SOC determination should be assessed to determine if one method can be recommended. Once these methodology issues are resolved, reasons for the remaining variability in the soil texture SOC relationships for IGP soils need to be considered. Possible remaining causes of variability could be differences in soil mineralogy, climate, organic inputs (especially animal manure) and time since land clearing (applies to Terai regions of the IGP). Mineralogy and climate factors relate to the accuracy of our conceptual model, manure use is a management factor, and time since clearing affects whether SOC has reached the equilibrium value associated with rice upland crop rotation.

Reduced Tillage and Residue Management Experiments

The only experiments with a complete no-tillage rice-wheat system are in the Nepal Terai. Two identical experiments compare conventional tillage (CT) with no-tillage (NT) and the effects of using straw mulch on loam and clay soils. They represent a no-tillage option for resource poor farmers without equipment.

In 2002-03, there was no effect of tillage on wheat yield, but straw mulch significantly increased yield in the NT treatment. The results of this experiment over the past four years reflect complex interactions involving tillage, soil-water relationships, weeds, and physical structure at the soil surface. Overall, they emphasize the importance of using mulch to maintain a good physical condition of surface soil with NT.

BIOTECHNOLOGY

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

The long-term objective of this SM CRSP project is to reduce the constraints of soil management via the development of cultivars with root systems suitable for specific soil environments.

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). Some examples include mapping QTLs for root morphology in rice (Shen *et al*., 2001; Kamoshita *et al*., 2002) and maize (Tuberosa *et al*., 2002).

The work we are proposing 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, due to the observed co-linearity between chromosomes or chromosome segments (synteny) of different legume species (Boutin *et al*., 1995; Lee *et al*., 2001; Brauner *et al*., 2002; Gualtieri *et al*., 2002; Yan *et al*., 2003), 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; different degrees of synteny have been reported for these species. For instance, gene controlling seed size were detected in orthologous chromosome regions in cowpea and mung bean (Fatokum *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.

RFP Proposals

The Soil Management CRSP issued an RFP for a multidisciplinary project focused on understanding the soil ecology impacts of a Bt crop. The use of Bt genes in crop plants has become a fast growing application in agriculture, and hence, it is of importance to understand its positive and negative impacts on the soil ecosystem in a more quantitative and holistic manner. The project should address, in a coordinated manner, more than one aspect of the soil ecology and management of a Bt crop, such as:

- Effects on the microbial ecology of the rhizosphere or detritosphere;
- Turnover and fate of plant residue carbon;
- Effect of soil nutrients, especially in nutrient deprived soils, on Cry production and excretion from roots;
- Science-based soil-crop management practices for the crops including LDC conditions.

FIELD SUPPORT TO MISSIONS

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

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 objective 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 in order to: 1) increase agricultural productivity and food security, 2) diversify and intensify crop production to generate new income and employment opportunities and 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.

Because crop yields are now so low, increasing crop yields should not be difficult. One bottleneck to rural development has been the lack of markets for surplus production. To circumvent this bottleneck, the project will collaboratively work with MAFF and local merchants to discuss the possibility that they will purchase locally grown rice instead of imported rice. It is likely local farmers can produce rice of equal quality and price as the imported rice. The German food security project plans to introduce new rice milling equipment in the Seical watershed and has expressed a desire to join forces with this project to produce higher quality rice.

Two secondary aims of the project are to 1) increase the yield and stability of maize production to enhance food security and 2) join forces with local and international partners to produce, process and market locally grown rice in order to increase household incomes. Ascertaining the economic feasibility of the two aims will be an important part of the project's training program. The project will also explore with local merchants and buyers the feasibility of marketing surplus maize, soybean and other crops not only for human consumption but also for other uses including feed for poultry, swine and beef cattle.

Moreover, a high global demand for candlenut oil exists. Farmers now receive low prices for the candlenut, but can obtain higher prices if the oil rather than the nut were to be exported. The project will explore local and external interest in the possibility of extracting the oil for export. Adding value to locally grown commodities and experimenting with import substitution are part of the overall training strategy of the project. In the future, MAFF personnel will need to look for other means to broaden the market base for continued economic expansion.

In the end, agricultural intensification that leads to income and employment generation must be accomplished without compromising environmental quality. Here again, the participation of the farming community is essential. Past efforts show that projects designed to persuade people to adopt practices for the good of the environment but at some personal cost are likely to fail. The key to success is to promote practices that are economically beneficial for the adopter. The training and institutional capacity building component will promote the application of a participatory approach that offers farm households' options and enables them to exercise choice in attaining sustainable land management.

Finally, the project provides opportunities for MAFF to join forces with projects of NGOs, the National University, Peace Corps, local organizations and the private sector to sustain this effort into the future.

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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.

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 for 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 did not meet as a collective group this past year. The Board Chair, Dr. John Havlin, participated in the annual meeting of the principal investigators and members of Technical Committee on the Montana State University campus in Bozeman, Montana in July 2003. 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
- Dr. Philip Thornton, ILRI, Nairobi, Kenya

Minutes of meeting are available by accessing the SM CRSP web site at the following URL, 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 Bozeman, Montana on the campus of Montana State University in July 2003 to review annual reports for PY6 and work plans and budgets for project year five (PY7).

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. Russell Yost, University of Hawaii

Dr. Charles Sloger of AID/EGAT/NRM/LRM who serves as the SM CRSP's Cognizant Technical Officer (TC) and Drs. Goro Uehara and Gordon Tsuji of the ME participated in the meeting. Dr. Sloger reported that the budget for PY6 totaled $3.0M with $2.4M this year plus the $600,000 received as advance funding in the past fiscal year.

Each PI made oral presentations of annual reports and work plans to members of the TC with the exception of Dr. James W. Jones of Florida who was too ill to participate. At the conclusion of all presentations, members of the TC met to discuss each project's progress and their work plans. Subsequent reports on each project's performance were forwarded to each PI by the TC chair.

This year for the first time, USAID advised the ME of the level of funding prior to the submission of the annual work plans. The operational budget for PY6 was set at $2.9M with the remaining $100,000 to be used in support of the next annual meeting of principal investigators and TC in Bamako, Mali.

Review Panel (for Phase 2 Biotech Proposals)

A sub-panel of the Technical Committee was designated by the ME to serve as technical reviewers of proposals received for the biotechnology program of the SM CRSP. In a meeting held in Atlanta, principal investigators and the chair of the Board concurred in having a 3-member group serve as the review panel. Drs. E. B. Knapp and Tom Walker agreed, as external members of the TC, to serve as two of the members. Dr. James Tiedje of Michigan State was invited to serve as the third member. He accepted.

The initial RFP was distributed only to participating institutions of the SM CRSP. Responses received were reviewed by panel members and one proposal was selected for funding. A second round of proposals was deemed necessary to address the fate of Bt genes from plant residues in soils. Revisions were made to the RFP and subsequently distributed more widely. Proposals received in late August were to be reviewed by the review panel in the fall.

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 PY6.

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 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 or email 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

A proposal for a second 5-year phase of the Soil Management CRSP was presented to SPARE in Washington, D.C. on November 28, 2001 and approved in early 2002. Funds for the first year, or PY6, became available first as "bridge-funding" in mod#9 for $636,188 to provide support for the period between February 12, 2002 to October 25, 2002 and in mod#10 for $2,863,812 for the period October 26, 2002 to September 30, 2003. The funding level included $600,000 to be used in the succeeding year, PY7. In summary the level of funding for PY6 was $2,900,000 (mod#9 + mod#10 - $600,000).

The start date for the second 5-year grant was determined to be October 1, 2002 as the end date of mod#10 was September 30, 2003. These dates are those of the federal fiscal year. Furthermore, we now have a correspondence between the project year and the fiscal year. The previous five years were difficult to manage administratively with a start date of February 11 and an end date for incremental awards or modifications of April 30.

Table 3 is a cumulative list of modifications to the grant with award totals and dates of the incremental awards.

EXPENDITURE REPORT

Tables 4a, 4b, and 4c list the cumulative annual expenditure report, cost sharing and allocation of funds from the ME to each participating institution and project, respectively. Texas A&M and NifTAL continue to be listed in PY6 as both projects close out their respective sub grants. The University of Florida has a new project and principal investigator for Phase 2. Montana State advised us their transmittal of expenditures would be delayed as a result of administrative restructuring within their fiscal system of reporting.

Table 3. Incremental funding awards to the SM CRSP for the period covering February 11, 1997 to September 30, 2003.

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

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 & 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 succeeding year, PY7.

Table 4. Financial summary statement ($'000) of expenditure, cost sharing and funding for PY 6 (July 25, 2002 to Sept 30, 2003) from vouchers received.

a. Summary of Expenditures reported during PY 6 (July 25, 2002 to Sept 30, 2003)

Institution	MSU	NCSU	CU	TAMU	NifTAL	UFL	UH	ME	Total
Total	166	761	354	102	5	190	279	306	2,163

b. Cost Sharing for PY 6 (July 25, 2002 to Sept 30, 2003)

Total	0	558	275	0	0	18	28	N/A	879

c. Summary of Cumulative Core Funding (February 11, 1997 to September 30, 2003)

Mod #2	194	1,000	483	361	190	58	-	214	2,500
	0	0	0	0	0	168	-	32	200[a]
Mod #3	39	173	604	57	36	0	-	61	1,000[b]
Mod #4	142	765	773	293	143	0	-	384	2,500
Mod #5	0	0	0	0	0	0	-	200	200[c]
Mod #6	176	876	523	276	73	95	-	380	2,499
Mod #6[d]	0	0	0	0	0	0	-	200	200[d]
Mod #7	138	784	470	200	140	74	-	340	2,146
Mod #8	0	0	0	0	0	0	-	0	0
Mod #9	130	63	141	-	-	71	145	87	637
Mod #10	423	188	474	-	-	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]

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 & 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 succeeding year.

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 either individually by a participating institution or collectively among participating institutions at the request of a USAID field mission. Funds to support these additional activities are provided by the mission to the ME institution for re-allocation to participating institutions. In PY6, a request for field support was received from East Timor (Timor-Leste).

Timor-Leste

Timor-Leste became the newest independent country in the world in 2001. The United States opened its embassy and the USAID mission in Dili, the capital, soon thereafter.

The University of Hawaii was invited by the USAID desk officer for Timor-Leste in Washington, D.C. to submit a proposal to the mission to provide assistance to the government of Timor-Leste in the area of food security and natural resource management in the fall of 2002. In December 2002, four University of Hawaii faculty including Goro Uehara and Russell Yost traveled to Timor-Leste to determine whether such a proposal would be forthcoming from the University of Hawaii. After the one-week visit, the four were in agreement to pursue development of a proposal and action plan for submission to USAID. In July 2003, in consultation with the Ministry of Agriculture, Forestry and Fisheries, the United States Agency for International Development approved a new project to begin the process of modernizing Timor-Leste's agriculture. The project brings together the Ministry's knowledge of local customs, conditions and capabilities and the University of Hawaii's experience in market- based tropical agriculture.

Funds for this field support activity would be channeled to the University of Hawaii through the Soil Management CRSP. The initial grant award amounted to $600,000 for six months from July 1, 2003 to December 31, 2003.

COST SHARING

Table 4b lists the cost sharing contributions from each of the participating U.S. institutions involved in the Soil Management CRSP.

Cost sharing refers to the required match of 25 percent of grant funds from USAID. Matching can range from in-kind support such as facilities and utilities to salaries or wages and fringe benefit costs. Funds for matching must be from non-Federal sources. The CRSP Guidelines (1975) states 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 sub-agreement, (3) costs of training participants in the CRSP and (4) hospital and medical costs of U.S. personnel of the CRSP while serving overseas.

LEVERAGING

Leveraging of human, fiscal, and material resources from collaborating institutions, organizations, agencies and individuals is reported herein. Values of these resources in dollars are best estimates asked of and provided by each of the principal investigators. The following lists the estimates of leveraged resources from national, regional, and global collaborators of the SM CRSP.

Carbon Sequestration	
NASA and SANREM CRSP	$500,000
(Mali, Ghana, Burkina Faso)	
IER, Mali	50,000
SARI, Ghana	25,000
Univ of Ghana	15,000
ILRI, Kenya	25,000
NuMaSS	
Kasetsart University/FAO	$75,000
Philippine Rice Research Institute	25,000
IER, Mali	50,000
NARI, The Gambia	25,000
INIDA, Cape Verde	25,000
Trade-off Analysis	
International Potato Center (CIP)	$50,000
Wageningen Agricultural University	35,000
ISRA, Senegal	25,000
Rice-Wheat	
CIMMYT, Bangladesh	50,000
IFAD, Cornell	50,000

PUBLICATIONS, REPORTS, AND PRESENTATIONS

JOURNAL SERIES, REPORTS AND BOOKS

Antle, J.M., S.M. Capalbo, E. Elliott and K. Paustian. 2003. Adaptation, Spatial Heterogeneity, and the Vulnerability of Agricultural Systems to Climate Change and CO_2 Fertilization: An Integrated Assessment Approach. Climatic Change. *In press*.

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. American Journal of Agricultural Economics 85:1178-1184.

Antle, J., J. Stoorvogel, W. Bowen, C. Crissman and D. Yanggen. 2003. The Tradeoff Analysis Approach: Lessons from Ecuador and Peru. Quarterly Journal of International Agriculture 42(2):189-206.

Ares, A., N. Falcao, K. Yuyama, R.S. Yost and C.R. Clement. 2003. Response to nutrient additions and nutrient deficiency diagnostics in peach palm in Central Amazonia. Nutrient Cycling in Agroecosystems. 3:221-232.

Attanandana, T. and R.S. Yost. 2003. A site specific nutrient management approach for Maize: Thailand's experience. Better Crops International 17:3-7.

Casimero, M.C., S. Pablico, R.S. Yost and M.L. Aragon. 2003. On-farm testing of the integrated Nutrient Management Decision Support System (NuMaSS) in Southeast Asia, Proceedings of the workshop on January 21-24, 2002 at PhilRice, Maligaya, Science City of Munoz, Nueva Ecija, Philippines. United States Agency for International Development-Soil Management Collaborative Support Program (Cornell University, North Carolina State University, Texas A&M University and University of Hawaii)-SM-CRSP Technical Bulletin 2003-01 and Philippine Rice Research Institute, Maligaya, Science City of Munoz, Nueva Ecija, Philippines. 179 p.

Jones, J.W., A.J. Gijsman, W.J. Parton, K.J. Boote and P. Doraiswamy. 2002. Predicting soil-carbon accretion: the role of biophysical models in monitoring and verifying soil carbon. In: A Soil Carbon Accounting and Management System for Emissions Trading, Soil Management Collaborative Research Support Program (SM CRSP), special publication 2002-4, University of Hawaii, Honolulu, Hawaii.

Jones, J.W., G. Hoogenboom, C.H. Porter, K.J. Boote, W.D. Batchelor, L.A. Hunt, P.W. Wilkens, U. Singh, A.J. Gijsman and J.T. Ritchie. 2003. The DSSAT Cropping System Model. Eur. J. Agron 18:235-265. Shuai, X., Z. Zhou and R. Yost. 2003. An Algorithm to Fit Continuous Segmented Regression Models. J. of Agricultural, Biological, and Environmental Statistics 8:1-13.

Shuai, X., Z. Zhou and R. Yost. 2003. An Algorithm to Fit Continuous Segmented Regression Models. J. of Agricultural, Biological, and Environmental Statistics 8:240-251.

Sidibé, Aminata, R. Yost, M.D. Doumbia, Tasnee Attanandana, A. 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 Analysis. *In press*.

Stoorvogel, J.J., J.M. Antle, C.C. Crissman and W. Bowen. 2003. The Tradeoff Analysis Model: Integrated Bio-Physical and Economic Modeling of Agricultural Production Systems. Agricultural Systems. *In press*.

Yost, R., P. Doraiswamy and M. Doumbia. 2002. Defining the contract area: Using spatial variation in land, cropping systems, and soil organic carbon. In: A Soil Carbon Accounting System and Management System for Emissions Trading. A Special Publication of the Soil Management Collaborative Research Support Program, Honolulu, HI.

PROJECT REPORTS

Antle, J.M. 2003. Why Scientists Should Talk to (and even work with) Economists and Vice Versa: Synergies and Surprises in Agroecosystem Research. Presented to the Center for Natural Resources Policy Analysis, University of California, Davis, May 9.

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

Forthcoming in American Journal of Agricultural Economics, December 2003.

Antle, J.M. and J.J. Stoorvogel. 2003. Incorporating Systems Dynamics and Spatial Heterogeneity in Integrated Assessment of Agricultural Production Systems. Paper presented at the international workshop on Reconciling Rural Poverty Reduction and Resource Conservation: Identifying Relationships and Remedies at Cornell University, May 2-3.

Antle, J.M. and L.M. Young. 2003. Policies and Incentive Mechanisms for the Permanent Adoption of Agricultural Carbon Sequestration Practices in Industrialized and Developing Countries. Paper presented at the Climate Change, Caron Dynamics and World Food Security Conference, The Ohio State University, Columbus, Ohio, June 10-11.

Antle, J.M. 2002. The Contribution of Agricultural Research to Environmental Sustainability Development Targets. Presented at the International Potato Center, November 21.

Antle, J.M. and J.J. Stoorvogel. 2002. The Tradeoff Analysis Model: Integrated Bio-physical and Economic Modeling of Agricultural Production Systems. Presented to the Department of Applied Economics and Management, Cornell University, October 30.

Aragon, M.L., M.C. Casimero, J.B. Lasquite, T.M. Corton, T. George and R.S. Yost. 2002. Intensive testing of NuMaSS in the Philippines. Paper presented during the Regional Workshop on Integrated Nutrient Management Support System (NuMaSS). Philrice, Maligaya, Munoz, Nueva Ecija, Philippines. January 21-24, 2002.

Aragon, M.L., M.C. Casimero, J.B. Lasquite, T.M. Corton, T. George and R.S. Yost. 2002. Integrated nutrient management support system (NuMaSS): A potential decision aids tool to manage fertilizers in acid upland rice-based systems. Paper presented during the 14th National Research Symposium of the Department of Agriculture-Bureau of Agricultural Research (DA-BAR). BSWM, Diliman, Quezon City, Philippines, November 26-28, 2002.

Aragon, M.L., M.C. Casimero, J.B. Lasquite, T.M. Corton, T. George and R.S. Yost. 2003. Predicting the lime, N and P requirement of cereals and legumes in acid uplands using the NuMaSS. Paper presented during the Philippine Society of Soil Science and Technology (PSSST) in Pili, Camarines Sur.

Attanandana, T. 2003. Importance of soil testing for fertilizer recommendations. Presented at the National Rice Research Program, Laos.

Badiane, A., M. Dieye, M. Khouma, M. Ndiaye and M. Sene. 2003. The Protocol for testing NuMaSS. In: A. Badiane, Workshop on Initiating the SM-CRSP Carbon and NuMaSS projects, Bambey, Senegal.

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.

Bostick, W.M., J.W. Jones, S. Daroub and J.T. Ritchie. 2003. A plant phosphorous model for agronomic crops. Presentation to the IFAS Graduate Research Symposium, University of Florida.

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 p.

Doumbia, M. 2003. Workshop on the use of remote sensing, GIS technology, and modeling in measuring C sequestration technology. Workshop held at the USDA-ARS, Beltsville, MD,

George, T. and J. Quiton. 2002. Extensive testing of NuMaSS in the Philippines. Paper presented during the Regional Workshop on Integrated Nutrient Management Support System (NuMaSS). Philrice, Maligaya, Munoz, Nueva Ecija, Philippines, January 21-24, 2002.

George, T. and J. Quiton. 2002. Impact evaluation of the NuMaSS project in the Philippines. Paper presented during the Regional Workshop on Integrated Nutrient Management Support System (NuMaSS). Philrice, Maligaya, Munoz, Nueva Ecija, Philippines, January 21-24, 2002.

Haggith, M. 2003. Recent experiences in merging software development and participatory approaches to increase learning as a development activity. In A. Badiane, Workshop on Initiating the SM-CRSP Carbon and NuMaSS projects, Bambey, Senegal.

Kablan, R. 2003. Possible use of soil test kits to identify nutrient limitations - experiences from Asia. In: A. Badiane, Workshop on Initiating the Sm-CRSP Carbon and NuMaSS projects, Bambey, Senegal.

Khaokaew, S. 2003. Use of soil test kits (demonstration) at the National Rice Research Program, Laos.

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 DSSATCENTURY. ASAE Paper No. 033041. ASAE, St. Joseph, MI, 49085. 13 p.

Koo, J., W.M. Bostick, V.K. Walen, G. Hoogenboom and J.W. Jones. 2003. A web-based agricultural data exchange and cataloging system. ASAE Paper No. 033070. ASAE, St. Joseph, MI, 48085. 7 p.

Mataia, A.B. 2002. Baseline assessment of farm households in upland areas. Paper presented during the Regional Workshop on Integrated Nutrient Management Support System (NuMaSS). Philrice, Maligaya, Munoz, Nueva Ecija, Philippines, January 21-24, 2002.

McCarty, G., M. Doumbia, R.S. Yost. 2002. Use of infrared technology to assess soil properties such as soil C and particle size distribution. ASA Meetings, Indianapolis, Indiana.

Roncoli, C., A. Berthé, K. Moore, R.Yost, C. Neely, H. Coulibaly, B. Traoré and S. Kanté. 2002. A Site Characterization of Conditions and Constraints Relative to Adoption and Implementation of Courbes de Niveau technology in Southern Mali. Report for Carbon from Communities Project.

Thiraporn, S. 2003. Installation of maize field experiments. Presentation at the National Rice Research Program, Laos.

Traoré, K.B., G. McCarthy, J.S. Gigou, M.D. Doumbia, A. Bagayoko, R.S. Yost, H. Konaré, L. Dioni, H. Coulibaly, A. Sidibe et R.A. Kablan. 2002. Aménagement en courbes de niveau et conservation du carbone. Paper presented at CIRAD Conference on Soil Carbon, Montpellier, France, September 23, 2002.

Walen, V.K., J.W. Jones, A.J. Gijsman. 2003. Estimating the Carbon Sequestration Potential in West Africa with the DSSAT-Century Model. Presentation to the IFAS Graduate Research Symposium, University of Florida.

Walen, V.K., J.W. Jones, A.J. Gijsman and W.D. Batchelor. 2002. Sensitivity analysis of carbon sequestration in West Africa to temperature and moisture using the DSSAT-CENTURY model. ASA meeting Poster. ASA Annual Meeting, Indianapolis, IN.

Walen, V.K., J.W. Jones, A.J. Gijsman, M. Doumbia and R. Yost. 2003. Estimating soil carbon sequestration under ridge tillage management in Mali. Report for the NASA Carbon from Communities and the SM CRSP Soil Carbon projects.

Yampracha, S. 2003. Use of fertilizer test kits (demonstration). Presentation at the National Rice Research Program, Laos.

Yanggen, D. 2003. Overview Analysis of Results of Ecosystems Health Research on Pesticides in Potato Production in Ecuador. IDRC Conference Ecosystem Approaches to Human Health, Montreal, May 19-23. Yanggen, D. 2003. Armonizando los Objetivos Globales y los Incentivos Individuales en el Manejo de Cuencas: Análisis del Uso de Subsidios III Congreso Lationamericano de Manejo de Cuencas Hidrograficas, 4-9 Junio, Arequipa, Perú.

Yost, R. 2003. Field testing of NuMaSS for nutrient diagnosis and recommendations in the Philippines. In: A. Badiane, Workshop on Initiating the SM-CRSP Carbon and NuMaSS projects, Bambey, Senegal.

Yost, R. 2003. Soil C sequestration activities proposed by Cabo Verde, Workshop on the initiation of the SMCRSP C and NuMaSS projects in West Africa, Bambey, Senegal.

Yost, R., M. Doumbia, G. Porter and A. Sidibe. 2002. Extracting information from uncertainty - use of geostatistics in soil organic C sequestration. ASA Meetings, Indianapolis, Indiana.

Yost, R.S., A. Sidibé, T. Attanandana and X. Wang. 2002. A Rock Phosphate Module for the PDSS (Phosphorus Decision Support System) and NuMaSS systems. In: M. Aragon, M. Casimero and J. Bajita (eds.). Proceedings of the 2002 Soil Management Workshop, PhilRice, Maligaya, The Philippines.

ACRONYMS

BARI	Bangladesh Agricultural Research Institute
BOD	Board of Directors
BRAC	Bangladesh Rural Advancement Committee
BRRI	Bangladesh Rice Research Institute
CARE	Cooperative for American Relief Everywhere
CGIAR	Consultative Group for International Agricultural Research
CIAT	International Center for Tropical Agriculture
CIIFAD	Cornell International Institute for Food, Agriculture and Development
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo
CIP	International Potato Center
CO_2	Carbon dioxide
CPATU	Eastern Amazon Research Center
CT	Conventional tillage
CU	Cornell University
DSS	Decision Support System
DSSAT	Decision Support System for Agrotechnology Transfer
EEP	External Evaluation Panel
EMBRAPA	Empresa Brasilerira de Pesquisa Agropecuaria Vinculada Ao Ministerior da Agricultura
ENEA	Ecole Nationale d'Economie Appliquée
FAO	Food and Agriculture Organization
FFS	Farmer Field Schools
HKI	Helen Keller International
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICRAF	International Center for Research in Agro-Forestry
IDIAP	The Panamanian Agricultural Research Institute
IER	Institu d' Economie Rurale, Mali
INIA	National Institute for Agricultural Research, Peru
INIAP	National Institute for Agricultural and Livestock Research, Ecuador
INIDA	Instituto de Investigacões e Desenvilimento Agrária
INIFAP	National Institute for Forestry & Agricultural Research
INPOFOS	Northern Latin American Programs
INTSORMIL	International Sorghum and Millet Collaborative Research Support Program
INTA	National Institute for Agricultural Technology
IRRI	International Rice Research Institute
ISRA	Institut Senegalais de Recherche Agricole
MAFF	Ministry of Agriculture, Forestry and Fisheries
ME	Management Entity
MIS	The Consortium for the Management of Fragile Soils of Central America
MSU	Montana State University
NARC	Nepal Agriculture Research Council
NARI	National Agricultural Research Institute, The Gambia
NCSU	North Carolina State University
NGO	Non-Governmental Organizations
NOx, NO, NO_2, N_2O	Nitrogen oxides
NuMaSS	Nutrient Management Support System
P Phosphorus	
PCRSP	Peanut CRSP
RCUH	Research Corporation of the University of Hawaii
PhilRice	Philippine Rice Research Institute
PI	Principal Investigator
PROINPA	Andean Products Innovation Program
PY	Project Year
RT	Ridge tillage
SM CRSP	Soil Management Collaborative Research Support Program
SOM	Soil organic matter
SRI	System of Rice Intensification
TC	Technical Committee
TOA	Tradeoff Analysis
TRF	Thailand Research Fund
UFI	University of Florida
URL	Universal Resource Locator
USDA	United States Department of Agriculture
USAID	United States Agency for International Development
WRC	Wheat Research Center